Prevalence and Seasonal Variation of Severe Childhood Protein Calorie Malnutrition in Khartoum: Implication for Brain Function

By

ZAHRA H. AHMED

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INSTITUTE OF BRAIN CHEMISTRY AND HUMAN NUTRITION

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Abbreviations and Acronyms

BF	Breast feeding (or breast-fed)
BiFrCShA	Bi fronto centro sharp activity
BiFrShSlA	Bifronto sharp slow activity
BMI	Body mass index
CED	Chronic energy deficiency
CHO	Carbohydrate
SAM	Severe acute malnutrition
FAO	Food and Agricultural Organization
DS	Dry season
FoShA	Focal sharp activity
FrPCShSlA	Frontal parietal central sharp activity
FrPCShSlA	Fronto parietal centro sharp slow activity
FrShSlA	Frontal sharp slow activity
GLM	General Linear Model
GLV	Green leafy vegetables
GRSiShA	Generalized right sided sharp activity
GRSiShA	Generalized right sided sharp activity
GShA	Generalized sharp activity
GShA	Generalized sharp activity
HA	Height-for-Age
HA	Height-for-Age
HAZ	Height-for-Age Z-score
HAZ	Height-for-Age Z-score
HH	Household
IDP	Internally displaced person
K	Kwashiorkor
LBW	Low Birth Weight
LCPTShA	Left centro- parietal- temporal sharp activity
LCPTShA	Left centro parietal sharp activity
LPTShA	Left parietal temporal sharp activity
LPTShA	Left parietal temporal sharp activity

LSiMFoShA	Left sided multifocal sharp activity
LSiShA	Left sided sharp activity
LTMFoShA	Left temporal multifocal sharp activity
LTMFoShA	Left temporal multifocal sharp activity
M	Marasmus
MDG	Millennium Development Goal(s)
MFoSlA	Multifocal slow activity
MFoShA	Multifocal sharp activity
MFoShSlA	Multifocal sharp slow activity
MK	Marasmic kwashiorkor
MoH	Ministry of Health
MUAC	Mid-Upper Arm Circumference
NCHS	National Centre for Health Statistics
NCHS	National Centre for Health Statistics
PCM	Protein calorie malnutrition
RCPTShA	Right centro- parietal-temporal sharp activity
RCPTShA	Right centro- parietal-temporal sharp activity
RCTSlA	Right centro temporal slow activity
RFrCTShA	Right frontal central temporal sharp activity
RFrCTShA	Right front central temporal sharp activity
SFP	Supplementary Feeding Programme
SlB	Slow Background
SPCM	Severe protein calorie malnutrition
UN	United Nations
UNICEF	United Nation International Children Emergency Fund
UTI	Urinary Tract Infection
VSlB	Very Slow Background
VSlB	Very Slow Background
WA	Weight-for-age
WAZ	Weight-for-age Z-score
WH	Weight-for-height
WHO	World Health Organization
WHZ	Weight-for-height Z-score
WS	Wet season

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Abstract

Protein calorie malnutrition (PCM) is one of the most serious public health problems in the developing world, including Sudan. This condition was investigated through studies which examined three main areas: prevalence and seasonal variation, influencing demographic factors and impact on brain function with use of electroencephalogram (EEG) assessment before and after clinical and nutritional interventions.

All 466 children admitted to the Khartoum Teaching Hospital and Ibn Oaf Children Emergency Hospital during July to September 2009 (the wet season) and during February to April 2010 (the dry season) were eligible for the study on the prevalence, seasonal variation and demographic factors influencing which influence the incidence of PCM. Questionnaires were employed to collect pertinent demographic, nutritional and anthropometric data.

The impact of PCM on brain function were examined through a case-control study of 48 children admitted to the Ibn oaf Children Hospital in Khartoum between July 2011 to July 2012 (16 underweight, 16 with kwashiorkor, and 16 with marasmus), The data obtained were compared with those of 12 healthy and well-nourished children. EEGs, clinical and neuropsychological assessment were performed on admission and at two time points after discharge (week 4 and 12).

The overall prevalence of PCM was 1.15%, and the distribution of marasmus, kwashiorkor and marasmic kwashiorkor 67.0, 23.0 and 10.0% respectively. Analysis of the 24-hour dietary recall revealed that the protein ($p = 0.001$), fat ($p = 0.020$), carbohydrates ($p = 0.005$) and energy ($p=0.0028$) consumption were statistically significantly lower than the recommended daily allowances. The coefficient of interaction between seasons and co-factors indicated that the wet season influenced significantly ($p<0.0001$) the incidence of PCM when the length of residence, paternal education, and sugar consumption were taken into consideration individually. In terms of demographic factors, mothers who delivered their first baby before they were 18 years old, mothers with a BMI of less than 18.5 Kg/m^2, a birth interval of less than 2 years, children aged 6-11 months (for marasmus), children aged 12-23 months (for kwashiorkor), children whose mid-upper arm circumference was less than

12.5cm and the number of children in a family were all highly associated with the incidence of PCM ($p<0.001$)

Neuro-cognitive investigation of the children showed that 70.8% had abnormal EEG patterns and 50-70% neuropsychological abnormalities. However, after four weeks treatment, 84.4% of the protein calorie malnourished children exhibited normal EEG patterns.

In conclusion, this study has revealed a high prevalence of PCM in Sudanese children with more cases during the wet season than the dry season. In addition, it has identified a number of predisposing demographic factors which must be addressed in order to help reduce the prevalence the disorder. Clinical and nutritional treatment of the children improved considerably clinical, neuropsychological and EEG outcomes. A more promising strategy to improve PCM outcomes may be to tackle the major risk factors for PCM: seasonality and demographic factors. It is envisaged that earlier intervention with the treatments would be beneficial. Future programmes should investigate the long-term impact of PCM on cognitive function including school performance.

This study has generated important information about the prevalence of protein calorie malnutrition and pre-disposing socio-economic factors. Nevertheless it has some limitations. The main limitations are: first, there is potential recall bias among respondents answering questions relating to household food consumption, and events happening in the past, such as the child's history of illness and breastfeeding patterns immediately after birth and then after. Second, information on some important confounding variables such as infection was not collected which could cause problems in interpreting the results. Third, the non-truly statement of the subjects regarding income which may cause bias was another limitation. Lastly, Lack of an address system limited follow-up with some patients

Overall, the findings have important implications for research policy and programme efforts towards improved growth monitoring and designing of interventions to mitigate protein calorie malnutrition and its determinants.

Chapter 1 - Introduction

1.1 Introduction

1.1.1The Sudanese Context

The Poverty Unity in the Ministry of Finance has declared that poverty in Sudan is in the range of 50-60% in the Northern state and much higher in the Southern state (Mustafa & Siddiq, 2007). Approximately 40% of the population live below the poverty line (Klaassen, 2007). Based on estimates from the 2006 Sudan Household Health Survey, more than 15% of the population are under five years old. These young individuals face daily threats from malaria, diarrhoeal disease, acute respiratory infections, vaccine-preventable diseases and malnutrition. Two thirds of children (66%) are not exclusively breastfed (SHHS, 2007), approximately 38% of children below the age of five are underweight; while 43% of children below five have stunted growth (FAO, 2005). The prevalence of protein calorie malnutrition (PCM) in Sudan has increased significantly and currently stands at 53.7% (Ibrahim and Alshiek, 2010). Concurrently, the Infant Mortality Rate is 81 per 1,000 live births and the child mortality rate below the age of five is 10.9% (109 per 1,000 children) (The World Bank, 2011).

In Sudan, marriage takes place at a young age, although there is a trend towards later marriage among the current younger generation, especially those with secondary or higher levels of education. However, the recently released Sudan Household Health Survey in 2006 showed that the percentage of women married before the age of fifteen ranged from 6.1% in Northern State to 24.1% in Upper Nile State. The percentage of women who were married before the age of eighteen ranged from 19.3% in Northern State to 56.8% in Upper Nile State. 85% of mothers were between the ages of fifteen and nineteen (SHHS, 2006). The fertility rate in the Sudan is high and in 2008 was 4.6, while the global average is 2.6 (The World Bank, 2012). Only 34.6% of women are literate. The MMR was estimated to be 556 per 100,000 live births (Kidani, 2010)**.** Today, Sudan has the world's biggest population of displaced persons, with more than five million internally displaced persons and international refugees. This large population displacement has led to conflicts over resources, food insecurity and a high prevalence of severe malnutrition (Thomson and Cohem, 2012).

Protein calorie malnutrition is considered to be a major contributor to mortality in developing countries. Malnutrition retards growth and development, resulting in stunted children compared to their healthy age-mates (Pipes & Trahms, 1993). If rehabilitation is timely and the child grows up in a stimulating environment, recovery in physical growth can be complete (Pipes & Trahms, 1993).

1.2 Background to the Study

1.2.1 Sudan

This section will present background information on Sudan and characteristics associated with PCM aetiology.

1.2.1.1 Geography

Sudan is located in the North Africa plateau, and shares borders with Eritrea, Ethiopia, Egypt, Libya, Chad, Kenya, Uganda, the Democratic Republic of the Congo, and the Central African Republic (Figure 1.1). The River Nile runs from north to south and the country covers approximately 2,505,813 square kilometres (UNFPA, 2013).

Figure 1.1: Map of Sudan and location of Khartoum

(Source UN 2012)

1.2.1.2 People

The population of Sudan in 2013 was 35 million people (UNFPA, 2013), and the annual growth rate is between 2.8 and 3.1%. Half of the population is aged under eighteen years old and there are more than 150 ethnic groups and about 400 languages. Sudan has the world's biggest population of displaced persons, with more than five million internally displaced persons and international refugees. This large population displacement has led to conflicts over resources, food insecurity and a high prevalence of severe malnutrition (Thomson & Cohem, 2012).

1.2.1.3 Economy

Sudan's economy has been in a growth phase over recent years, which has been characterised by relatively low inflation and a long period of positive growth. In 2008, Sudan's gross domestic product (GDP) grew by 8%; however, this high growth rate could not be maintained and the forecast was lowered to 5% growth for the year 2009 (IMF, 2008). The main drivers for success in Sudan were the peace dividends and exploitation of the oil reserves. The influx of a significant number of foreign direct investments has also played a role in maintaining a high economic growth rate, together with a boom in the service sectors, such as communication and transportation. Other than the oil sector, Sudan has little to offer in terms of sustaining an economy, and macroeconomic stability is also affected by the rise of an oil based economy, resulting in new challenges, and a strong Sudanese pound was the first warning indicator (Almosharaf & Tian, 2012).

1.2.1.4 Education

According to WFP (2005), literacy in Sudan stood at 46.1% (57.7% of males and 34.6% of females). The Sudanese government provides free education to all children between the ages of 7 to 12 years, and plans to expand the scope of free education by the year 2010 to all children who are capable of attending schools. However, there are a significant number of obstacles, including low enrolment rate in secondary schools, a lack of financial resources to support school-going children, an inadequate infrastructure, a lack of hygienic toilets, and a lack of clean drinking water, etc. (UN, 2003). About 45% of schools in Southern Sudan tend to operate in open areas, such as under trees, where there is often a lack of facilities, such as toilets and safe drinking water. According to a report by ECOIN (2003), the Southern region is the most educationally deprived region, and contains less that one seventh of the total number of primary schools in the entire country. The disparity in literacy rates between boys and girls has narrowed in recent years, and currently, adult literacy stands at 69% for males and 46% for females (FAO, 2005).

1.2.1.5 Climate

The climate in Sudan is varied, ranging from arid, dry and mainly desert in the north, to tropical, hot and humid in the south. Mountainous areas are present in the south, northwest, and east, while the remainder of the country is mainly flat plains with little vegetation (Klaassen, 2007). Rainfall ranges from rare and occasional in the northern desert regions, to relatively abundant and frequent (rainy seasons of six to nine months) in the southern third of Sudan, and there is a progressive increase in the annual rainfall from 150 mm to over 1,000 mm. There are two dry seasons in northern Sudan: from December to February and from March to June, with the rainy season beginning in July and finishing in October (Klaassen, 2007). Seasonality is of significance to the human population as it influences food availability, consumption patterns, and the probability of disease (Chambers et al., 1981). The prices of cereals vary due to seasonal trends in production; during June to August, the scarcity of grain due to dwindling grain stocks held by producers and traders, combined with a sudden increase in demand, results in rising grain prices, and grain prices peak during the July to September period. The magnitude of this increase depends on the intensity of the rainfall throughout the season (June-September), and cereal and general food prices continue to increase in April (SIFSIA, 2010).

Children are vulnerable during these periods as they need a constant supply of adequate food for growth and development, and due to limited resources they may not receive sufficient food. Even in years of normal rainfall, many Sudanese suffer from temporary undernourishment on a seasonal basis, a situation that worsens during droughts, locust infestations, or when other disasters strike crops or animals (Huss-Ashmore, 1988). Protein energy malnutrition (PEM) is believed to occur frequently, but there is very little documented information on the importance of marasmus, kwashiorkor and marasmic kwashiorkor as a public health concern.

1.2.1.6 Food Consumption

The geographical diversity of Sudan results in differential consumption of foods according to region. Foods consumed by family members in West Sudan, mainly Darfur, are primarily millet based, sorghum is consumed more widely by most of the Sudanese population and particularly in rural areas, whilst wheat is the main staple food in the northern and urban areas of the country (Abdalla & Sulieman, 2009). A family's diet in Khartoum frequently lacks an adequate intake of fruit and vegetables, due to very low incomes (Khatab, 1996), and the consumption of fish is also low due to its expense. Animal products, such as beef, mutton and poultry, are used for sauces but to a rather limited extent, again due to expense. Cereals and sugars are therefore the main source of calories within the daily diet. In addition, climatic problems, such as drought and floods, have resulted in severe food deficits, the loss of livelihoods, and chronic food insecurity.

1.2.1.7 Medical Health

In Khartoum, there are not enough health care facilities to meet the needs of the population. More than 50% of Medair's PHCC (Primary Health Care Centre) patients come from outside the catchment area of the camp. Clinics outside the camps and squatter areas are often too far away for many IDPs to reach, and are also prohibitively expensive. In addition, most of the IDP population in Khartoum have limited knowledge of basic hygiene, the benefits of preventive measures; and the importance of seeking clinical treatment at the onset of any disease. Some patients and/or relatives of patients turn to traditional healers and medicines before seeking appropriate medical care (Klaassen, 2007). It is extremely common for parents to report performing traditional procedures on their child before taking them to a hospital; some mothers use cauterisation in an attempt to treat gastroenteritis, whilst others apply small burn marks in a pattern on their child's abdomen as they believe this will cure diarrhoea. Families are reported to have smothered ash into the umbilicus of their child following their birth, and then to burn a special wood that filled the ward with smoke in an attempt to 'heal' their children and improve the smell of the ward. This is despite the fact that the ward also houses infants who may have bronchitis, as well as other illnesses. Even after explaining to mothers that this practise was detrimental to the children's health, the burning wood was not removed (Klaassen, 2007).

1.2.2 Description of the Study Area

From 1983 to 1993 the population of Khartoum where the study was conducted grew from 1,340,646 to 2,919,773, more than doubling in size within a period of 10 years, and since then the rate of growth has further increased. According to the latest census from 2007, the population of Khartoum state numbered 8,363,915, approximately 19% of the total population of Sudan. Khartoum state consists of the most heterogeneous concentration of people in the country, with many linguistic and cultural groups present. It is estimated that between 1.2 and 1.5 million people living in Khartoum are internally displaced persons; the highest number of internally displaced persons worldwide (LANDINFO, 2008), and from this figure it is estimated that the annual growth rate between 1993 and 2007 was more than 4%.

A heavy influx of migrants to Khartoum, escaping war, famine resulting from drought and the desertification of land, and in search of work and the need to improve their living conditions, account for the greatest proportion of population growth. Moreover, the public services and infrastructure in the countryside are poor, and trained health workers are concentrated within Khartoum. Meanwhile, some of the population already resident in Khartoum's residents have also begun to move away from the central areas of the capital to the slum areas on the outskirts of the city due to the increase in the cost of living. Other contributory factors include a high rate of fertility in Sudan, the result of the high marriage rate coupled with ineffective family planning procedures (Khalifa et al., 1986).

The majority of people who have fled other areas and settled in Khartoum are from agricultural backgrounds, and are illiterate and possess limited skills. Only about 5-10% have been able to find permanent jobs in the public or formal private sector, while others depend on incomes earned as casual workers, domestic servants or petty traders. Most migrants in Khartoum State are scattered throughout hundreds of unauthorised squatter areas or settlements. An assessment conducted by the UN, non-governmental organisations and government agencies in 15 of the main squatter areas, found them to be characterised by overcrowding, poor housing, and unhealthy water and sanitation conditions (Dinar, 1998).

In Khartoum, there are insufficient health care facilities to meet the needs of the population. More than 50% of Medair's Primary Health Care Centre (PHCC) patients come from outside the catchment area of the camp (Khalifa et al., 1986). Clinics outside the camps and squatter areas are often too far away for many internal displaced persons to reach, and are also prohibitively expensive. In addition, most of the internal displaced persons population in Khartoum have limited knowledge of basic hygiene, the benefits of preventive measures, and the importance of seeking clinical treatment at the onset of any disease (WHO, 2014). The heath of most Khartoum residents worsens during the wet season, which may be due to the seasonal variation in food supply, or as a result of epidemic infections, such gastrointestinal infections related to the proliferation of flies and insects (Blum & Feachem, 1983).

1.2.3 Protein Calorie Malnutrition and Food Security in Sudan

According to the National Baseline Household Survey (NBHS) from 2009, almost a third of the Sudanese population suffered from a lack of sufficient food to keep them in good health. The level of nutrients required for an average person is calculated on the basis of their daily requirement of calories. It has been determined that the number of calories required by urban and rural households to meet the minimum dietary energy requirement (MDER) are 343 and 344 Kcal, respectively (Southern Sudan Centre, 2009), yet the average calorie intake of urban and rural households was 31% and 34%, respectively, below the MDER. The southern states showed an even more severe degree of undernourishment, with about 47% of people not receiving enough food. The states of Western Bahr Al Ghazal, Unity, Upper Nile and Lakes contained the highest number of undernourished people within the nation.

According to the FAO (1998), food security is defined as 'A situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.' There can be various reasons as to why there is insufficient food security, including inappropriate distribution, the unavailability of food, and inadequate use of food at the household level or insufficient purchasing power. A lack of food security could be a transitory problem, a seasonal problem or a chronic one (Teklu et al., 1991).

There are a number of areas in Sudan where food security has not been available for over a generation (NBHS, 2009). Droughts and other related climatic variations have contributed to the lack of food security, whilst war and underdevelopment has also taken a very high toll and in turn has reduced the ability to utilise alternative sources of food or income during such harsh situations (Français, 1993). The bad rainfall season of 2004/2005 led to even more severe food shortages across the country than normal, and in such harsh situations, the people who suffer the most are those who have limited access to arable land, those who have been displaced, and those who do not have sufficient income generating opportunities (WFP, FAO, NGOs, GOS & SSC, 2005). Poverty is a major cause of food insecurity in Sudan and this poverty is not limited to only the rural areas, but also affects the urban population, which is becoming increasingly poor due to population displacement.

Generally, food security is founded upon the notion of consuming one's own production, with the excess being sold, and this is supplemented by other income generating activities that can help tide over an individual in cases of drought or other calamities. According to the Southern Sudan Centre (SSC, 2009), the lack of income generating activities, in addition to natural disasters, has made it increasingly difficult for families to survive. Different locations influence the type of livelihood systems that can be implemented, and these include fishing, livestock, trade, agriculture and the collecting of wild foods. Due to war and frequent in-fighting in regions of Africa including Sudan, these livelihood systems are coming under a great deal of stress (Guvele et al., 2004).

1.2.4 Government Policies Associated with PCM

The nutritional status of a nation in general, and that of its children in particular, is a powerful indicator of the socio-economic development of that nation. Mahgoub & Adam (2012) examined morbidity and mortality among Sudanese children and report that the Sudanese Government has understood the importance of children and identified health policies which will improve child nutrition and development. Although Sudan is rich in terms of natural and human resources, PCM is a significant public health problem affecting more than half (53.7%) of all children under the age of five years (Mohieldin & Alshiek, 2010). Marasmus and kwashiorkor are by far the most prevalent forms of PCM, with 62% of children suffering marasmus and 20% kwashiorkor (Elbushra & Eltom, 1989). Seasonal variations in food production and fluctuations in the prices of food can be considered as contributing to transitory food insecurity in poor households, which over time, escalates into chronic food insecurity and nutritional deterioration (Huss-Ashmore, 1988). Consequently, Mahgoub & Adam (2012) argued that the lack of clear governmental efforts to control food security was a primary reason for the nutritional deterioration observed. Effectively tackling malnutrition is therefore a global health priority with the potential for far reaching impact.

According to Sudan's Federal Ministry of Health (FMH, 2003), significant relevance has been attributed to the overall improvement of the population's health, with the strategic plan for the Sudanese health sector extending to 25 years. Furthermore, there is a claim by the FMH (2005) that the Federal Government of Sudan has made it a priority to improve the health and nutritional status of the Sudanese people; however, some significant criticisms have been raised by global organisations. For instance, the FAO (2010) identified that Sudan is extremely rich in terms of natural resources and human resources, which are both extremely important for the country's development, but the lack of clear policies for human development and healthcare has resulted in a population that is prone to a large amount of sickness. According to the WHO &FMH (2004), the nutritional situation in Sudan, especially with regard to its children, has not been given significant attention at the national level in terms of priorities and policies. A report by the WHO &FMH (2004) clearly stated that the nutritional policies of Sudan have shown significant growth and reform over recent years; however, this growth is not completely shaped and lacks a strategic plan to promote health related intervention strategies. A survey conducted by the FAO (2010) revealed that 18.1% of children younger than five years were suffering from moderate or SAM and 48% were stunted.

The Sudanese Government has attempted to reduce poverty and improve health conditions among pre-school children in order to reduce the high prevalence of PCM; however, Babikar et al. (2012) found that the governmental interventions had been relatively limited. The authors indicated that despite the fact that a significant number of policies had been dedicated to reducing child malnutrition and PCM, the degree of implementation had been relatively small. UNICEF (2007) have reported that whilst a substantial amount of attention and resources have been devoted towards improving health conditions and reducing PCM among pre-school children in Sudan, the prognosis is mixed, and it is commonly believed that the country will fall short of achieving its key goals.

UNICEF (2004) argued that governmental support is largely limited in nature and is not targeted at specific age groups of children, reporting that most importance was given to children who are above the age of 12 months. Furthermore, it can be argued that the health initiatives which have been proposed focus mainly on primary curative services, with a limited view on long term interventions. Suliman et al. (2011) argued that governmental initiatives which are directed at specific curative clinical factors have resulted in other associated disorders. The UNICEF (2004) report also identified that fewer people have ready access to government health services due to the limited number of hospitals, as well as the limited number of doctors. Health services are concentrated in urban areas, while in terms of health facilities and personnel, rural areas still suffer from inadequate preventive and curative services (FAO, 2005).

Chapter 2 - Review of the Literature

2.1 Introduction

According to Strobel and Ferguson (2005), at a global level, hunger and malnutrition are two of the most commonly occurring challenges faced by children and the highest risk factor for illness and death Furthermore, Muller & Krawinkel (2005) have identified that malnutrition increases the risk of disease due to a rise in infection rates, and that children and infants are the most susceptible to death due to infection. There is growing empirical evidence to support the argument that undernourished and malnourished children are at the highest risk of dying (Torun, 2006; Caulfield et al., 2004).

Researchers argue that severe childhood malnutrition continues to be a major disease in the Africa. A WHO (2012) report identified that malnutrition, and its severe form, protein calorie malnutrition (PCM), has led to over two million deaths in Africa, which is largely associated with growing evidence of poverty and hunger. According to the United Nations (UN) Food and Agriculture Organization (GORTA, 2012), the total number of hungry people in Africa grew from 175 million in 2000, to 239 million in 2010, with a further 20 million increase in the last four years, making one in every four individuals hungry. More than 70% of malnourished children live in Asia, followed by 26% in Africa (Ahmed et al., 2013). Lawn et al. (2005) reported that most children face malnutrition due to a lack of effective feeding and poor nutrition in pregnant women, which has led to an increase in the total number of neonatal deaths in sub-Saharan regions, and the birth of malnourished children who have poor health, blindness, learning disabilities and mental retardation.

Waterlow et al. (1992) argued that there are three main types of PCM disorder: kwashiorkor, marasmus, and marasmic kwashiorkor. The aetiology and associated characteristics of this disease will be discussed in more detail later. PCM is a major health burden around the world (Muller et al., 2005), especially in developing and underdeveloped nations. In addition, PCM is also the most important risk factor for death and illness among the younger generation, and is a major cause of death among children under the age of five in developing countries (Anwar et al., 2010). Hence, it is vital that the nutrition of these children be improved in order to lower the overall under five mortality rates and ensure that the proper physical, social and mental growth of children is guaranteed (Ubesie et al., 2012). The majority of PCM cases occur in sub-Sahara Africa, where the average PCM associated mortality is between 25% and 35% (Rutherford et al., 1985).

Researchers have identified that infants and young children are the most susceptible to PCM and the full impact on different aspects of child development, including mental, physical and emotional attributes is well understood (Laghari et al., 2013; Gladstone et al., 2014).

2.2 Definition of Protein Calorie Malnutrition

PCM is the generic name for a group of nutritional disorders that manifest mainly in children; extreme living conditions may contribute to the clinical syndrome of marasmus (energy deficiency), kwashiorkor (protein deficiency) or marasmic kwashiorkor (Waterlow, 1960). The manifestation of PCM varies widely according to the nature of the causative factors, the age of a child, and the time at which they operate (Jelliffe, 1966). PCM is defined by the WHO as a pathological condition that results from a lower ingestion of protein and calories; which occurs more frequently in children under five years of age (Rodríguez, 2011). From this point onwards, the acronyms PCM and PEM will be used indifferently for protein calorie and protein energy malnutrition respectively, without any deviation of meaning implied.

2.3 Classification of Protein Calorie Malnutrition

2.3.1 Welcome Classification

This classification system is based on analysing the expected weight-for-age of a child and the presence or absence of oedema (Table 2.1). It is used to distinguish between marasmus and kwashiorkor (Waterlow, 1992).

Table 2.1: Welcome classification of PCM

% Expected Weight-for-Age	Oedema	
	Present	Absent
80-60%	Kwashiorkor	Underweight
<60	Marasmic Kwashiorkor	Marasmus

2.3.2 Gómez classification

This system is based on the expected weight-for-age of a child (Table 2.2, Gómez et al., 1955; Waterlow, 1977).

Table 2.2: Gómez classification of PCM

% Expected Weight-for-Age	Grade	Classification
>90		Normal
76-90	I	Mild
61-75	II	Moderate
≤60	III	Severe

2.3.3 Waterlow Classification

This system is based on weight for height and height for age (Table 2.3, WHO, 2003).

Table 2.3: Waterlow classification of PCM

Height for age	Weight for height	
	>80	<80
>90	Normal	Wasted
<90	Stunted	Wasted and stunted

2.3.4 WHO Recommendations

The WHO recommendations are as follows: -2 SD or -2 z-score for all the indices * <2 z-score height for age = stunting * <-2z-score weight for height = wasting * The -1z-score and -3z score can also be used to determine the degree of stunting and wasting.

2.4 Clinical Signs of Protein Calorie Nutrition

2.4.1 Marasmus

Marasmus is caused by an overall deficiency in protein and energy, and is characterised by poor growth, very low body weight, and a severe loss of subcutaneous fat (Waterlow, 1992). The skin is wrinkled, especially around the buttocks and thighs, the muscles are always extremely wasted, there is an absence of oedema, and a child has the appearance of a wizened old man with very emaciated limbs; the child has become ‘skin and bones’ (Latham, 1997). Children with marasmus are quiet and apathetic, some to the point of developing anorexia. Hair may become thin, sparse, and brittle, and nails thin and fissured; children fail to thrive (Shah et al., 2007). Advanced cases are characterised by a subnormal body temperature, and a decreased pulse and metabolic rate (Castiglia, 1996). Serum albumin measurements are generally normal or slightly reduced, and anaemia and evidence of vitamin deficiencies is common (Winkes, 2002). Marasmus is observed more frequently in infants and very young children.

Figure 2.1: A child suffering from marasmus

2.4.2 Kwashiorkor

Kwashiorkor results from a deficiency of protein with adequate energy intake, and is characterised by oedema and a low body weight (Waterlow, 1992). Children with kwashiorkor have the typical rotund appearance of a 'sugar baby', reflecting the fatty infiltration of the liver (Coulter et al., 1988). Children with kwashiorkor suffer from a poor appetite, apathy, anorexia, irritability, poor growth, and muscle wastage, seen particularly in the buttocks, thighs, scapular region and upper arms, although wastage is hidden by the presence of extensive oedema. Additionally, hair is sparse, straight, silky, and easily plucked out (Shah et al., 2007). The syndrome is most frequently observed in children aged 1-3 years, and is precipitated by an infection, or more commonly, by a series of infections occurring successively or concurrently (DeMaeyer, 1986). The primary laboratory hallmarks are decreased serum albumin and plasma creatinine levels (Hedayat et al. 1968). The serum albumin level is well below 3g per 100ml of blood, and there is also a reduction in the albumin/globulin ratio (DeMaeyer, 1986). Kwashiorkor usually has a peak incidence of between one and two years of age, and although medical, social, and cultural conditioning factors are also always operative, the primary cause is a diet low in protein, but containing some, or even substantial, calories in the form of carbohydrate foods **(**Jelliffe, 1963).

Figure 2.2: A child suffering from kwashiorkor

2.4.3 Marasmic Kwashiorkor

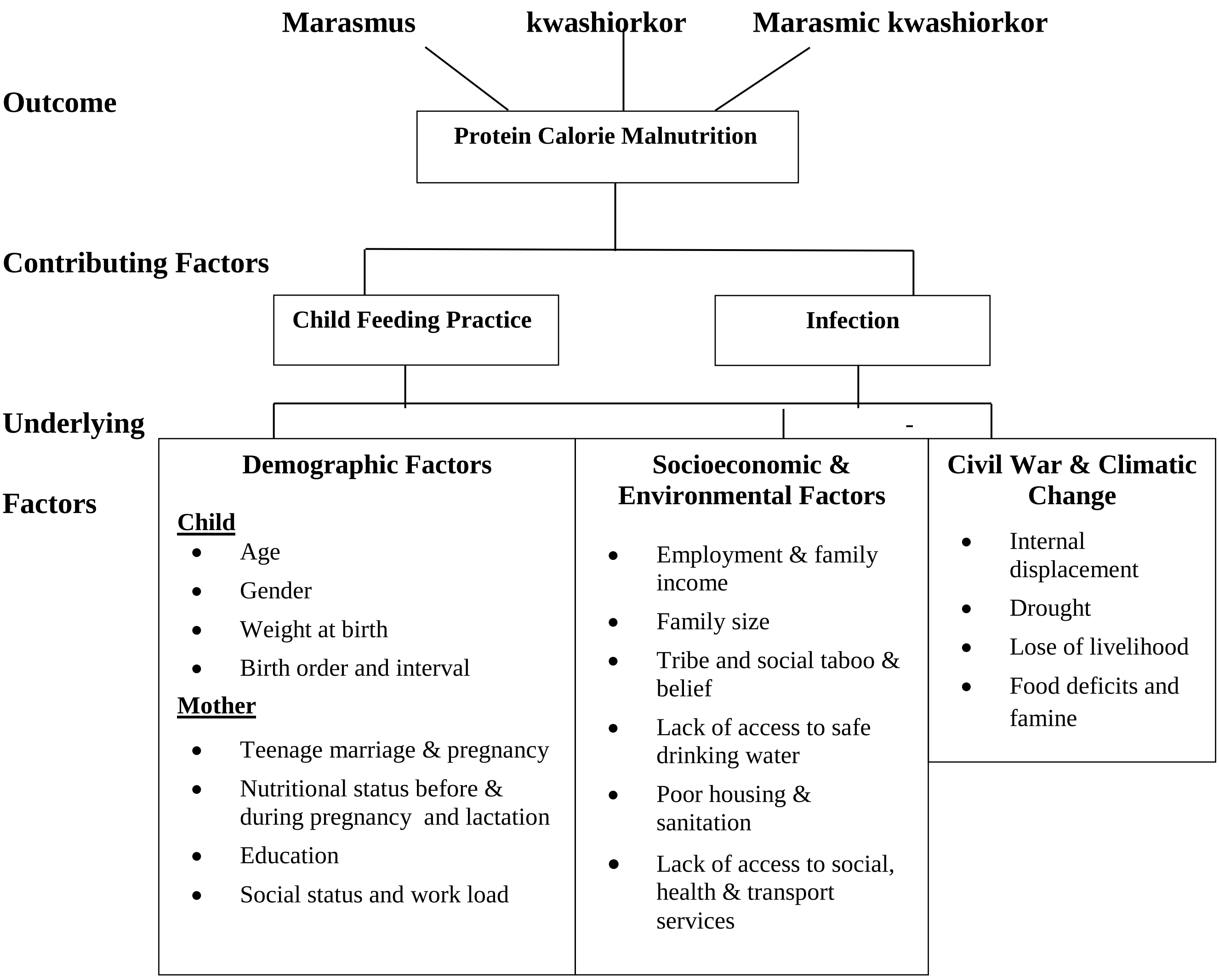
Marasmic kwashiorkor is a mixed form of PEM with oedema occurring in children who are otherwise marasmic (Giliberto, 2005). This form of PCM is easier to recognise clinically than to define with precision (Jelliffe, 1963**).** Children with marasmic kwashiorkor have all the clinical features of marasmus and have severe muscle wastage in the presence of subcutaneous fat. Some of the other variable features of kwashiorkor are often present, including hair changes and liver enlargement (Latham, 1997). The aetiology is the same as in classical kwashiorkor. Some affected children may recover from this phase, while others will be precipitated into frank kwashiorkor by a concurrent infection or some other conditioning factor (Jelliffe, 1963).

2.5 Determinants of Protein Calorie Malnutrition in Sudan: Demographic Factors

In Sudan and other developing countries, demographic factors, such as mother's age and weight and child's gender are thought to seriously affect growth and development of children (Abdalla & Sulieman, 2009). Child feeding is an essential element in the care of infants and young children. According to UNICEF (1990), nutrient intake and the presence of disease are the direct determinant of child growth and development. Dietary intake and illness are, in turn, influenced by underlying factors.

Figure 2.3 illustrates a simplified conceptual framework of the determinants of PCM in Sudan. The underlying variables in this model are divided into three groups: demographic factors, socioeconomic and environmental factors and civil war and climatic change.

Figure 2.3: Simplified determinants framework for the prevalence of PCM in Sudan



2.5.1 Children Characteristics and Protein Calorie Malnutrition

2.5.1.1 Gender

The prevalence of PCM was found to be higher among males compared to females in the Khartoum area (Taha et al., 1976), although no widespread pattern of gender differences for

PCM has emerged from other studies to date in children. Discrimination against girls during feeding and health care are often cited as reasons for the poorer nutrition among girls than boys in many developing countries (Pebley & Amin, 1991; Abeykoon, 1995), probably due to the fact that in some communities, males are considered of more value than females. The unequal distribution of food within a family with a definite gender discrimination against females has also been observed in poorer societies (Gulati & Jaswal, 1995).

2.5.1.2 Child Age

In Sudan, PCM can affect all age groups but usually manifests early in children, between one to two years of age (Nabag et al., 2013). Children aged 24 months are no longer exclusively breastfeed and they have high nutritional requirements because they are growing quickly. A study in Sudan indicated that kwashiorkor is more frequent between the age of 12.4 to 27.8 months, when the food supply does not meet the rapid rate of growth (Nabag et al., 2013), and typically occurs in children with diets consisting of starchy gruels, diluted cereal-based beverages, and vegetable foods rich in carbohydrates but almost devoid of proteins of good nutritional quality, i.e. lacking one or more essential amino acids. Some studies in Sudan have regarded marasmus as a disease of early infancy (Coulter et al., 1988; Suliman et al., 2011), associated with bottle feeding since birth, as the majority of protein calorie malnourished children were between 13-36 months (Suliman et al., 2011). At this age a child's growth increases the nutritional requirements, but children cannot yet obtain food on their own, and infants and children living under poor hygienic conditions frequently become ill with diarrhoea and other infections. Infants become protein calorie malnourished due to a lack of adequate energy and protein intake if they are either weaned early or breastfed for a prolonged period of time without adequate food or the delayed introduction of a low protein complementary diet (Kwena et al., 2003; Rodríguez, 2011).

2.5.1.3 Low Weight at Birth

An adequate weight at birth is an important determinant of normal growth, and low birth weight babies (less than 2500 grams) are at increased risk of compounding PCM during infancy and remain so during childhood (Khan et al., 2006). The prevalence of a low birth weight (less than 2500 grams) was found to be high, at 31%, for neonates in northern Sudan (FMH, CBS & UNICEF, 2001), although this figure seems improbably high given the limited number of health facilities and personnel, thus the validity of the prevalence of low birth weight is uncertain (FAO, 2005).

Low weight birth children are more vulnerable to disease, frequently have a history of breastfeeding failure, and are at a disadvantage in relation to growth (Victora et al., 1987; Nóbrega et al., 1994). Thus, the need for a reduction in the prevalence of low birth weight within a specific area is a vital measure for improving the nutritional status of children (Leone et al., 1992).

2.5.2 Maternal Factors and Protein Calorie Malnutrition in Sudan

2.5.2.1 Maternal BMI

Maternal nutrition continues to be crucial for child health. Maternal malnutrition before, during and after pregnancy may result in underweight new born babies (Martorell, 1992). Intrauterine malnutrition increases the occurrence of PCM after birth, because the infants do not receive sufficient food to meet their requirements for catch-up growth (Torún & Chew, 1994). Low weight during pregnancy contributes to a high prevalence of low birth weight among infants (Uthman, 2007), and a study in Sudan found a strong relationship between maternal nutritional status and child health (Rahman et al., 1993). Infants who survive the intrauterine environment of malnourished mothers tend to become malnourished themselves. A study in 1995 determined that the prevalence of chronic energy deficiency (CFD) among 3,586 Sudanese mothers (age not specified) was 18%, with the highest prevalence among mothers from North Kordofan (32%) and the lowest from Gezira State and in South Darfur (5% for both) (MOH &WHO, 1997). According to one report, the mean BMI of women at 15 years of age was 22.5 kg/m² in 2002 (FAO, 2005). A hospital in Karachi reported a significant association between severe stunting and severe malnutrition (Ejaz & Latif, 2011). The consequences of maternal malnutrition have implications for the mother and offspring (Lartey, 2008).

2.5.2.2 Mother's Age

In Sudan, age of a mother plays a crucial role in the prospect of child health, and is considered to be one of the essential determinants of PCM (Nabag et al., 2013; Ahmed, 2003). Maternal age is linked with a high birth rate, large number of children in a household and short interval between births (Rutstein, 2008). Growth retardation (height-for-age) in children is also positively associated with maternal age and family size, and children of young mothers have poorer outcomes (Finlay et al., 2011). The proportion of malnourished children was found to increase with the number of older surviving children (Mozumder, 2000), and children of younger women (<20 years) were found to have an increased incidence of PCM (Nabag et al., 2013; Ahmed, 2003).

Studies have indicated that the optimum time for mothers to bear a child is in their early twenties, and women ought to stop bearing children at about 35 years (Nortman, 1974; Standley & Kessler, 1979). Especially in the developing world, a woman having her first child in her early thirties is at special risk, of immaturity and prematurity. Women who continue childbearing into their late thirties and forties are also at risk, as are their children (Adhikari, 2003; Abdullah et al., 2007).

2.5.2.3 Teenage Marriage and Pregnancy

In Sudan, marriage at a young age has health implications for both mothers and children (Nabag et al., 2013). Early marriage and negative perceptions of family planning still predominate among Sudanese communities (Ahmed, 2003). Early teenage marriage and pregnancy, particularly when under the age of 16, results in a higher of childhood risk of PCM (Thurnham, 2013). In this period of life there will be frequent pregnancies and lactation, and there is a marked relationship between the weight of new born babies and the age of mothers (Gueorguieva et al., 2001). Most teenage mothers stop breastfeeding because of another pregnancy (Smith et al., 2012). In Sudan a study reported that teenage marriage and pregnancy contributed to PCM (Abdelwahab, 1990), and it has been found that mothers of protein calorie malnourished children were likely to be pregnant (Coulter et al., 1988). Many pregnancies occur frequently and at short intervals, giving the mother insufficient time to replenish her nutrient stores before the next pregnancy (King, 2003), and this in itself will lead to protein calorie malnutrition in the child (Rodríguez et al., 2011). After delivery, social requirements and pressures all mitigate against the proper establishment and maintenance of breastfeeding, with the customary far-reaching consequences for survival under the type of circumstances prevailing in the developing world (UNU, 1983).

2.5.2.4 Interval between Child Birth and PCM

A short birth interval is a significant contributory factor for PCM noted among the Sudanese population (Coulter et al., 1988), and compromises the care received by infants and young children, as mothers have little time to take care of their children. A short subsequent birth interval can also place a child at risk because a new pregnancy often triggers premature weaning of the current child, or at least a reduction in the volume of breast milk consumed, which can be hazardous both nutritionally and in terms of resistance to infection (Bøhler & Bergström, 1996). Several studies in developing countries have shown that children born within a short period (less than two years) of their mother's previous child, have higher levels of stunting (Nojomi et al., 2004; Sommerfelt et al., 1994), because these children may have received inadequate care from their mothers or experienced more competition for household resources (Nojomi et al., 2004).

2.5.2.5 Birth Order

In Sudan, there is good evidence that the health of children is seriously affected when birth order is high. It is particularly true in the case of PCM (Ahmed, 1982), it is expected that parents give less attention to older children when they give birth to a new child who needs much attention and care. A study in two urban areas in the Sudan found the relationship between PCM and birth order. Children who were of the fifth birth order had significant higher risk for PCM (Nabag et al., 2013). In Colombia, 49% children with PCM were the sixth born or later (Pollu, 1973). High parity could influence PCM, not only because of short birth spacing but also because a large number of children carries a higher risk for spreading infections and many children competing for a mother's time, care and family resources.

2.5.2.6 Family Size

In Sudan, family size is an important determinant of child PCM, where nearly 40% of families of children with PCM have been found to have five or six children (Nabag et al., 2013). Family size affects the availability of food and nutrition, and large families have a greater risk of children suffering from PCM (Taha, 1979). The proportion of young children within a family places a heavy educational and medical burden on a limited budget and at the family level, it would be reasonable to expect better nutrition if the number of children is small (Taha, 1979). In the Philippines, there was a significant incidence of PCM among pre-school children in households with more than six members compared to smaller families (Aguillon et al., 1982).

2.5.2.7 Tribe

Sudan continues to be a country characterised by diversity; numerous tribes are found in the northern Arabic and southern African regions together with eastern and western tribes. These different tribes contribute to multi-cultural and ethnic features of the country (Abdella and Sulieman, 2009). In some tribes, fathers have very little influence on child feeding practices.

In the rural Beja tribe, mothers have been observed to breastfeed girls longer than boys, and mothers weaned their children abruptly, which was traumatic (MSC, 1977). For example, a mother may spill breast milk on the floor in front of a child prior to feeding, and a faith healer may be called in to reduce the psychological trauma. In contrast, some urban mothers weaned their children gradually; beginning by decreasing the number of breastfeeds or breastfeeding after a child has eaten a heavy meal (Elbusra & Eltoum, 1989).

The association between ethnicity and health is complex, and involves interactions between social, cultural and economic factors (Stronk et al., 2013). Some tribes experience higher rates of poverty than others in terms of income, benefits use, a lack of basic necessities, and area deprivation. Much of the variation in health between and within tribes can be explained by differences in socio-economic status (Torún & Chew, 1994; Torún, 2006).

2.5.2.8 Length of Residence

A meta-analysis of nutrition and mortality surveys conducted in Darfur, Sudan during 2004 and 2005, showed that PCM decreased significantly by 28%, whilst in West Darfur, PCM increased among internal displaced persons and decreased among residents (Nielsen et al., 2011). Geographical migration from rural areas to urban centres results in migrants becoming slum dwellers, living in poor environmental conditions, where there is overcrowding, poor quality drinking water and sanitation, and no waste removal (Reyes et al., 2004). . Adaptation to the new situation is difficult and takes time, and when families come to live in a hostile environment they have limited access to information regarding childcare (Reyes et al., 2004). Civil unrest, the manipulation of trading conditions, natural disasters, and religious and cultural factors, all amplify the difficulties families have to face (Torún & Chew, 1994; Torún, 2006). Landlessness is also considered to be a cause of PCM (NDoH, 2003).

2.5.2.9 Building Materials, Sources of Water and Latrine

Household materials, the number of rooms, sources of water and the presence of a latrine in the house influence PCM. About 33.3% of children with PCM were found to be living in a rented house and 20% lived in scattered houses (Nabag ey al., 2013). The houses, rooms, toilets and standard of hygiene are linked to the occurrence of PCM. In unhygienic surroundings the contamination of food and water is inevitable, and infection spreads readily (Taha, 1979). Less than 30% of Sudan’s population use sanitation facilities, while only 60.5% drink appropriately treated water, increasing the risk of diarrhoea. Nearly 50% obtain their water from a caro (donkey cart), while 60.0% of children had pit hole (traditional) and 19.2% of children no latrine (Nabag et al., 2013). These findings agree with those of Park and Park (2002), who noted that when family living conditions are poor, children suffer from PCM (Nabag et al., 2013). Mothers of protein calorie malnourished children have been found to have poorer housing, sanitation and water supply (Coulter et al., 1988)

2.5.3 Additional Factors Contribute to PCM in Sudan

2.5.3.1 Feeding Practices of Infants and Children in Sudan

2.5.3.1.1 Breastfeeding

The importance of breast milk as the best and only food for infants aged less than six months is recognised worldwide (Santos-Torres & Vasequez-Garibay, 2003). Breast milk is necessary for normal growth, and exclusive breastfeeding is the policy of the WHO& UNICEF for feeding full-term babies for the first four to six months of life in developing countries (Lunn, 1996; Hoddinott et al., 2008).

In Sudan, more than 60% of mothers do breastfeed their children for up to one year (Suliman et al., 2011). The practice of infant feeding in some parts of Sudan has witnessed a decline according to tradition and the teaching of the Holy Koran, where weaning occurred after the end of the second year (Suliman et al., 2011). The advent of a new pregnancy used to be the cause for stopping breastfeeding, but now more and more children are deliberately weaned at a younger age and introduced to bottle feeding with highly dilute and contaminated fluid, often milk formula (Taha, 1979). The exposure of children to artificial feeding, using milk and bottles, is considered a risk factor for protein calorie malnutrition among children, because the type of sterilisation was only water (53.4 %), and mothers may dilute the formula which affects the constitution of the milk and leads to an inadequate intake of suitable food elements, as well as improper preparation of artificial feeding (Nabag et al., 2013).

In Sudan, almost all mothers (85%) initiated breast-feeding, and by four to five months of age 20% of children were exclusively breastfed, but at six to seven months only 10% of the children were exclusively breastfed, and the breast-feeding rate with supplementary feeding was determined to be 29% at one year (SHHS, 2006). However, between six and nine months of age, less than half the infants received complementary food in addition to breast milk (FAO, 2005).

2.5.3.1.2 Weaning and Weaning Practice

Early weaning and the absence of breastfeeding are important risk factors for PCM (Iqbal et al., 1999; Nóbrega & Campos., 1996; Bittencourt et al., 1993). In Sudanese culture infant feeding traditionally omits supplementary feeding and too little poor quality food is added to a child's diet too late. In effect, therefore, children undergo a prolonged period of under nutrition until they are thought old enough to be weaned abruptly onto the family diet (Taha, 1979). Inadequate weaning practices and poor infant feeding practices lead to insufficient protein and energy intake (Torún & Chew, 1994; NDoH, 2003). From birth to the age of four months, all an infant's nutritional needs are perfectly met by breast milk, but between four and six months of age, breast milk is no longer sufficient to satisfy an infant's energy and protein requirements.

Abdelwahab et al. (1991) studied the feeding patterns of 346 children in Sudan with PCM and concluded that improper feeding and weaning practices and poor environmental hygiene were the major causes of PCM in the children (Metz, 1991). In two third of kwashiorkor Sudanese children there was a definite history of premature weaning because the mother had become pregnant. It is believed by various family groups that the milk of a pregnant woman is deleterious to the health of an infant at the breast, a view widely held in other parts of Africa too (Hassan, 1960). In all the kwashiorkor cases the diet after weaning was deficient in protein, especially milk and meat (Hassan, 1960).

Basic porridges are often given, based on the local staple food, yet such porridges are generally prepared with water of uncertain quality, causing diarrhoea (Corbett, 2003). A study in the Sudan into household food consumption found that food intake for children was not related to food availability; rather it was determined by inequitable intra - family distribution. This is postulated to be the main factor in the ecology of childhood PCM which is prevalent in this area (Taha, 1979).

2.5.3.2 Infections Contribute to PCM among Children in Sudan

In Sudan, it has been increasingly recognised that communicable diseases such as diarrhoea, respiratory infections, pneumonia, gastrointestinal infections, urinary tract infection and TB contribute to PCM (Suliman et al., 2011).

In Sudan, poor weaning practices lead to a high incidence of diarrhoea. The majority of people in Sudan use a seer (a pot) for the preservation of drinking water; this contains a high degree of faecal contamination due to crowded houses which is then also present in feeding bottles (El Bushra et al., 1988). Researchers studying cultural beliefs concerning breastfeeding and weaning in the Beja tribe of eastern Sudan, found that the mismanagement of diarrhoea contributed to the high prevalence of PCM (El Bushra & El Tom, 1989). In contrast, a cohort of Sudanese infants receiving breast milk only had a prevalence of diarrhoea of around 30% for each home visit, yet there was minimal impact on rates of weight gain (Zumrwai et al., 1987).

Measles was often reported as the precipitating infection among children with marasmus or kwashiorkor in Sudan (Coulter et al., 1988), causing growth faltering in children who developed post-measles dysentery (Tomkins and Watson, 1989). A study in Sudan investigating ecological factors for PCM found that respiratory infections are associated with PCM (Taha, 1979), and accordingly, pneumonia and malnutrition are two of the biggest killers during childhood (Chisti, 2009). In Sudan, acute upper respiratory infections were most prevalent among children with PCM (Suliman et al., 2011), while lower respiratory infections were most prevalent among children with either acute or chronic malnutrition (Rodríguez et al., 2011).

Urinary tract infections (UTIs) are common in protein calorie malnourished children in Sudan (Suliman et al., 2011). This common association between infection and PCM may be explained by the immunodeficient status of protein calorie malnourished children, and the poor socio-economic and unhygienic conditions in which these children usually live (Coulter et al., 1988), and in Sudan some malnourished children have been shown to have pulmonary TB (Suliman et al., 2011).

Most children with PCM in Sudan have been found to be anaemic, which was more severe in marasmic kwashiorkor patients, and a very high incidence of megaloblastic anaemia has also been reported (Suliman et al., 2011; Taha, 1979; Omer et al., 1975). Taha (1979) reported that more than 70% of cases had either pure megaloblastic anaemia or a mixed iron deficiency and megaloblastic erythropoeisis, while Omer et al. (1975) found megaloblastic anaemia in about 50% of cases.

In Sudan, the low levels of immunization against communicable diseases are a contributory factor to PCM (Nabag et al., 2013). The vaccination coverage of protein calorie malnourished children has been reported as 71.4%, which is comparable to the national coverage of 62%.

This may be explained by the fact that most of the protein calorie malnourished children were from urban areas for displaced families. Nevertheless, this also indicates a great improvement in vaccination coverage compared to the figures given by Coulter et al. (1988) who reported vaccine coverage at only 1.2% for children with PCM group (Suliman et al., 2011). The lack of a national policy for immunization against preventable specific infections makes the situation worse (Taha, 1979).

2.5.3.3 Socioeconomic and Environmental Factors Contribute to PCM in Children in Sudan

2.5.3.3.1 Socio-economic Risk Factors

It is well known that socioeconomic and environmental conditions are important determinants of PCM (Abdella et al., 2009). The relationship between socioeconomic and PCM is observed to be inverse, and is concentrated on those at the lowest end of socioeconomic scale. In Sudan, >60% of the population live in rural areas lacking basic services and overburdened by poverty (Abdella et al., 2009). In terms of social factors, food distribution among a family culturally favours adult males and guests. The dietary problem is therefore, as much social, within the family, as economic.

A vicious cycle exists, whereby poverty leads to inadequate food intake and under-nutrition, and imposes restrictions on the food intake of poorer people, especially young children (Gulati, 2010). For the majority of families in Sudan (58.5%), expenditure is less than 20 Sudanese Pounds (roughly equivalent to £2) per day, whilst the expenditure of 18.7% of families lies between 20 and 29 Sudanese Pounds (roughly equivalent to £2 - £3) per day (Haroun et al., 2008).

In Sudan, the low maternal literacy rate is considered a risk factor for PCM (Taha, 1979; Nabag et al., 2013; Ahmed, 2003; Ahmed et al., 2011). Moreover, the high illiteracy level among Sudanese women (50%) is a key challenge to good nutrition practice (Ali et al., 2013). It was found that the number of cases of PCM were significantly fewer for children whose mothers had received four years of elementary education than those who had received no education at all (Taha, 1979).

According to El Shazli (1979), the main etiological factors leading to PCM among pre-school age children in Sudan are ignorance, taboos and traditional infant feeding practices. When a child develops diarrhoea, most mothers stop breastfeeding and provide other foods instead; to treat the diarrhoea, some women give a potion called 'dilka' which contains pleasant-smelling herbs and fermented sorghum,; and in cases of vomiting, a mixture of garlic and lemon is mixed in water and given to a child (El Shazali, 1979).

2.5.3.3.2 Environmental Factors

Food-hygiene practices of mothers in Sudan have an important impact on the prevalence of PCM among children. Ibrahim & Alshiek (2010) demonstrated that the risk for a child being protein calorie malnourished was higher among children: whose mothers did not separate utensils used for raw and cooked food (75.5%); whose mothers did not wash their hands after handling rubbish (94.1%); and when raw food came in contact with ready-to-eat and the usage of public toilets (52%). Simple behavioural changes, such as covering ready-to-eat food can prevent contamination by flies and other insects and influence a child's nutrition (Ibrahim & Alshiek, 2010). In Sudan, there is poor hygiene and inadequate dietary intake. Knowledge of hygiene and infant/child feeding practices among carers is very low, and poor feeding practises for under-fives include the consumption of very few meals, with only 5.3% receiving three meals a day and 94.7% consuming two or less meals per day (Reliefweb, 2006).

Cultural and social factors contribute to PCM (Taha, 1979). In Sudan, there are many cultural practices that undermine nutritional well-being, such as low rates of exclusive and continued breastfeeding (almost 40% for both), limited dietary diversification (either due to a lack of food variety or limited knowledge), and intra-household food distribution, which prioritises men (Taha, 1979) In addition, taboos, early marriage, and negative perceptions concerning family planning still predominate among Sudanese communities. The high illiteracy level among Sudanese women (50%) is a key challenge to good nutrition practice. These cultural issues hinder the positive behavioural practices needed to improve the nutritional situation and maternal and child care (Ali et al., 2013).

2.5.3.4 War and conflict contribute to protein calorie malnutrition in Sudan

Protracted civil conflict in Sudan has its origins in socioeconomic inequalities caused by the neglect of the agricultural sector, misguided land reforms, the unfair distribution of resources for development between urban and rural areas and for irrigated and traditional farming, and the exclusion of local communities from decision-making (IFAD, 2010). Instability due to the prevailing civil war in Sudan has played an important role in the predisposition to the prevalence of PCM. The civil war and its sequential effects are blamed for the seriousness of the problem and the change in the patterns of PCM (Taha, 1990).

2.6 Prevalence of Protein Calorie Malnutrition

2.6.1 Global Epidemiology of Malnutrition

PCM in young children is currently the most important nutritional problem in most countries in Asia, Latin America, the Near East and Africa (de Onis et al., 1992)

Box 1 An estimate of prevalence of PCM in developing countries (WHO 2000)

Area	**Population aged 0-5 y (millions)**	**No. of children with protein energy malnutrition (millions)**	
		severe	**moderate**
South America	46	0.7	8.8
Africa	61	2.7	16.3
Asia	206	6.6	64.4
Total	313	10.0	89.5

2.6.2 Prevalence of PCM in Sudan

Sudan as a nation has numerous advantages and opportunities, due to vast areas of agricultural lands, extensive water resources, a wealth of livestock of all types, and minerals and other underground resources, including oil. It also faces numerous challenges in the form of inequality in the allocation of resources between urban and rural areas, conflicts in different parts of the country, and a poor infrastructure, among others, which must be overcome before it can take full advantage of its natural endowments. Sudan is currently ranked 147th among the 177 countries on the Human Development Index, compared to 141st in 2006 (UNDP, 2008). This is despite high economic growth during this period, and is a reflection of Sudan's inability to harness its growth potential for the benefit of all its citizens (FAO, 2010).

In Sudan, the collection of reliable health and nutritional data for children and adults is hampered by a lack of trained investigators, a paucity of financial resources, and an inaccessible environment. It has been reported that 53% of children living in Gezira, a prosperous farming region of Sudan, had PCM (Taha, 1979). In a survey conducted in 1984, Dundas and Futrell (1987) observed childhood malnutrition rates of 75%, 73% and 42% in the desert region north of Khartoum, in villages near the Ethiopian border, and in White Nile province, respectively. Similarly, El Samani et al. (1988) conducted a study in a village north of Khartoum, and observed that 65% of children were undernourished. Coulter et al. (1988) in a study conducted at the Children's Hospital and Soba University Hospital, reported a PCM fatality rate of 20%, with mortality rates of 43% for marasmic kwashiorkor, 19% for kwashiorkor, and 14.5% for marasmus. In 2000, the prevalence of malnutrition among children under five years old was very high, reflecting the critical nutritional situation inherited from recent decades; overall, 41% of children were underweight and 15% were severely underweight (FAO &WFP, 2006).

According to the Welcome classification, the commonest type of malnutrition was classified as underweight (38.2%), whilst marasmus and kwashiorkor were detected at an incidence of 6.4% and 0.9%, respectively, whilst there were no cases of marasmic kwashiorkor in the studied population (Mamoun, 2009). Only 47% of children were found to be well nourished, and of the remainder, 1% had severe, 17% moderate and 35% mild PCM (Taha, 1979). Significant increases in malnutrition rates among 842 children aged 6-59 months were observed in the Darfur region during a survey which was conducted in September 2004 of a crisis-affected population residing in an area covering all three states of Darfur (CDC & WFP, 2004). The prevalence of wasting among these children was 22%, and the high child malnutrition rates were directly linked to the on-going crisis, the loss of livelihoods, and internal displacement (CDC & WFP, 2004). The prevalence of PCM in another study was 5%, with the 12-17 and 18-23 month age groups suffering the most (8.7% and 8.5%, respectively). The most common form of PCM among 172 children was marasmus (92.4%) followed by marasmic kwashiorkor (5.2%) and kwashiorkor (2.3%), whilst 8% of the PCM cases were female. The researchers concluded that a decade of drought, introducing supplementary feedings late, and poor weaning habits were responsible for these figures (El Bushra & El Tom, 1989). In the years 1980-1986, it is reported that 33% of Sudanese children below five years of age suffered from mild or moderate PCM (Mabyou, 1990). More recently, an overall rate of 16% of children were wasted (acute malnutrition) was reported, with SAM affecting 4% of the children. The prevalence of wasting varied by region, and levels were particularly high in Northern Darfur, where 23% of the children showed signs of wasting (FAO, 2005). Scant data are available after 2001, but significant increases in malnutrition rates have been observed in the Darfur region (CDC & WFP, 2004).

2.6.3 Seasonal Variation Influences PCM among Children in Sudan

Seasonal fluctuation influence PCM (Egata et al., 2013), but there is also a well-recognized synergistic interaction between seasonal variation and other factors. Either alone or, more often, in combination, they can contribute substantially to PCM.

In Sudan, where infections occur frequently, linear growth has little opportunity to catch up, resulting in high levels of PCM. Malaria, acute respiratory infections and diarrhoeal disease are highly associated with PCM, and there is seasonality in the incidences of such diseases together with changes in the quality of care, both family and health care. During the rainy seasons, the prevalence of childhood diarrhoea, malaria/fever and acute respiratory infections increases, and during this period, health facilities' supplies are at their lowest and the quality of child care is at its worst because caregivers are working outside the home in order to earn money. Infections experienced by children during their early years are a major factor in PCM (Jarrett, 1979).

The majority of kwashiorkor cases report to hospitals during the months of October, November and December. The only possible explanation for this seasonal phenomenon is the common shortage of milk, meat and vegetables during the dry months of May, June and July. In addition, the incidence of gastroenteritis is highest in July and August (Hassan, 1990).

Protein calorie malnutrition commonly becomes prevalent during the rainy season, a period characterised by infectious diseases, such as diarrhoea, respiratory tract infections and malaria (Oomen et al., 1964). A study conducted by Brown et al. (1982) observed a seasonal fluctuation in the prevalence of PCM among children aged 6-60 months in two rural villages in Bangladesh, and noted that the period of poorest nutritional status of the children persisted from shortly after birth to approximately two years of age. Children of this age are known to have lower immune competence, and consequently are the first victims to develop kwashiorkor, marasmus or marasmic kwashiorkor. Infectious diseases, including malaria and diarrhoeal diseases, demonstrate a seasonal pattern due to climatic effects on the breeding grounds for the disease vectors and the proliferation of microbes (Chambers et al., 1981).

Seasonal food shortages are known to have an effect on weight during pregnancy, birth weight, lactation and early infant growth (Prentice et al., 1981), child linear growth, and rate of wasting, underweight and stunting (Martorell & Yung, 2012). In a study conducted in Gambia, height and weight increases were found to be subject to dramatic seasonal variations, with a marked deterioration during the rainy season. Weight-for-age and weight-for height measurements also demonstrated variation and were lower during the rainy season (October) than the dry season (February) (Tomkins et al., 1986). In most developing countries, these difficult conditions coexist with demographic factors for PCM, such as maternal age, teen marriage and pregnancy, birth spacing and order, parity, gender, family size and ethnicity. It is unacceptable that Sudan, a country that has natural, human and food resources, has such a high prevalence of PCM. Therefore wider efforts to better understand and effective strategies to tackle PCM will form the theme of this study.

2.7 Effect of Protein Calorie Malnutrition on Brain Function

2.7.1 Brain Function

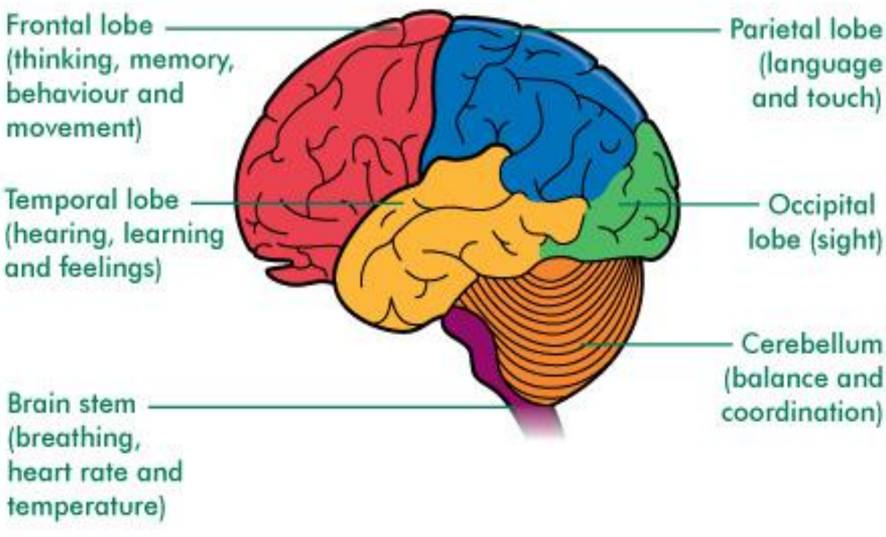


Figure 2.4: Brain function by lobes © 2009 Amicus Visual Solutions

The brain contains approximately 1×10^{11} neurons, each connecting to approximately 10,000 other neurons (Pelvig et al., 2008). The brain consists of three main parts: the forebrain, midbrain, and hindbrain: the forebrain consists of the cerebrum, thalamus, and hypothalamus (part of the limbic system); the midbrain consists of the tectum and tegmentum; and the hindbrain consists of the cerebellum, pons and medulla (Figure 2.4). Often, the midbrain, pons, and medulla are referred to together as the brainstem. The cerebrum or cortex is the largest part of the human brain, and is associated with higher brain function, such as thought and action. The cerebral cortex is divided into four sections called ‘lobes’: the frontal lobe, parietal lobe, occipital lobe, and temporal lobe (Frackowiak et al., 2004).

2.7.2 Brain Development

PCM is recognised as the most common and serious form of childhood malnutrition in developing countries and is one of the principal factors affecting brain development (Gilgen et al., 2001). According to Muhimbula & Issa-Zacharia (2010), PCM can be understood as a structural and functional pathology of the brain which results in multiple impacts on the body, including a reduction in synapses, and improper differentiation, as well as delayed myelination. However, in PCM there are also long term alterations associated with the observed physiological damage. Dahl & Yamada (2008) contend that long term alterations in brain function can be linked to extended issues of cognitive impairment, as well as an impact on the overall development of dendritic arborisation in the developing brain.

Experimental tests on animals have indicated that malnutrition affects growth development and functions of the brain. This may result in a cellular deficit and lower brain weight (Dierssen & Ramakers, 2006), and if it occurs during certain sensitive periods within early child development, it is likely to produce brain damage, possibly resulting in impairment in brain function (Levitsky, 1995). Pre-school children with PCM are more likely to suffer permanent brain damage than older children, and it is also reported that in cases of PCM, if the deficiencies occur in the period of rapid brain development (below two years of age), then a child's brain may be irreversibly damaged (Alleyne et al., 1979).

Although most brain structures eventually recover and are able to grow well, permanent impairments in the hippocampus and cerebellum remain. However, a recent study has revealed long-lasting, if not permanent, changes in brain neural receptor function resulting from an early episode of malnutrition (Yatkin & McLaren, 1970; Levitsky & Strupp, 1995). Nutrition rehabilitation reverses the increase in cell packing in the cortex during early malnutrition (Bedi et al., 1980; Thomas et al., 1980; Warren and Bedi, 1988) due to the recovery of the cortical width (Diaz-Cintra et al., 1990). Experimental studies have proved that nutritional rehabilitation can reverse the effect of PCM on peripheral nerves (Jones and Dyson, 1981), and in the neurophysiological field, changes in EEG have been noted (Nelson and Dean, 1959) and potential tracings evoked (Kawai et al., 1989; Flinn et al., 1993; Hernández et al., 2008). It has been shown that early malnutrition, marasmus and kwashiorkor, produces marked alterations in the electrophysiological parameters (Barnet et al., 1978; Bartel et al., 1986). EEGs have been shown to be abnormal in PCM, and the dominant frequency of the EEG is reported to be much lower (Figure 2.5) in PCM children than that found in children without malnutrition of the same age (Bartel et al., 1979). A study conducted by Barnet et al. (1978) demonstrated that marasmus caused increased latencies of auditory evoked potential (AEP) waves that were considered to be irreversible, since they were detected not only during the acute phase of malnutrition but also after a long period of nutritional rehabilitation (de Lima et al., 2008). Bartel et al. (1986) detected AEP abnormalities in children with kwashiorkor both during hospitalisation and following discharge (Figure 2.5).

Figure 2.5: EEGs for a malnourished chil aged 30 months

Figure 2.6: EEGs for a normal child aged 24 months

During a recovery period of between a few weeks and a few months the EEGs of malnourished children returned to normal (Taori & Pereira, 1974), and EEGs reported in some studies attained levels comparable to those of healthy children (Nelson, 1959).

2.7.3 Cognition

Children who are economically, socially and culturally disadvantaged frequently suffer from PCM (Wadia & Sinha, 2005), and children who survive PCM may experience some reduction in their intellectual functions (Gilgen et al., 2001). PCM also causes notable morphological changes in the brain, resulting in damage to the intellectual potential of those who survive, and limiting their capacity to become part of the competitive world (Cornelio-Nieto, 2007). A study conducted in Nigeria on children suffering from kwashiorkor found considerable effects of early PCM on physical and intellectual development (Nwuga, 1977). Stunted children, compared with non-stunted children, are more likely to enrol late, as observed in Nepal (Grantham-McGregor et al., 2007), Ghana and Tanzania (Brooker, 1999), and are more likely to attain lower achievement levels or grades for their age, and have poorer cognitive abilities or achievement scores. Those who do not reach their developmental potential are less likely to be productive adults (Grantham-McGregor et al., 2007).

In a controlled study on the long term effects of malnutrition on growth and intellectual performance of teenage children with a history of kwashiorkor or marasmus, Galler et al. (1987) found no marked differences in the growth of children who had a history of malnutrition, but their intellectual performance, including IQ tests, were significantly lower than their healthy counterparts. This would tend to confirm the excellent prospects of rehabilitation and full return to physical growth (Pipes and Trahms, 1993), but precludes the possibility of complete intellectual development (Winnick, 1987). Researchers from the Dominion University studied the effect of improved nutrition on severely retarded children, and found that retarded children who were fed on an improved food formula recorded significant higher IQ scores than those who had been fed placebos (Walker et al., 2007). This echoes the findings of studies carried out on severely malnourished children who were later adopted by more affluent families, indicating that intelligence improved markedly when health care and nutrition were continually provided (Colombo, 1992; Worobey et al., 2004).

2.7.4 Psychological and Behavioural Problems

Malnutrition has often been linked with major psychological and behavioural problems (Wachs et al., 1995). During the acute phase of PCM, most children exhibit behaviour changes (Taori & Pereira, 1974); are more apathetic and less active, irritable when disturbed, have low amplitude cries, and exhibit attenuated orienting responses to auditory stimuli

(Grantham-McGregor, 1995). This followed on from a study carried out on dogs, which highlighted behavioural abnormalities in PCM-affected dogs, as their brain size was reduced and pathologic lesions appeared (Michael et al., 1971). While PCM is severe, developmental levels of affected children are very low, but they improve markedly during recovery in all areas of development (Yatkin and McLaren, 1970).

2.7.5 Psycho-Motor Functions

Evidence has been gathered as to the fact that malnutrition early in life causes delays in the psychomotor development in children (Reyes et al., 1990), which had previously been observed in malnourished young animals (Wainwright and Russell, 1983). There has been growing evidence that PCM contributes to growth retardation within the central nervous system of human beings in early life, which significantly impairs motor and sensory nerve conduction, contributes to motor weakness, and hypotonia and hyporeflexia in infants and children (Jones and Dyson, 1981). However, experimental studies have shown that nutrition rehabilitation can reverse the effect of PCM on peripheral nerves (Chopra, 1991).

The widely held conclusion is that PCM in early life leads to permanent impairment, and might also affect future generations. These issues contribute to a diminished adult working capacity, making them inefficient as citizens in their countries (Hass and Brownlie, 2001). There is additionally a decreased ability for individuals, families and communities to reach their full potential, and a reduced ability to be vitally important through their role with regard to the intergenerational transmission of poverty (Grantham-McGregor et al., 2007).

2.8 Summary and Evidence Gaps in the Literature

A study is needed to identify and highlight knowledge gaps. This would involve coordinating and harmonising research protocols, to document all relevant information and make it available in one place, and to disseminate results through moderating ongoing discussions and regularly updating relevant information. Nutrition Science Committee might fulfil this function until a broader more inclusive study is established to coordinate in the long term.

2.8.1 Protein Calorie Malnutrition: Overview

Nova et al. (2002) argued that the primary risk factors associated with PCM are similar to those for malnutrition, and include multiple factors such as quality healthcare, inadequate breastfeeding, possible chronic infections, negligence associated with food habits, a lack of maternal and paternal education, poverty, cultural and religious factors. Similarly, Marino et al. (2006) also argued that malnutrition, as well as PCM, had similar consequences which can be linked to multiple factors, including physical growth, mortality, reproduction, morbidity, cognitive development and physical work capacity. Ouedraogo et al. (2008) supported this argument, indicating that PCM has an advanced impact on infants and young children as it causes more dire consequences when associated with infectious diseases.

Batool et al. (2011) presented the most encouraging evidence associated with PCM, which is that it is a common nutritional problem which is present worldwide, but with a greater presence in developing economies. The authors argue that PCM causes a decrease in the overall resistance to infection which is caused as a result of impairment to physiological processes. The causes and consequences of PCM are similar to those of malnutrition, although PCM has a greater impact due to the associated secondary consequences, including the impairment of immune responses and infectious disorders (Rodríguez et al., 2011), leading to post-neonatal mortality as well as morbidity (Fraker er al., 2000) . The availability of food is environmental factor with the highest impact on PCM and malnutrition (Laus et al., 2011), and there is an associated need also to manage multiple factors, including infection, culture and socio-economics factors, amongst others. The risk factors of PCM and malnutrition should therefore be examined from all perspectives. From the above assessment it can be argued that the overall risk factors and consequences of PCM and malnutrition are the same, although there are differences associated with the progression of the disease.

Growing evidence of research indicates that progress in reducing PCM is substantially uneven from place to place, even down to the district level within countries (Dickson et at., 2013). The prevalence of PCM and trend estimates available for public health planning is mostly available only at the level of global regions and/or at country level (Amugsi et al., 2013). To support targeted intervention to reduce PCM, public health planners and policy-makers require access to more data analyses than are presently available. To filling the gap of this need in Sudan, this study presents the prevalence of PCM within the country's geographic district.

Severe form of PCM is estimated to contribute to 1.7 million child deaths every year (Pelletier, 1994). Brundtland, (2003) argued that PCM is found to have a direct impact on child deaths (aged under 5). In Sudan, Coulter et al. (1988) reported a PCM mortality rate of 20%. This estimate either in developing countries or in Sudan does not include oedema.

Oedema is very common in Africa (Schofield and Ashworth, 1996). Thus underestimation of the prevalence and impact of PCM is likely to be large.

The literature review allows the study to investigate the effects of seasonal variation risk factors prior to and after controlling for the socioeconomic, household food consumption and child feeding practice. This enables the study to determine to what extent the PCM is driven by season or point to the influence of socioeconomic or household food consumption or even child feeding practice account for the prevalence of PCM. There are no data on prevalence of PCM in wet and dry season in Khartoum. In this study, because the data were collected in both wet and dry seasons, the following factors were studied: socio-economic, household food consumption and child feeding.

2.8.2 Prevalence of PCM by Demographic Characteristics

Many researchers have treated the impact of protein and energy deficiency as the prominent cause of PCM (Zere & Melnthyre, 2003; Duggan and Golden, 2005), whilst others have stated that infectious disease is responsible (Rodriguez et al., 2001; Suliman et al., 2011). However, demographic factors are also contributing factors in PCM, but their association remains yet to be determined (Frank & Zeisel, 1988). Identification of important determinants of child PCM in Sudan would make it possible to know which could be manipulated by policy decisions in order to plan national preventive programmes to reduce the prevalence of PCM. One example would be the implementation of family planning programmes if short birth spacing was found to influence PCM.

Demographic factors relating to mothers form an essential contribution to the health and growth of a child, and could be the basic cause of marasmus, as a result of maternal neglect and food rejection by the child. Maternal deprivation is also a widely recognised cause of growth failure within affluent societies (Frank and Zeisel, 1988). Dixon stated that children develop kwashiorkor when they are separated from their mothers, despite a relatively good nutritional situation (Dixon et al., 1982). Maternal competence can also contribute to PCM; for example, some children in Mexico become malnourished while others did not, although their socioeconomic situations were comparable (Cravioto et al., 1967). It is difficult to explain in a homogenous community why only some children develop PCM, indicating that food alone will not solve the problem (Latahm, 1997). This indicates that the prevalence of PCM is not dependent upon a single factor, but rather on many factors, including social, demographic, economic, environmental, and cultural and health services facilities. For infants and children who depend on their mothers to satisfy their needs, the demographic influences of mothers play an important role on the extent to which a child grows healthily or suffers from PCM. Therefore the concept underlying this study was to approach the issue through an examination of the demographic factors. Indeed, ignoring this aspect is what has made research findings from Sudan less than adequate, and sometimes misleading, as they fail to provide the full picture. This represents an important research gap. There are several reasons, All underpinning the demographic study, why demographic may have a role in the prevalence of PCM.

Children of adolescent mothers are more likely to have PCM than those born to older women (Ahmed, 2003), as during adolescence, a young woman's body is still developing and the additional stress of pregnancy at this time creates an extremely high risk of the child being born at a low birth weight (WHO, 2009). Children from a large family suffer from PCM (Taha, 1979). This is because in a family there is less food for each person. Because the mother in Sudan has so much work to do she may not pay enough attention in the feeding of young children. Number of children, which can be approximated by the number and ages of children the mother has and the number of children below five years of age, can be used to judge the work load of the mother and the amount of time and resources she can devote to the feeding and care of the youngest child.

The proportion of PCM in higher birth order (>3) is more than those with first birth order (Ahmed, 1982). A lower birth order has an advantage. The prevalence of PCM is rarely seen in children with first birth order (Sommerfelt et al., 1994). If a mother has pregnancies too close together, the health of babies will suffer. She will have less breast milk to feed the baby and the older child will get less time and care (Bøhler & Bergström, 1996) and may have PCM. It is generally believed that the higher the number of children below five years a mother has, the less time she will have available to devote to the feeding and care of the children with negative nutritional implications. The recommended period of 2-3 years is optimum birth interval for both mother and child (Cameron & Hofvander, 1983).

The way through which household income factors influence PCM is through the decreased availability of health services, poor sanitation, inadequate water supply and reduced health knowledge (Girma & Genebo, 2002). It has also been recognised that women from low-income classes are not able to devote sufficient time to caring for their children; consequently, childcare becomes the responsibility of older siblings (Gulati, 2010). The level of family income also reduces their access to household appliances and, thus, explains the association between the number of people in a household and prevalence of PCM in children in Sudan and in other developing countries.

The majority of studies on child nutritional status have described a prevalence of PCM among under-five children and associated socioeconomic, demographic and cultural factors associated with PCM in children in SSA (Taha, 1979; Abdalla & Sulieman, 2009; Reed, 1996). However, little is known about the links between PCM and tribal determinants, including length of residence and other demographic factors, due to restricted methodologies. Marasmus, kwashiorkor and marasmic kwashiorkor differ from tribe to tribe. This may imply that there is no consistent tribal pattern that predicts the type of PCM a child will manifest, but it rather depends on interplay of factors

The provision of adequate, safe and clean water is a component of Primary Health Care. In studied population the majority of Sudanese has no pipe borne water supply (Musa et al., 1999). The quality of water for a household has some influence on the hygiene of the environment and that of the food for the child (Musa et al., 1999). This is especially serious if un-boiled water is used to dilute already cooked, ready to feed children's porridges as this could lead to constant diarrhoea (Musa et al., 1999). The distance to the water source is also important because if the water source is far, the mother will spend more time getting the water than in cooking for and taking care of the children. Availability and cleanliness of latrine facilities is another indirect indicator of the general health status of the child

Children between 6 months and 5 years of age are growing fast. They may get PCM easily if they do not get enough of the right foods for their needs (Kwena et al., 2003). Several hypotheses can be made to explain these children's higher susceptibility to PCM in the first months of life, among them early weaning, inadequate consumption of supplementary food, and low coverage and low quality of public health (Kwena et al., 2003; Rodríguez et al., 2011). In Sudan most mothers breast-fed for 12-24 month, and in cases the breast milk was not exclusive as other carbohydrate introduced early (Zumrawi et al., 1987). This contributes to the incidence rate of PCM as additional food might not hygienically handle. Therefore episode of diarrhoea and vomiting are common before this age. It is evident therefore, that the onset of PCM is closely related to the age.

Some studies concluded that males had better nutritional status than females (Abeykoon. 1995; Pebley & Amin, 1991); other studies indicate that the prevalence of all the three types of malnutrition was higher among boys than among girls (Sommerfelt & Stewart, 1994;

Basu, 1993). However, the care and feeding practices makes up for the difference. In some societies in Sudan women may wean their girls early to increase chances of having a boy in the next pregnancy. Therefore, the gender inequality of male preference over female among the care givers is responsible for the difference in prevalence of PCM. Further studies are required to definitively explain the relationship between gender and the nutritional status of children. Such studies will assist in identifying factors that may be related to this observation and generate information that can inform the development of interventions.

Low birth-weight babies who survive are likely to suffer growth retardation and illness throughout their childhood, adolescence and into adulthood (Victora et al., 1997; Batista-Filho & Rissin, 1993; Leone et al., 1992). Growth-retarded adult women are likely to carry on the vicious cycle of malnutrition by giving birth to low birth-weight babies (Lartey, 2008). Children born with a low birth weight are more likely to suffer protein calorie malnutrition throughout their life and are unlikely to “catch-up” in terms of growth (Torún & Chew, 1994). Most of protein calorie malnourished children do not receive the full course of the triple vaccines (Coulter et al., 1988). However, this under-utilization is not peculiar to Sudan. It is a phenomenon in most developing Countries.

2.8.3 Prevalence of PCM by Socioeconomic and Environmental Factors

2.8.3.1 Prevalence of PCM by Socio-Economic Factors

There exist a direct relationship between educational qualification of mothers and PCM (El Shazli, 1979). It is expected that the more educated a mother is, the more likely she is to be receptive to developmental initiatives such as the childhood survival strategies. This has the resultant effect of improved family nutrition and less risk of PCM (Gulati, 2010).

Poverty at the family level is associated with PCM. Hence, low wages certainly limits families' purchase power and prevents them from meeting their material needs, making children living at this level of poverty highly vulnerable to PCM (Lima et al., 2004). In Sudan the earning power of father could determine the finances of the family and is directly related to the nutritional status of children. Employed women could supplement the finances of the households and help in reducing the prevalence of PCM. More importantly, in the absence of standard measures of the socioeconomic status of families and communities, researchers have typically used their own indicators, making cross-study comparisons difficult (Fotso & Kuate-Defo, 2006). These indicators may measure slightly different dimensions of socioeconomic factors, leading to different classifications of economic determinant factors and subsequently to the identification and selection of different population groups (WHO, 2010).

2.8.3.2 Prevalence of PCM by Household Food Cconsumption

In Sudan, data on actual food consumption are not available. Differences in food availability, climate, as well as regional food habits and traditions result in considerable regional variation in food consumption patterns in Sudan. Sorghum is the main staple of a major part of the rural population. Legumes consumed mainly in the northern part of Sudan (Abdalla & Sulieman, 2009). In urban areas, broad beans are generally eaten as a main dish for both breakfast and dinner. The consumption of fresh vegetables, especially green leafy varieties, and of fruit is limited. Mutton and beef are favoured over other types of meat. Consumption of fish is low. Groundnuts and sesame are the main sources of local vegetable oils (FAO, 2005).

In poor households the first response is to save on food costs and cut down on non-staple food consumption. These coping strategies affect first the diversity and quality, and then the quantity and safety of diets, with mothers usually the first to make such sacrifices. Distress sales of assets and cutbacks in health expenditures due to a temporary shock may further jeopardize the nutrition situation (Muss, 2011).

Assessing the household food consumption and child feeding practice influences on PCM in Sudan has special appeal for policy and programmes targeted at improving the well-being and survival chances of children. Unfortunately, the literature on socio economic has been growing asymmetrically, the knowledge being built mainly on evidence from developed countries (Fotso & Kuate-Defo, 2006). This gap is most glaring in the case of comparative and nationally representative studies of PCM.

2.8.3.3 Prevalence of PCM by Child Feeding Practices

Poor children's feeding practices can lead to PCM. Breastfeeding is important to provide the child with safe and complete nutritional requirements (Hoddinott et al., 2008). It is generally agreed that by the 6th month of age, breast milk is not sufficient (Cousens et al. 1993), both in quantity and quality, to meet the growing nutritional needs of the child; breast milk at 6 months of lactation is low in micronutrients. Children should be gradually introduced to weaning foods between 4-6 months of age. The issue is complicated by lack of a standard definition of breast feeding (Martin et al., 2005). The most important aspect of breast feeding is the duration of breast feeding. Some studies advocate breast feeding "as long as possible" for mothers in developing countries (Braun et al., 1993) while others outright condemn the advice (Schanler et at., 1999).

A study from Sudan reported that children from poorer households were more likely to receive less than adequate complementary feeding (Fawzi et al., 1997). In Sudan, prolonged breastfeeding was found to be associated with a higher risk of under nutrition (Fawzi et al., 1998**)**, and the supplementary food offered to children was cereals, which are naturally deficient in protein constituents (Abdella & Sulieman, 2009). Moreover, in Sudan, food distribution favours adult males and guests. Consequently, the dietary problem is as much a social issue within a family as an economic one. Another equally important social factor affecting infant feeding is the traditional absence of supplementary feeding within Sudanese culture; too little and poor quality food is added to a child's diet too late (Taha, 1979).

For PCM, there is strong and high quality evidence of effects from child feeding practices and household food consumption (Fawzi et al., 1997). Most research, however, focuses on high-income developed countries. Few studies are set in low-income developing nations - where it is PCM and preventable mortality that are high (Grantham-McGregor et al., 2007) . This represents an important research gap. There are several reasons; all underpinning this study, why child feeding practices and household food consumption may have a role in the prevalence of PCM.

2.8.4 Implication for Brain Development

Protein calorie malnutrition (PEM) has a greater impact on brain development. Tizzau et al. (2010) further argues that PCM can be considered as a group of allied disorders, which include kwashiorkor, marasmus, and intermediate states of marasmic kwashiorkor, and are worse than general malnutrition. Similarly, Rodríguez et al., (2011) proposed that children who suffer from PCM have more severe impacts compared to general malnutrition. Black (2003) concluded that PCM is a term which identifies severe forms of malnutrition, including problems of wasting and/or withering, as well as a maladaptive response to starvation. Therefore, children affected with PCM are found to have deficiencies associated with essential fatty acids, vitamins and trace elements, which can contribute to dermatosis (Dicko et al., 2006). EEGs have been shown to be abnormal in PCM (Bartel et al., 1979). From the information above two fundamental questions have arisen:

Can EEG abnormalities in protein calorie malnourished children be improved?

What factors, apart from the brain itself, are associated with adverse results?

Interventions with the potential to improve PCM are therefore important: clinical, nutritional, neuropsychological and EEG assessment and follow-up describe the potential of functional food and hospital management to fulfil this role. Improving PCM outcomes in brain functional disorder requires better understanding of all factors involved.

2.9 Study Rationale

Comprehensive information associated with the prevalence of PCM in Sudan is relatively limited and hence cannot be considered to be conclusive. However, it is quite clear from the information that is available on protein calorie malnourished children and observations from feeding centres that there is a need to focus on PCM as a separate entity. Furthermore, it can be argued that the exponential growth of Khartoum City, from about 3 million to its current population of over 8 million (LANDINFO, 2008), is a clear indication of migration of a large sector of the population from rural to urban areas.

In Sudan, as in other large developing countries, collection of reliable health and nutritional data of children and adults are hampered by lack of trained manpower, financial resources and inaccessible environment. Nevertheless, Taha (1979) reported 53% of children living in Gezira, a prosperous farming region of Sudan, had protein calorie malnutrition. There is scarcity of comprehensive data on the current prevalence of PCM in Sudan. However, data of hospital beds occupied by malnourished children and observations from feeding centres in the various regions of the country indicate malnutrition of children under the age of 5 may have increased significantly over the last two decades.

At present, children with protein calorie malnutrition in Sudan are treated with Kwashiorkor milk formula. This formula, which has not been modified for decades consists of cow's milk, sugar and corn oil, and is devoid in nutrients vital for optimal growth and development and health, such as vitamin A, omega 3 fatty acids and some trace elements. Given this existing evidence base for PCM treatment, knowledge gaps with potential to improve public health impact remain and are the motivation behind this work

Fluctuations in rainfall patterns have alleviated factors which expanding the prevalence of PCM in rainy season. There is a need to examine whether Sudan is vulnerable to seasonal variation in food availability, to address how the impact of season sensitive prevalence of PCM can be reduced, this study undertakes a literature review to identify, characterise and evaluate preventative interventions for PCM control.

After an extensive search for literature specific to Sudan, it appears that very few research studies have been undertaken in this country on the demographic factors influencing childhood PCM. Therefore this research is comprised of an ethnographic study, which looks at the maternal factors that may play important roles in the occurrence of PCM. The outcome of this study provides information which it is hoped that will form the basis for effective health planning in Khartoum in relation to PCM care.

Chopra (1991) highlighted that there is growing evidence of PCM contributing to growth retardation in the central nervous system during the early years. This can result in significant impairment with regards to motor and sensory nerve conduction leading to motor weaknesses, as well as hyporeflexia in infants, although nutritional rehabilitation can reverse the effects of PCM and its effect on a child's brain. Robinson et al. (1995) found that no differences in electroencephalography (EEG) patterns were observed among protein calorie malnourished children, although they noted that electrophysiological abnormalities were associated with chronic rather than acute aspects of malnutrition. The authors therefore concluded that these factors can be associated with other attributes of brain function which are more permanent rather than temporary. As a result, it can be argued that there is significant proof from investigative research on human beings and animals of the impact of nutrition on brain growth. Almeida et al. (2002) postulates that the prevalence of developmental delay and neurological disabilities in low birth weight, preterm human new-borns as a result of PCM, although there are a lack of clear EEG results by other authors (Hackett and Iype, 2001).

The differences in representative evidence which have directly established a causal relationship between PCM and EEG patterns in humans motivated the researcher to examine their existence among children with PCM in Khartoum.

2.10 Study Aims and Objectives

The overall aim of the study was to determine in Sudan the prevalence of PCM, seasonal variation and causative factors (underlying and immediate).

Aim 1:

To determine the prevalence and seasonal variation of PCM in Khartoum, Sudan.

Objectives:

As data were collected during both the wet and dry seasons, the following objectives were identified:

- Demographic and socio-economic
- Child feeding practices
- The types and quantities of foods fed to infants and young children so as to estimate the energy and nutrient intake of these children and identify deficiencies
- Household food consumption

Aim 2:

To determine the effect of demographic factors on the prevalence PCM

Objectives:

- To collect detailed information on mother and child characteristics
- To explain the relationship between selected demographic factors and PCM
- To evaluate which demographic factors have the largest influence on PCM

Aim 3:

To estimate the impact of PCM on brain development

Objectives:

- To localise the site of pathological lesions in the brain by abnormalities
- To evaluate the relationship between nutritional assessment and EEG abnormalities
- To study the relationship between clinical signs and EEG abnormalities
- To evaluate the relationship between neuropsychological signs and EEG and severe malnutrition changes
- To evaluate the improvement of the patients

2.11 Study Hypotheses

This study examines the following null hypotheses:

In Sudan:

- The prevalence of protein calorie nutrition does not show season variability.
- Maternal age, teen marriage and pregnancy, birth order and spacing, parity, ethnicity and family size do not influence the prevalence of PCM
- There is no difference in cognitive function or behaviour between children with and without PCM.
- Clinical and nutritional interventions do not have any effect on cognitive function or neuropsychology of children with PCM.

2.12 Originality

This work is original in that it:

(1) Investigated the effect of (a) PCM on brain function as assessed by EEG and neuor-psychology; (b) clinical and nutritional intervention on EEG and neur-psychology of children after recovery from PCM. To our knowledge such a study has not been conducted before in Sudan or any other country.

(2) Assessed the effect of seasonality (dry and wet seasons) on the prevalence of PCM in Khartoum, Sudan. Previous studies on the subject in Sudan have not studied season influence on PCM.

(3) Studied the influence of birth interval, teenage marriage and pregnancy and high parity on prevalence of protein calorie energy malnutrition in Sudan. Perhaps surprisingly, such investigations have not been conducted in the country before.

The information obtained will contribute significantly for any programme designed to prevent or reduce the prevalence of protein calorie malnutrition in Sudan. I believe the problem will not be eradicated without addressing socio-economic and demographic factors and maternal education which are critical pre-disposing variables. The current nutritional therapy for protein calorie malnutrition is devoid of nutrients which are vital for the structure and function of the brain. The fact that PCM to have an adverse effect on brain, there is a need to modify the current nutritional therapy which has been in use for decades.

Chapter 3 - Setting, Subject and Methods

3.1 Introduction

This chapter covers the methodological aspects of the research project. After detailing the setting and the study site, it explains the methods that were used to investigate the impact of seasonal variation on PCM, the demographic factors that contribute to PCM in Sudan and the impact of PCM on brain function.

The most common methods for both prevalence of PCM and implication of PCM on brain development are described in this chapter. Specific methodology are described in the respective chapters (chapter 4 and 6)

3.2 The Project Site

The study was carried out in Khartoum Teaching Hospital (KTH) and Khartoum Children's Emergency Hospital (CEH). Khartoum is the one of Sudan's 26 states, and it is the national capital, located in the centre of the country between latitude 15.28' –16.08' and longitude 32.43' –33.70', within the poor savannah region. Its estimated land mass is approximately 2,800 km^2 and it is bordered by seven states. The state has a high population density, and the estimated total population is 5.7 million, with an under five years old population of 951,623 (CBS, 2008).

Khartoum Teaching Hospital (KTH) is the biggest hospital in Sudan, both in size and catchment area. The total number of staff is approximately 3000; 400 doctors and 700 nursing staff. Khartoum is the centre for medical care in the country, and there are 35 physicians for every 100,000 people (LANDINFO, 2008)**.** Patients admitted to the university hospital represent all areas of the country: from the Northern State to Port Sudan in the east, from the western war-torn provinces of Darfur to the southern areas. Many of these patients and their families have been forced to relocate to Khartoum because healthcare in their home areas was insufficient or simply not available**.** There is a markedly uneven distribution of healthcare facilities, workers, and funds across the country, with the majority concentrated in urban areas (Klaassen, 2007). Both hospitals follow the WHO protocol guidelines.

CEH is also a tertiary referral centre. However, CEH is a teaching hospital, and whilst the clinical and diagnostic expertise is greater than elsewhere in the country, there is not always a significant amount more that can be offered in terms of medical treatment.

Malnourished children present either directly to these two hospitals or arrive via local health centres following an initial assessment by community based health workers. KTH and CEH are part of the government health service and all services are provided free of charge

3.3 Study Participants

i) Prevalence and seasonal variation of PCM: influence of demographic factors

A total of 466 children with PCM (marasmus, kwashiorkor and marasmic kwashiorkor) admitted to KTH and CEH, between 0-59 months of age were eligible for the study

ii) Implication of PCM on brain function

A total of 48 children with PCM (marasmus, kwashiorkor and underweight) admitted to CEM along with 12 children (control), aged 12-36 months were recruited for the study

The Sudanese National Guidelines for admission were severe wasting or bilateral pitting oedema +++, or any grade of bilateral pitting oedema with severe wasting.

iii) Inclusion criteria were as follows:

- children whose parents agreed to participate
- children without chronic diseases, such as HIV, malignancies or any physical or mental condition that could have predisposed them to protein energy malnutrition
- children without cerebral palsy; an obvious dysmorphic syndrome
- PCM was not secondary to major surgical problems
- PCM without complications.
- patients who did not show any neurologic involvement, for instance brain damage, fits, birth trauma or coma while in the hospital or hypoglycaemia.

3.3.1 Procedure for Admission to the Nutrition Ward

- Screening: check severe wasting, bilateral pitting oedema and measure mid upper arm circumference (MUAC) and weight-for-height
- Medical history and physical examination: evaluate nutritional status and health condition,
- Check for medical complications
- Check if PCM without medical complications
- Check if PCM with medical complications
- Admission to outpatients or inpatients care for treatment
- Referral for continuing treatment in outpatient care: appetite return (passed appetite test), oedema decreasing, medical complication resolving
- Upon arrival at the health facility critically ill children are triaged and receive priority treatment, sugar water is made available to prevent hypoglycaemia

3.3.2 Initial Assessment

A child's nutrition status is defined based on standardised measurements.

3.3.2.1 Anthropometric Measurements

- Measurement of weight, length and MUAC following standard methods (de Onis et al., 2004).

3.3.2.2 Clinical Assessment and Recording of Clinical Signs

Every patient was assessed by a Sudanese clinician as soon as possible following admission. If admitted out-of hours, core details would be taken by the nurse in-charge or on-call doctor and full details reported.

3.3.3 Treatment for Severe Protein Calorie Malnutrition

Provide treatment for underlying infections, and decide if treatment for additional health conditions is needed. WHO's 1999 guideline, "Management of severe malnutrition: a manual for physicians and other senior health workers" provides practical guidelines for the management of children with severe malnutrition (WHO, 1999).

3.3.3.1 Medical Assessment

Take the child's medical history, conduct a physical examination, and determine if the child has a minor health problem or a medical complication, and record on the treatment card.

- Children with PCM and medical complications need inpatient care and treatment
- Test appetite – this is a critical criterion for deciding whether a child with PCM without medical complications is treated in outpatient care or inpatient care.
- Decide whether to treat a child with PCM in outpatient care or refer him/her to inpatient care.

3.3.3.2 Inpatient Treatment

Medical treatments in WHO 1999 include routine antibiotics for infection. The WHO guideline also recognised the importance of environment and psychosocial interventions towards improving outcomes from severe malnutrition (WHO, 1999). Inpatient treatment was comprised of two main treatments delivered in parallel according to the clinical indications:

- Provide weekly (or bi-weekly) amount of ready-to-use therapeutic food (RUTF), based on +/- daily ration of 200 kcal of RUTF per kg bodyweight
- Counsel the caregiver on key messages for treatment, the intake of antibiotics and RUTF, and care practices, and to return to the health facility for monitoring sessions or whenever a problem arises

3.3.3.3 Nutritional Treatment

- Preparing F-75 and F-100 and learning about RUTF
- Feeding F-75 during stabilisation
- Adjusting to RUTF and/or F-100 during transition
- Feeding on RUTF or freely with F-100 during rehabilitation
- Planning feeding for inpatient care
- Management of PCM
- The quantity of therapeutic feeds, both milk and RUTF was adjusted according to a child's weight using standard charts in the national guidelines.

3.3.3.3.1 Stabilisation phase (Phase 1)

The F-75 therapeutic milk is designed to restore hydration, electrolyte and metabolic balance and provide the necessary calories and nutrients for maintenance needs. Weight gain is not obtained during this phase. A large volume of F-75 than is required with a reduced number of feeds, on rare occasions, can provoke osmotic diarrhoea, which is why ideally, eight or more feeds should be given daily. All children are initially fed F-75 therapeutic milk which is given every three hours, including overnight. This stabilisation phase lasts for a minimum of one night.

3.3.3.3.2Transition phase (Phase 2)

When children with PCM complete the stabilisation phase, they commence treatment in the transition phase. During this phase medical treatment is continued and the dietary treatment changes for children, with RUTF being progressively introduced and F-100 therapeutic milk used to complement the RUTF feed if a child did not successfully complete the RUTF amount per feed. The quantities of the milk diet provided remain the same as in the stabilisation phase, but the calorie intake changes. The duration of treatment in the transition phase is on average two-to-three days. Children are gradually prepared for referral to outpatient care. As soon as a child eats 75 percent of his or her daily RUTF ration, then the child will be referred to outpatient care to continue treatment.

Criteria for progression to transitional feeds are clinical improvement and return of active appetite, which is defined as easily finishing the prescribed volume of F-75 milk; RUTF is introduced into the diet at this stage (Briend et al., 1999). A full RUTF prescription provides 200 kcal /kg body weight/day. Recognising that not all children were able or physiologically ready to eat the entire RUTF target amount at this stage, is the reason why F-75 milk is continued. Mothers are instructed to give initially small amounts of RUTF and to gradually increase the amount as guided by the child’s appetite.

3.3.3.3.3 Rehabilitation phase (Phase 3)

Some children with PCM as they progress from the transition phase will still require inpatient care and are therefore moved to the inpatient rehabilitation phase. This phase is associated with a full recovery and rapid catch-up of lost weight. A child progressing to the rehabilitation phase and who is on a RUTF diet can be referred to the outpatient department of a health facility and monitored weekly if there is an outpatient care site close to his or her community.

A good appetite reflects a clinical improvement and is the main criterion for moving forwards from the transition phase. When easily eating at least 75% of his/her RUTF target ration, a child has by definition moved him/herself onto the next phase and hence this is a much more child/physiologically led process, in contrast to the traditional phase transition, when the clinician in-charge decides when a child was ready to move to the next phase. As long as clinically they are also well at this point, a child is ready for transfer to home-based rehabilitation at the next available opportunity. During this phase, free fluids and other foods were also allowed alongside the RUTF.

3.3.3.4 Clinical Treatment

Routine medicines and supplements should follow the schedule as described for outpatient care. Routine antibiotic therapy should be continued for four more days after stabilisation, and a child can be referred to outpatient care and continue the drug regimen. If a child has to complete the antibiotic schedule while in outpatient care, then this should be noted on the child's referral card.

3.3.3.5 Outpatient Treatment

Once clinically well, children are transferred from ward to outpatient care, to complete their nutritional rehabilitation at home. Sufficient RUTF rations and any other treatment needed are also supplied, e.g. for finishing a course of oral antibiotics. At fortnightly intervals, children attend outpatient clinics at KTH or CEH for a clinical review and to collect further rations of RUTF.

3.3.3.6 Discharge

Children that meet the criteria listed below are discharged:

- Fifteen percent weight gain for two consecutive days
- Sustained weight gain
- No bilateral pitting oedema for two weeks
- Clinically well and alert

3.3.3.7 Follow up

As the risk of relapse is greatest soon after discharge, a child should be seen after one week, two weeks, one month, three months and six months. Provided a child's weight-for-height is no less than -1 SD (90%) of the median NCHS/WHO reference values, progress is considered satisfactory. Children are also enrolled on a nutritional support programme for four-six months.

3.4 Ethics Principles

Research was designed, reviewed and undertaken to ensure integrity and quality. Participants were fully informed of the purpose, methods and intended possible uses of the research. The confidentiality of information was respected to maintain participant confidentiality and anonymity within the study. Research participants have participated in a voluntary way, free from any coercion. The research has guaranteed the absence of harm to the research participants. ('harm' is taken to mean more than just physical harm, and can refer to emotional harm and risk of upset, as well as to reputational damage).

Research design has enabled the researchers to remain independent throughout the research process. The research was conducted using researchers with experience in using different research methods. Multiple methods were used to collect data (interview, questionnaire, dietary assessment, clinical assessment). These methods allowed for data transmission. The information was cross- indexed. The researcher employed constant comparison between data and emerging theory by regularly reviewing the record. This interplay between data collection and analysis phases is an important feature of grounded theory research (Strauss and Corbin 1994). Trustworthiness was also enhanced through interviewers' prolonged engagement with the study setting and participants.

3.5 Methodology: Ethical Implication of Study Methodology

3.5.1 Anthropometry

High quality anthropometry is important for nutrition-focused research. For both the prevalence of SPCM and the implications of PCM studies, the following equipment was used and measurements were taken to optimise the data quality.

Anthropometric measures identify the affected people and asses the determinants of PCM. Using anthropometric data and socio -economic information, for example, in the demographic and health surveys, allows a careful assessment of the socio -economic, demographic and also determinants of PCM that can be of critical importance for the formulation of appropriate policies (Kandala, et al., 2002).

Implications of anthropometry include the extent to which measurement error can influence interpretation, and the length of time needed to take measurements. For large studies, a number of anthropometrics may be needed, and this influences the degree of measurement error, especially if there is between-observer bias. In choosing the instrument to assess nutritional status, researchers often elect to measure only height and weight. These measures are quick, simple and require only limited training, but more comprehensive measurement sets which include skinfolds and circumferences require more training and carry different degrees of error with them (Ulijaszek & Kerr, 1999).

3.5.1.1 Weight

Mothers and older children (aged 24 to 59 months): Weight was measured immediately after admission using a digital electronic scale, accurate to the nearest 100 grams, while wearing light weight clothing without shoes and with the mother or child standing in the middle and remaining still until the measurement was taken (Gibson, 2005). Calibration was checked daily using 2.3kg and 5kg reference weights.

Children below 24 months: Weight was measure using an infant scale, when the child was naked or wearing minimal clothing. The child was placed on the scale so that the weight was distributed evenly, and the measurement was taken to the nearest 10 grams whilst the child was lying still.

Particular problems: when weighing children in distress or if an infant scale was not available, the mother/caregiver and child were weighed together on a platform scale, and then with the mother still on the scale, the child was removed and the mother/caregiver was weighed separately. The weight of the child was then subtracted from the mother/caregiver's weight to get the weight of the child. When weighing both mother/caregiver and child a minimum amount of clothing was worn, for children this was a nappy with underclothes or only one layer of lightweight clothes (Gibson, 2005). In most cases, babies wore only a clean nappy. Three weight measures were taken and the average determined.

3.5.1.2 Length

The recumbent length of infants and children below 24 months of age was measured from the crown to the heel using a paediatric measuring board to the nearest millimetre. The measurement was only taken if the head was level with the headboard and the end of the measuring mat or board was against a flexed heel. The measurement was taken at eye level (Gibson, 2005). Three height/length measures were taken and the average determined.

3.5.1.3 Height

In adults (mother/caregiver) and older children, height measurements were taken using a stadiometer to the nearest millimetre. Participants were required to remove their shoes while standing straight on a horizontal surface with their heels together touching the back of the height measure, legs straight, arms alongside the body, shoulders relaxed and eyes looked straight forward. Those of two to three years of age who are unable to stand were measured using a standard calibrated board. Length and height can be particularly difficult to measure, as children are often crying and moving,

3.5.1.4 Head Circumference

This was measured by placing a non-stretch tape firmly around the maximum circumference of the head (usually forehead to occiput). The tape touched the skin everywhere but was not pulled too tight, and the measurement was recorded where zero overlapped the next round of the tape.

3.5.1.5 Chest Circumference

This measurement was carried out by placing the tape at the level of the nipple in a plane at the right angle to the spine and the measurement was recorded in mid respiration**.**

3.5.1.6 Upper Arm Circumference

This was measured by placing a non-stretch measuring tape around the mid upper arm at the midpoint level (between the bent elbow and the knob at the top of the shoulder) and measured to the nearest millimetre. Only bilateral oedema was considered to be an indicator of PCM (kwashiorkor). The middle point of this distance was calculated and a mark made on the skin of the upper arm, and at this mark the circumference of the upper arm was measured. The measuring tape was fitted tightly, but did not make a dent in the upper arm (Gibson, 2005). The arm was kept in a relaxed position along the side of the body. Oedema was assessed by applying medium thumb pressure on the upper side of both feet for three seconds. It was diagnosed if a bilateral depression (pitting) remained after the pressure was released.

MUAC has practical advantages in research setting as it is a non-passive measure which requires minimal equipment. As children’s arms are very small the relative importance of even 1mm of difference makes MUAC reliability vulnerable to measurement error (Colins et al., 2000)

3.5.1.7 Body Mass Index (BMI)

Body mass index was calculated using the formula BMI = weight in kg/ height in m². BMI is widely used anthropometric assessment measure in assessing adult nutritional status. The WHO recommends the use of BMI to classify adult in groups including underweight if their BMI was less than 18.5, normal from 18.5 to 24.9, overweight from 25.0 to 29.9, and obese if ≤30 (WHO, 1995).

While BMI is recognised as being one indicator of underweight, it is not always a reliable indicator. For example with individuals who are very tall or individuals who are very muscular BMI can be deceiving. In muscular people BMI may be more likely to indicate over weight, as lean body mass tissue is dense and heavier (WHO 1995). The Cormic Index can be used to help to correct for variability in body shape (Collins et al 2000). In this study, sitting height was not recorded and therefore the Cormic Index was not calculated.

When conducting a nutritional assessment of an individual, using only one measure is not sufficient to diagnose underweight. Additional measures including weight history, waist to hip ratio and body composition analysis can help to form a more complete picture of nutritional risk. In this case however nutritional status of mother was not part of research protocol, and these additional measures may have been seen an invasive.

3.5.1.8 Repeat Measurements

These followed standard research protocols, whereby trained observers measured in pairs. If the measurements were within set agreed limits, the mean of the two measurements was taken as correct. Otherwise, both observers would re-measure until their agreement was acceptable.

Criteria for repeating measurements were:

Their two length measurements differ by >7mm

The measured length decreased since last measurement

Length or MUAC increased by >20mm since last measurement

Their two MUAC measurements differ by >5mm

3.5.2 Age Assessment

Age is an independent variable and is also important for determining anthropometry z-scores. To minimise errors, the study questionnaires asked the age and date of birth as separate questions. If the answers were inconsistent, further details could be asked and the true age determined with greater accuracy.

3.5.3 Interviews

The participating mothers were informed about the interview by the researcher, and a questionnaire was used to interview the mothers of the children in the wards within two days of admission. The interviews were carried out by the researcher, a dietician or a trained assistant nutritionist. As the questionnaires were written in English, each question had to be translated into Arabic at the time of the interview. The child's age in months, an important variable in anthropometric surveys, was obtained with a high degree of accuracy, through birth certificates. Where these were not available, the mothers were asked to recall when their child was born. If the mother was not sure of the exact date of birth, she remembered the season, and whether the birth had taken place at the beginning, the middle or the end of the season.

Interviews can be used to examine much broader issues in more depth. Interview is ideally suited to examining topics in which different levels of meaning need to be explored, and is a method which most research participants accepted readily. This is partly due to familiarity with interviews in general; however, equally important is the fact that most people like talking whether to share enthusiasm or to air complaints, but rarely have the opportunity to do so with interested outsiders. Interviewees commonly enjoy the experience, and in some cases find that it has helped them clarify their thoughts on a particular topic (Cassel & Symon, 2004). In Sudan, regarding this study the researcher identified that interview was a useful tool to explore sensitive research topics in a more flexible way by leaving room for participants to raise relevant issues not necessarily captured by a survey or a questionnaire.

On the other hand, as already emphasized, developing an interview guide, carrying out interviews, and analysing their transcripts, are all highly time-consuming activities for the researcher. Interviews are also tiring to carry out, as they involve considerable concentration from the interviewer. Interviews are also time-consuming for interviewees, and this may cause problems in recruiting participants. A difficulty faced by many researchers using qualitative research interviews is the feeling of data overload as a result of the huge volume of rich data produced by even a moderate-sized study (Cassel & Symon, 2004). Add to this in this study interviewing methods were not only time-consuming to carry out, but can also generate unwieldy levels of data which can become problematic and difficult to analyse.

3.5.4 Structure of the Questionnaires

The questionnaire was prepared in English, translated into Arabic and then back into English in order to check language consistency. The questionnaire was pre-tested in KTH and CEH for the pilot study. This procedure was undertaken before the actual data collection to help with the standardisation process, the accuracy of responses, and to estimate time needed. The same questionnaire and measurements to be used in the main study were used in the pilot, together with identical inclusion criteria. A trained, registered dietician completed the questionnaires and the same procedure to be used in the main study was followed for the pilot study. On completion of the pilot study, some of the questions were rephrased to guarantee that the interviewee would provide valid information. No real problems were experienced when the interviews were conducted during the pilot study.

Advantages of questionnaire: Leedy (1993) justifies the use of the questionnaires by stating that if a researcher wants to observe and collect data that is beyond physical reach, a questionnaire is an appropriate instrument. He further states that it is an impersonal probing instrument in which the researcher is remotely removed from the sources of data collected (Leedy, 1993). In this researchers collected data from respondents, and they had no chance of knowing or even possibly meeting. Add to this, large amounts of information can be collected from a large number of people in a short period of time and in a relatively cost effective way, can be carried out by the researcher or by any number of people with limited affect to its validity and reliability The results of the questionnaires can usually be quickly and easily quantified by either a researcher or through the use of a software package Can be analysed more ‘scientifically’ and objectively than other forms of research (Vale, 2014)

Regarding the limitation of these methods**,** it is argued to be inadequate to understand some forms of information – i.e. changes of emotions, behaviour, feelings etc. The respondent may be forgetful or not thinking within the full context of the situation. People may read differently into each question and therefore reply based on their own interpretation of the question – i.e. what is ‘good’ to someone may be ‘poor’ to someone else, therefore there is a level of subjectivity that is not acknowledged (Vale, 2014). Questionnaires and surveys are not always the most useful tools for understanding how or why people act as they do and may require complementary qualitative methods to generate more in depth data.

3.5.5 Clinical Examinations

The clinical observations performed included observing the general health status of a child and examining the colour and strength of a child's hair and its resistance to plucking. Eyes were examined for a vitamin A deficiency to determine if there were Bitot's spots, and an iron deficiency was identified by examining the eye lids and finger nails for pallor, and the gums to find out if they were pale, bleeding or normal. The skin of the stomach, arms and legs of a child were also examined for dryness, scales and scabs. The feet, legs and abdomen were examined for oedema, using the 'pitting' method described by Cameron and Hofvander (1983). Oedema was present if the depression 'pit' made by the thumb stayed printed in a child's leg.

Every child included in the study was subjected to a thorough clinical examination with the emphasis on their general condition at the time of admission, including weight, appetite, skin and evidence of PCM, such as oedema and lower foot or facial ascitis. Other factors included wasting, anthropometric measures, signs of vitamin A deficiency, and signs of dehydration were assessed. Subcutaneous fat stores were assessed by measuring skinfold thickness, whilst the upper arm circumference, in conjunction with triceps skinfold thickness, was an indication of skeletal muscle mass. However, it is difficult to measure skinfold thickness accurately in young children, so this reduces its use in reflecting short-term changes in body composition. Haemoglobin, protein and albumin levels were also measured.

PCM was diagnosed using the modified Welcome classification (Hendricckse, 1991) based on weight-for-age and the presence/absence of oedema, into the following grades: 80-60 without oedema were classified as underweight; 80-60 with oedema were kwashiorkor; <60% with oedema were marasmic kwashiorkor; and <60 without oedema were marasmus. The children were therefore categorised into the three clinical syndromes of PCM: kwashiorkor, marasmus and marasmic kwashiorkor. Clinical examinations are useful nutritional assessment tools as they are inexpensive, often requiring no equipment at all. However, they are highly subjective and require clinical skills and experience as one clinical sign may indicate a number of nutrient deficiencies. To gain more validity, clinical examinations should be accompanied by biochemical analysis and/or anthropometric measurements.

The National Centre for Health Statistics/WHO (NCHS/WHO) guidelines and cut off points were followed to determine the degree of wasting and stunting. Underweight was diagnosed when the weight-for-age (WAZ), weight-for-height (WHZ), and height-for-age (HAZ) were equal to -2SD below the mean of the reference population. In addition, -1z and -3z scores were used to define different grades of PCM (De Onis et al., 1997).

Using the MUAC, patients with a circumference of <12.5cm were considered to have SPCM, those with between 12.5 and 13.5cm were classified as having moderate PCM, and those with > 13.5cm were deemed to be normal (WHO, 1998). If the chest circumference failed to increase, the ratio of the chest to the head circumference remained below one, and this was used as an indicator of PCM.

3.5.6 Nutritional Assessment

3.5.6.1 Food Frequency Questionnaires (FFQ)

The most accurate dietary assessment methods such as weighed food records are not always applicable especially in developing countries as it is not easy to find the number of subjects with enough skills, motivation and compliance required in such methods (Rush & Kristal, 1982; Harbottle & Duggan, 1993). In developing countries, methods that require weighing and/or recording are limited by the difficulties with estimating or weighing an individual's portion of food from a shared bowl (Hudson, 1995). Furthermore, in Sudan visitors, different occasion (Eid), the presence of a stranger in the home over a number of days might precipitate alterations in the family's usual food habits. FFQs are commonly used to rank individuals by intake of selected nutrients. Although FFQs are not designed for estimating absolute nutrient intakes, the method may be more accurate than other methods for estimating average intake of those nutrients having large day-to-day variability and for which there are relatively few significant food sources (FAO, 2015).

3.5.6.2 The 24-hour Food Recall

The 24-hour hour food recall is the most commonly-used method of dietary intake, especially in developing countries (Rush & Kristal, 1982). In Sudan as in developing countries where meals are monotonous with little day-to-day variations, the 24-hour food recall may indeed be the best estimate of the "usual diet" with a high level of reliability. Twenty-four hour food recalls have been found to correlate reasonably with weighed food intake (Pipes & Trahms, 1993). Information of portion sizes consumed, using household measures, photographs etc., is requested to enable estimation of quantities consumed. Akinyele & Omotola (1986) found no significant differences in the energy and protein intakes of children derived by either calculations from 24-hour food recalls or by direct nutrient analysis of duplicate diets.

In some situations, the recall is self-administered by the subject, but this approach may not yield sufficiently reliable data. A brief activity history may be incorporated into the interview to facilitate examination of foods and beverages consumed (FAO, 2015).

3.5.7 Staff Training and Supervision

The assistant nutritionists had been trained by the investigator prior to the survey, as recommended by the FAO (1990), and helped to provide feedback on the pilot study form. They were responsible for completion of the questionnaires, were responsible for study related paperwork and the anthropometric measurements. During the study, they were directly supervised by the study's principal investigator. Study forms were regularly checked, and problems were identified and discussed with the responsible staff member.

3.6 Validity and Reliability

Validity is defined as the degree to which an instrument measures what it is supposed to measure (Leedy & Ormrod, 2005). Reliability is ensured when the findings generated are the same when the study is repeated under the same conditions (Bailey, 1997; Leedy &Ormrod, 2005). Validity and reliability thus measure the extent to which there may be an error in the measurements (Leedy & Ormrod, 2005).

3.6.1 Anthropometry

The researcher and dieticians used standardised techniques as recommended by Gibson (2005), and all fieldworkers that took anthropometric measurements were trained to ensure that these standardised techniques were used. Using high quality measuring equipment and calibrating the measuring equipment regularly ensured validity. World Health Organization (WHO) recommended that the US National Centre for Health Statistics (NCHS) and the Centre for Disease Control (CDC) reference curves be adopted as the International growth reference for use in both developed and developing countries (Grummer-Strawn et al., 2010).

The international reference standards have been criticized for setting the same standards for children in developed and as well as developing countries whereas the former are usually born heavier and have faster growth rates (Bagni et al., 2012)

3.6.2 Questionnaire

Ten percent of all the questionnaires were repeated to ensure that the information gathered was reliable. Using the same trained interviewers at the same hospital also ensured reliability. According to Babbie (2001), using interviewers yields an 80-85% higher response rate than when questionnaires are completed by the respondents. For the reliability of the survey, 10% of the respondents were contacted for a repeat of the questionnaires and the questionnaire was re-administered. When the answer to a question differed by more than 20%, then the question was considered unreliable, and the results were not reported. The researcher was the only person that coded the questionnaires and this also ensured reliability. The questionnaire was based on published information related to the factors contributing to PCM, clinical and nutritional as discussed in the literature overview. All the questions in the questionnaire were designed according to the aims and objectives of the study.

3.7 Pilot Study

The questionnaire was implemented in KTH and CEH for the pilot study. The patients who participated in the pilot study did not participate in the main survey. The pilot study helped with the standardisation process, and was viewed as an opportunity for the questionnaire to be tested and adapted for use in the main study, together with an indication of how long it took to complete. The same inclusion criteria, questionnaire and measurements that were to be used in the main study were piloted. A trained, registered dietician completed the questionnaires and the same procedure that was to be used in the main study was followed for the pilot study. On completion of the pilot study, some of the questions were revisited and some questions were rephrased to guarantee that the interviewee provided valid information.

3.8 Qualitative Research Technique

3.8.1 Ethical Approval

Ethical clearance was obtained from the Faculty of Medicine, University of Khartoum in 2009, and the administration offices of KTH and CEH were informed about the study objectives via a letter to enhance cooperation (please see ***Appendix A1*****).** The implication of PCM study was granted ethical approval as an extension to prevalence of PCM study in 2012 (please see ***Appendix A2*****).**

3.9 Consent

Informed consent was obtained from the participants in Arabic, during which time the procedures were explained to the mothers/caregivers in detail. According to the Children's Act of 2005 (Act number 38, 2005) a 'caregiver' is seen as any person other than a parent or guardian, who actually cares for a child. Not all mothers/caregivers that were approached to participate in the study signed the consent form and some refused to participate. Confidentiality of the information was maintained by ensuring that no names were disclosed or written within the questionnaires. Coding was used during the data analysis and in the presentation of the results.

Interviews were conducted in a private setting to ensure confidentiality. Participation was voluntary, and respondents were given the freedom to withdraw from the study at any time. The rights of the child and the interviewee were respected if they refused to participate in the study; in total, three caregivers/mothers refused to take part. All actions that were undertaken in this study regarding the child were part of the normal service delivery actions that would be performed under normal circumstances in the hospital setting. Children admitted to the paediatric or childcare units were referred to a dietician to ensure that they were evaluated according to the inclusion criteria. All children participating in the study were already being treated and thus did not have to be referred for management. A final report will be made available to the Department of Health of the Northern State, and the results of this study will provide an indication of whether they need to intensify their strategies for combating severe malnutrition.

3.10 Data Analysis

The data was checked for consistency and then coded and entered into a computer using EPI6 software. The software has a program (Epi-Nut) which converts nutritional data into Z-scores of the indices; height/age, weight/height and weight/age using the NCHS reference population standard of the WHO. The data were then exported to the Statistical Package for Social Sciences (SPSS) programme. Descriptive summaries were obtained in the form of proportions, means and standard deviations. Cross tabulations were drawn for some selected variables.

Tests to examine the descriptive statistics were performed for each variable collected. Statistical significance was determined using a chi-square test, and the risk factors for PCM in children were determined using logistic regression analysis.

3.10.1 Independent (Student) t-Test

An independent t-test was used to verify if there were significant differences in the prevalence of SPCM during the wet and dry seasons. Because the wet season and dry season in Khartoum are quite different, the factors affecting child PCM may have different effects in wet and dry areas. For these reasons, the analyses of factors affecting child malnutrition were carried out separately for the wet and dry seasons. Data collected on housing characteristics, household nutritional information, child feeding practices, frequency of food consumption and 24 hours dietary recall were used to provide basic information on the study population. Factors were tested by applying cross-tabulation, which was an important first step for studying the relationship between PCM in general (marasmus, kwashiorkor and marasmic kwashiorkor), with season as a factor and several other cofactors. A Chi squared test was used to assess the strength of the association between SPCM and the independent variables collected during the rainy and dry seasons. A difference was considered to be statistically significant when the p- value obtained was less than 0.05. Significantly related variables were included in the model of multinomial logistic regression.

3.10.2 Multinomial Logistic Regression Model

This model was applied since the dependent variable of the model is nominal in nature, to marasmic kwashiorkor as the reference category. Logistic regression was used to provide the net effect of risk factors, and was used to provide the study with more flexibility in order to determine whether there are differences in each parameter for children with different types of PCM (marasmus, kwashiorkor and marasmic kwashiorkor). Logistic regression also provides the coefficients and odds ratios associated with different independent variables.

3.10.3 Generalised Linear Model

A generalised linear model was used to assess the effect of seasonal variation on the prevalence of PCM, while taking into consideration both socioeconomic factors and child feeding practices. Regression was used to identify predictors for malnutrition during both the wet and dry seasons.

3.11 Qualitative Assurance

3.11.1 Selection Bias

Selection bias operated in this research, as children were recruited at the facility level rather than community level. Results cannot be generated to population level. This work is however, relevant to facility level care.

The sample was selected from within Khartoum district; it is possible that children and families living in Khartoum district are somehow different from Sudanese living in other parts in the country. Selection bias related to the sample being selected with Khartoum district has not affected the results

3.11.2 Interview Bias

Interview bias may caused by incorrect use of probing questions or incorrect recording of responses, could be by distraction and confidentiality over the degree of reports between the interviewer and the respondents (Fowler & Mangione, 1990)

3.11.3 Respondent Family Lapses

The respondent may fail to recall foods actually consumed (errors of omission) or may report foods that were not consumed during the recall day (errors of commission). Both sources of errors have been reported in several studies in which 24-h recalls were compared with recorded measurements on the same day (Krantzler et al., 1982; Brown et al., 1990)

The existence of household food consumption inaccuracy attenuates correlation between the food consumption and the outcome parameters, so that important association between food consumption and PCM may be obscured. Efforts for overcome the problem of household food consumption overestimating led the researcher to exclude overestimators from the data set (milk, milk product, eggs and fish)

Chapter 4 - Prevalence and Seasonal Variation of Protein Calorie Malnutrition

4.1 Introduction

A deficiency in macronutrients, such as protein, carbohydrate and fat, provokes PCM, and when combined with micronutrient deficiencies, this is one of the most important nutritional problems (Rodríguez et al., 2011). The nutritional status affects every aspect of a child's health, including normal growth and development, physical activity, and response to serious illness (Rodríguez et al., 2011). Protein calorie malnutrition may originate from a deficiency or absence of any nutrient, whilst the establishment and severity of malnutrition depends on the cause, intensity and duration of the nutritional deficiency (Borelli et al 2004). PCM can be caused primarily, by an inadequate diet, or secondarily, by a deficiency in gastrointestinal absorption and/or increase in demand, or even, by an excessive excretion of nutrients (Borelli et al., 2004).

Protein calorie malnutrition is the one of the world's most serious health problems and occurs in a greater number of infants and young children in developing countries, including Sudan (Waterlow, 1979). It affects 30-50 million children worldwide (Latham 1997), and the most severe form of PCM affects between 1-10% (Sunguya & Koola, 2006). The prevalence of PCM in Sudan is 53.7% (Mohieldin &Alshiek, 2010).

The prevalence of PCM is usually subject to seasonal variation that may be due to epidemics, for example, malaria, or gastrointestinal infections related to the proliferation of flies during the hot season, or to the seasonal variation in the food supply, or both (McMichae et al., 2003)

Several studies have demonstrated that seasonal variation places children at higher risk of PCM, although the relationship between malnutrition and seasonality differs considerably between communities (Brown et al., 1982; Champer et al., 1981). It has also been shown that seasonality and demographic factors influence the prevalence of PCM (Brown et al., 1982). It has been claimed that malnutrition is a proxy for demographic factors rather than a determinant of SPCM, because the prevalence of PCM associated with seasonality could be due to demographic factors (Prentice, 1981)..

To combat these problems in Sudan, it was decided that a greater emphasis needed to be placed on the provision of facilities for children's healthcare in order to reduce PCM. There was to be a greater transfer of resources from urban to rural areas and camps, as well as counselling on family planning. In contrast to earlier approaches, preventive rather than curative care was to be emphasised. This meant that programmes needed to be designed to prevent infectious diseases and to educate mothers concerning improved child care, combined with services which actively improve environmental hygiene.

4.1.1 Objectives

The study objectives are as follows:

- To assess the prevalence of PCM
- To estimate whether seasonal variation (wet and dry) increases the risk of PCM in children

4.1.2 Employed Questionnaire

The main method of investigation in this study was by means of an administered questionnaire. The questionnaires are presented in full in Appendix B (demographic and nutritional questionnaire).The research tool was a standard questionnaire with open and closed questions, designed to collect information concerning the children and their family environment. This Questionnaire was validated by the jury method; i.e. reviewed by several experts (Uwaegbute, 1991).

The baseline survey was planned between August 2008 and June 2009, and the managers of the selected hospitals were contacted in order to explain the aims of the study, to obtain ethical approval and to discuss the research with staff in the two hospitals. A pilot questionnaire was tested in June 2009 and modified accordingly. The questionnaires were completed by the researcher and three dieticians, and the interviewers received instruction on interviewing techniques and were accompanied by the researcher during the first day of field contact.

The survey was implemented in July-September 2009 and in February-April 2010. The questionnaires were reviewed before leaving the wards, and amended as necessary. The data was coded using coding sheets which were checked with the questionnaire for any inconsistencies, and then data were entered into a database. Between May 2010 and July

2010, a first descriptive analysis was carried out using the SPSS analysis software. From August 2010 to September 2010, multinomial logistic regression was carried out.

Questionnaire 1 was composed of six sections, was 11 pages in length, and was divided into five major parts. Parts 1 and 2, which made up the main body of the questionnaire, dealt with demographic factors concerning the children and their mothers, such as socio-demographic, dietary, health and nutritional factors. Parts 3, 4 and 5 dealt with factors concerning household characteristics, feeding practices, and maternal knowledge.

Section 1 included questions on the demographic characteristics of the parents, such as age, BMI, education, occupation, working activity, number of hours the wife spent on different activities, number of hours the wife spent outside the home, household income per month, estimate of money spend on food, age at marriage, family size, original home, length of residence, ethnicity, head of the household (who is mainly responsible for bringing up children), number of pregnancies, birth spacing between the ill child and older siblings, mother's age at first pregnancy, age of mother at youngest child, birth order, and whether the mother was pregnant at the time of the study.

Section 2 dealt with anthropometric measurements and demographic characteristics of each child under five years of age admitted to hospital with PCM, and included the following variables: age (years and months), gender, weight, height/length, MUAC, head circumference, chest circumference, skin fold thickness, weight at birth, place of delivery, breastfeeding and vaccination status, and a biochemical assessment.

Section 3 was related to housing characteristics, such as home ownership, number of rooms, building materials, number of people living in the house, source of water, type of cooking and lighting fuel and household waste disposal.

The household nutritional survey was the focus of section 4, and included sources of food, who, when, where and how often did the shopping, where food was stored, who normally cooked, how often the family cooked, what form of energy was used for cooking, number of meals and snacks the family consumed, where the family ate, what type of foods were consumed in the household. The mothers were asked about any special food consumed during pregnancy and lactation, and the reason for this.

As the child nutrition survey, section 5 and 6 dealt with child feeding practices. The mother was asked whether the hospital admitted child received solid food, at what age the child started eating solid food and when was the child completely weaned, what was the reason for starting food supplementation, when was breastfeeding stopped, and what type of weaning foods did the child start with regardless of whether the child was breastfed or not.

Section 7 dealt with 24 hours dietary recall.

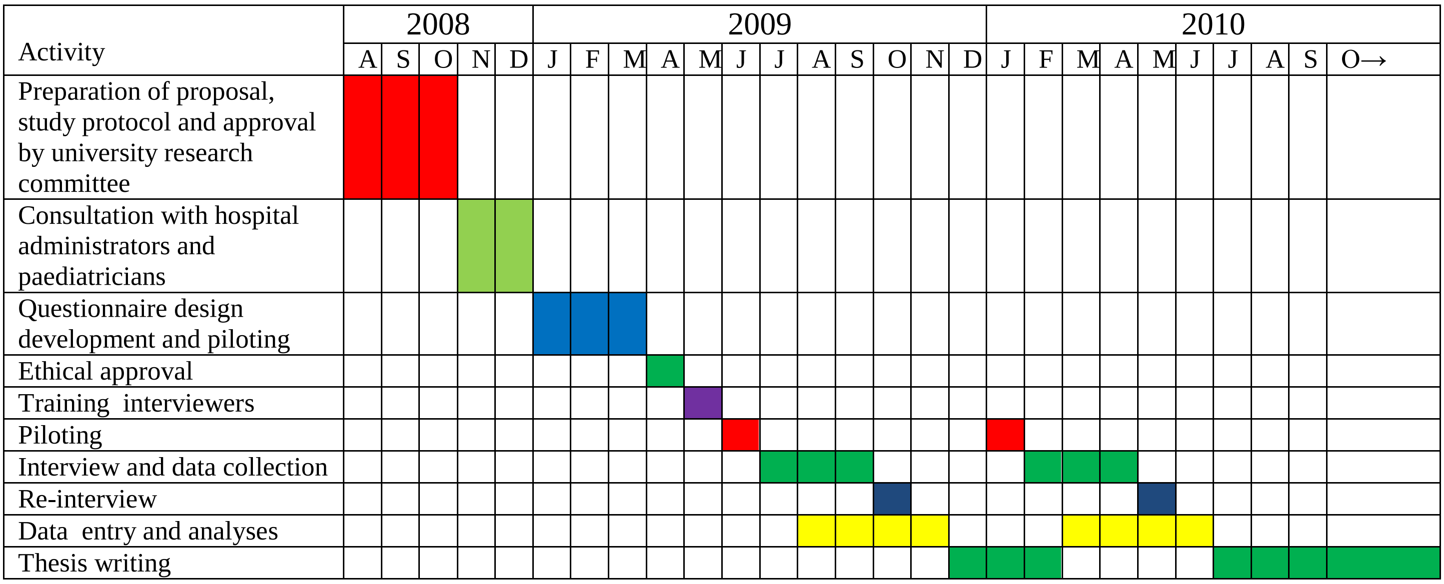
4.2 Subjects and Methods

The base survey was carried out in July-September 2009 (wet season), with a follow up survey carried out in February-April 2010 (dry season) to determine the prevalence of PCM in the wet and dry seasons, and to assess the possible association between demographic factors and PCM. The study was conducted in the paediatric wards of KTH and CEH which are referral hospitals located in the eastern part of Khartoum. Although some patients were referred to Soba Hospital, the analysis was restricted to those patients admitted to KTH and CEH only, which represented 466 participants.

4.2.1 Collecting Data

While the survey period covered both the wet and dry seasons, data on socio-demographic, socioeconomic, child characteristics , household food consumption, child feeding practices and 24 hours dietary recall were only used in this part of the study. Figure 4.1 simplified methodological framework for prevalence and seasonal variation of PCM in Sudan.

Figure 4.1 A schematic representation of the PCM prevalence study and associated activities



4.2.1.1 Sample Size

The study used the following formula for the sample size in the (n) wet and dry seasons:

$$n = (Z_{\alpha/2}+Z_{\beta})^2 * (p_1(1-p_1)+p_2(1-p_2)) / (p_1-p_2)^2$$

where $Z_{\alpha/2}$ is the critical value of the normal distribution at $\alpha/2$ (e.g. for a confidence level of 95%, α is 0.05 and the critical value is 1.96), Z_{β} is the critical value of the normal distribution at β (e.g. for a power of 80%, β is 0.2 and the critical value is 0.84) and p_1 and p_2 are the expected sample proportions of the two groups (in the wet and dry seasons). There is inadequate data on a value for the prevalence of PCM in wet and dry season, and there is no known value of *p1* and *p0* from previous studies or pilot studies. However, the study used data from research conducted in 2005, indicating that the prevalence of PCM was 12%. The study assumed that the prevalence of 12% would be for the dry season and predicted 8% in wet season, so that the sample size of the study could be calculated as follows:

$$N = (0.84+1.96)^2 \text{ x } (0.12(1-0.12) + (0.08(1-0.08)/ (0.12-0.08)^2$$
$$N = (2.8)^2 \text{ x } (0.12 \text{ x } 0.88) + (0.08 \text{ x } 0.92) / (0.04)^2$$
$$N= 7.84 \text{ x } (0.11 + 0.07) / 0.0016$$
$$N= 7.84 \text{ x } 0.18 / 0.0016= 882 \text{ cases}$$

The study therefore set out to include 882 cases in the wet season and 882 in the dry season. For the study to have 80% power, the total sample size would be 2646. Therefore due to time and financial restrictions, it was agreed that all children with PCM attending A&E in the wet and dry seasons would be recruited. This sample is sufficiently large that statistical analyses could be performed to identify major risk factors associated with PCM among children less than five years of age admitted to hospital in the district.

4.2.1.2 Sampling Technique

The convenience sampling method was applied in the study because it is relatively easy and inexpensive to conduct. In this manner, all children less than five admitted to KTH and CEH were selected for the study. The period of time for selecting subjects was from July-September 2009 (wet season) and February-April 2010 (dry season). Over a time span of six months, 466 subjects were recruited into the study (278 in wet season and 188 in dry season = 466 children).

4.2.1.3 Selection of Cases

A total of 466 children with PCM (marasmus, kwashiorkor, marasmic kwashiorkor) less than five years of age admitted to KTH and CEH from July-September 2009 (wet season) and February-April 2010 (dry season) were recruited after their parents expressed their willingness to participate in the study. If the parent did not express their willingness to participate, then the child was not recruited. The willingness to participate by the parents was confirmed after detailing to them the contents of the consent form. Pleases see (exclusion criteria ***section 3.3)***

4.2.1.4 Pilot Testing

As described in *chapter 3*, prior to the main study, a pilot testing exercise was conducted in the study hospitals and in the same wards. The patients who participated in the pilot study did not participate in the main survey. The pilot study had a sample size of 20 respondents, 10 during the wet season and 10 during the dry season, and the results were utilised when designing the final questionnaire and making the final preparations for the main study (please see *section 3.7*) No real problems were experienced when the pilot interviews were conducted, and it took approximately 45-60 minutes to conduct the interview with the mother/caregiver.

4.2.1.5 Anthropometric Measurement

Please see ***section 3.4.1***

4.2.1.6 Questionnaires

Please see ***section 3.4.3***

4.2.1.7 Dietary Assessment

This study assessed the diet of the children in several ways. The questionnaire contained sections on the family's diet and sources of food, 24-hour food recalls and food frequency recalls, to which the mothers provided the answers. Please see *section 3.5.6*

4.2.2 Data Analysis

Data processing was carried out using the SPSS version 19. Categorical variables were analysed by creating and examined by cross-tabulation with chi-squared tests when relevant. To compare the seasonal patterns of PCM and other major indicators, descriptive analyses were generated and examined. Dependent variables were plotted by age and gender and other selected variables in order to visualise differences in the level of seasonal patterns and to gain a sense of the significance of the spread of data for each season. Analysis of variance was used to measure the relative significance of the major differences between these sub groups by season. Seasonal variation was quantified through the analysis of multinomial logistic regression and generalised linear models using the variables for the season. Association between variables, adjusted for selected covariates, were calculated for each season as the first step in measuring the strength and association between marasmus, kwashiorkor and marasmic kwashiorkor and the independent variables.

Generalised linear models were produced for the data stratified by season in order to investigate how the variables differed in their impact on the prevalence of marasmus, kwashiorkor and marasmic kwashiorkor for each of the two seasons. The differences across the seasons were finally held as interaction terms. Please see *section 3.10*

4.3 Results

4.3.1 Prevalence of Protein Calorie Malnutrition

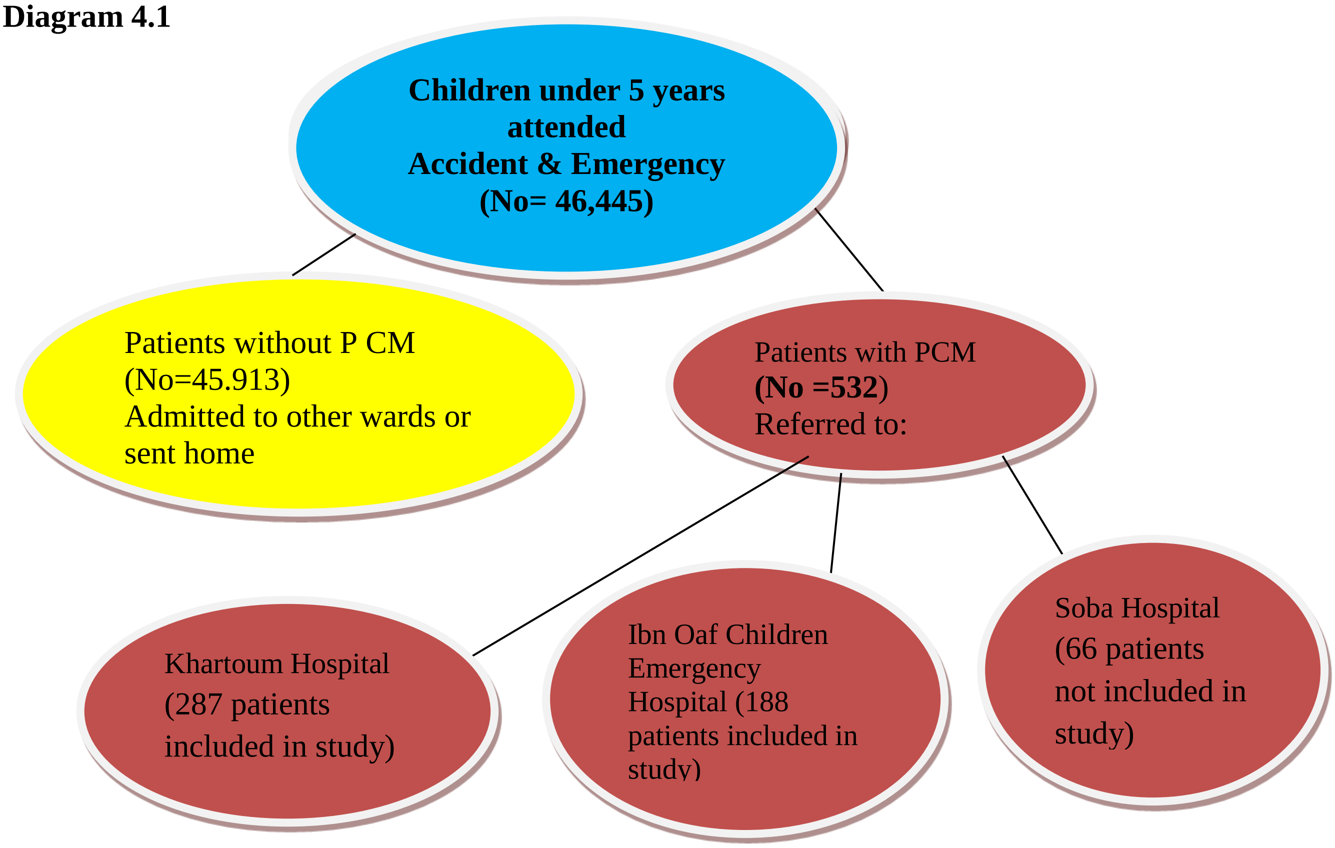
4.3.1.1 Overall Prevalence of Protein Calorie Malnutrition

In total, 46,445 children attended KTH and CEH during the study period: 23,705 in the wet season and 22,740 in the dry season and approximately 1.15% was suffering from PCM. Of these children, 67% were found to be marasmic, 23% had kwashiorkor and 10% were marasmic kwashiorkor, and this distribution was statistically significant (p=0.0001, Figure 4.2).

Diagram 4.1:- Admission Routes to KTH and CEH

All children presenting to the Hospital were first seen in the Accident and Emergency (A&E) area. Here they were assessed, triaged and referred according to clinical indication

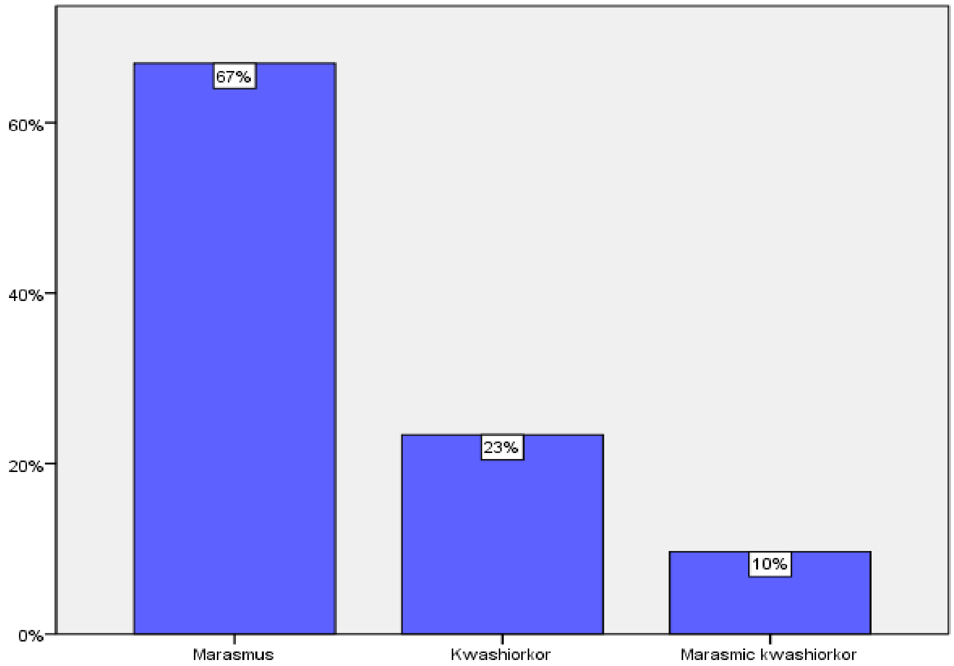
Diagram 4.1



$$\text{Prevalence} = \frac{\text{No. of cases in a defined population at one point in time}}{\text{No. of persons in a defined population at the same point in time}}$$

$$\text{Prevalence of PCM} = \frac{532}{46445} \times 100 = 1.15\%$$

Figure 4.2: Prevalence of marasmus, kwasiorkor and marasmic kwashiorkor



Chi squared =46.458, P=0.0001

4.3.1.2 Prevalence of Protein Calorie Malnutrition by Season

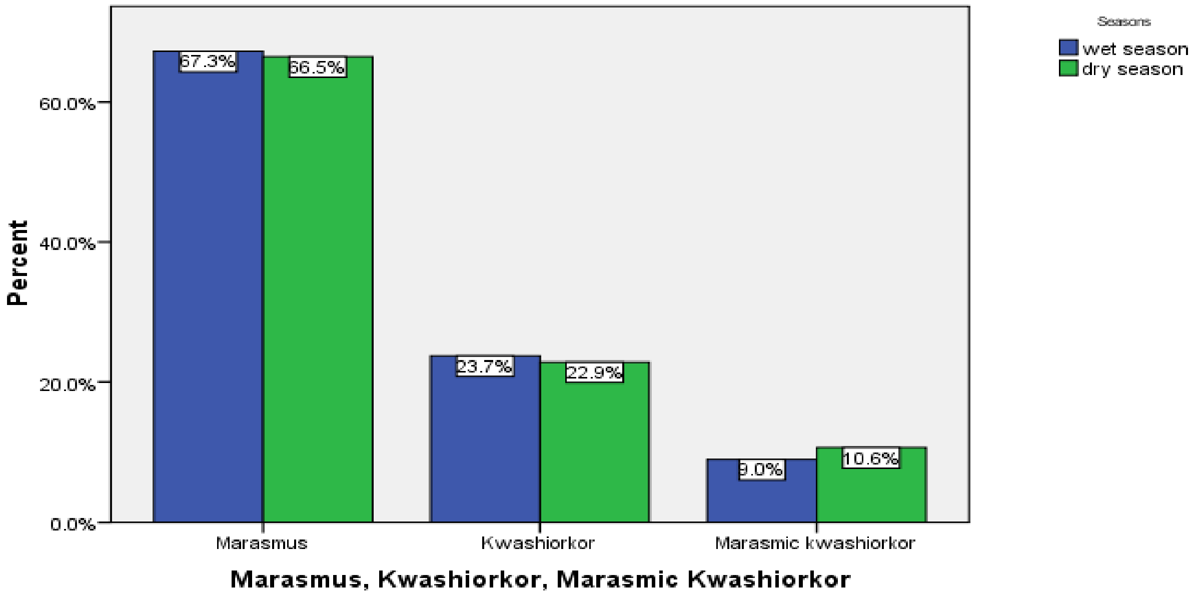
From Table 4.1 it can be observed that there is seasonal variation with regard to the prevalence of PCM (p =0.023) with more cases during the wet season (61.4%) than the dry season (38.6%). From Figure 4.3, it is clear that there are no differences across seasons with respect to the occurrence of marasmus, kwashiorkor and marsmic kwashiorkor (p=0.835)

Table 4.1: Seasonal distribution of PCM

Chi squared =-2.285, P =0.023

Seasons	N	Mean	Std. Deviation	Std. Error Mean
Wet season	326	1.35	.614	. 034
Dry season	206	1.48	.717	.050

Figure 4.3 Seasonal distribution of PCM (marasmus, kwashiorkor, marasmic kwashiorkor)



Chi squared = 0.361, p=0.835

4.3.2 Results of Patient Characteristics at Baseline

4.3.2.1 Seasonal Distribution and Demographic Characteristics

Table 4.2 provides demographic characteristics of individuals and the differences in PCM occurrence across seasons (a more detailed supplementary table is provided in Appendix D1). From Table 4.2 it can be observed that there is no association between seasonal variations in PCM occurrence and gender (p=0.582), maternal BMI (p=0.287) and tribal distribution (p= 0.364). However, a significant difference across seasons was observed with respect to years of living in Khartoum (p=0.000), child birth order (p=0.000), number of children (p=0.004), family size (p=0.000) and child age (p=0.003).

Table 4.2: Seasonal distribution and patient demographic characteristics

Variable	Chi^2	P-value	Variable	Chi^2	P-value
Gender	0.303	0.582	Child birth order	17,640	0.000
MBMI kg/m^2	3.774	0.287	Number of children	30.931	0.004
Tribe	12.633	0.364	Family size	24.959	0.000
Years of living in Khartoum	24.426	0.000	Child age/m	14.500	0.003

Most of the patients enrolled in the study were male (57.5%), between the ages of 12-23 months (48.3%), and were part of a family which had 2-5 members (46.1%), with three children in the family being less than 5 years of age (52.8%). The birth order of the child showed significant differences, with 19.5% of children being the fourth child, 17.6% being the second child and 17.4% being the third child. The maternal BMI was found to be between 18.5 and 24.9 and 69.5% of the patients were from families who have lived in Khartoum for less than 10 years. From the above analyses, it can be argued that the changes in season strongly impact children who live in larger families and who have recently moved into the Khartoum area in search of work.

4.3.2.2 Seasonal Distribution and Socioeconomic Factors

Table 4.3 provides details of the socioeconomic factors of individuals and the differences in PCM occurrence across seasons (a more detailed supplementary table is provided in Appendix D2). From Table 4.3 it can be observed that there is no association between seasonal variations in PCM prevalence and paternal education (p=0.118), money spent on food/SP (p=0.681) and presence of latrine (p= 0.271). However, there is a significant association between season and maternal education (p=0.003), maternal occupation (p=0.034), time spent outside the home by the mother (p=0.004), overall family income (p=0.029) and total number of rooms (p=0.004). It is observed that most of the fathers had received a primary education (45.3%), whilst most mothers had no education (52.1%). It is also observed that most mothers were unemployed (52.1%) and were found to spend more than four hours a day outside the home (95.1%). The overall family income was less than 300 Sudanese Pounds per month (56.9%) with people living in houses which had only two rooms (50%). Most of the patients lived in houses which did not have latrines (56.2%).

From the above analysis it is clear that the maternal characteristics are those which have an impact on the prevalence of PCM. An association between a lack of education, unemployment and time spent outside the house indicates the possibility of limited income, as well as limited time to take care of children. It is also observed that there is a significant impact of house size and the presence of latrines in a house. There is a possibility of an increase in infection during the wet season (278 reported cases) compared to the dry season (188 reported cases).

Table 4.3: Seasonal variation and socioeconomics

Variable	**Chi^2**	**P-value**	**Variable**	**Chi^2**	**P-value**
Maternal education	8.502	0.003	Overall house income	7.159	0.029
Paternal education	7.178	0.118	Money spent on food	7.759	0.681
Maternal employment	9.007	0.034	Number of rooms	8.584	0.004
Time spent in the house	8.584	0.004	Presence of latrine	0.469	0.48

4.3.2.3 Seasonal Distribution and Household Food Consumption

Dietary intake surveys in developing countries are usually limited by the problem of estimating the exact quantities of food consumed. This is more difficult in such settings where people do not normally weigh food before cooking and where food is usually eaten from a common plate (Rutishauser, 1974; Hudson, 1995). Once a child can sit and feed him/herself, a mother saves time by putting food on one plate and the children feed themselves. It then becomes very difficult to estimate how much each child has consumed, and in order to estimate the frequency at which foods were consumed by children, a food frequency questionnaire (FFQ) was included in the main questionnaire. The FFQ contained a total of 8 foods, with four frequencies; number of times per day, per week, per month and never. The FFQ in this study was mainly qualitative, as it was not possible to quantify the foods eaten. The results of the FFQ are presented in Table 4.4, which provides an analysis of the food consumption characteristics of the home and the differences in PCM prevalence across seasons (a more detailed supplementary table is provided in Appendix D3). From Table 4.4 it can be observed that there is no association of seasonal variations in PCM occurrence and consumption of bread (p=0.075), oil (p=0.641) and fruits (p=0.470). However, there is a significant association between season and consumption of vegetables (p=0.000), sugar (p=0.001), cereals (p=0.032) and legumes (p=0.000). It is observed from the analysis that seasonal association between legumes, vegetables products can be linked to seasonal availability and possible fluctuations in prices.

It can be argued that irrespective of the season, the consumption of staples, including bread (twice daily consumption by 56.5% of children during the wet season and 56.9% during the dry season), cereals (twice daily consumption by 52.5% of children during the wet season and 50% during dry season). Products like bread are often made locally and can be easily accessed, whilst products like cereals can be stored long term and hence there would be no immediate impact of seasonal variation in terms of access.

In contrast, product like legumes (twice daily consumption is higher during the dry season, 55.9% of the children), is found to show greater availability during the dry season. The reduction in availability of this product during the wet season may be limited due to the decrease in access to larger markets. Therefore, seasonal impact needs to be discussed in relation to available infrastructure facilities.

Products including green leafy vegetables (twice weekly consumption is higher during the wet season, 30.2% of children) and other vegetables (twice weekly consumption is higher during the wet season, 29.9% of children) are greater during the wet season. It is argued that such products are often available when there is more water. This may account for the seasonal impact on child consumption.

Table 4.4: Seasonal distribution and household food consumption

Variable	Chi^2	P-value	Variable	Chi^2	P-value
Bread/day	6.904	0.075	Other Veg./ Week	9.284	0.319
Cereals/day	8.806	0.032	Fruits/Week	5.597	0.470
Legumes/day	75.110	0.000	Oil/ Day	0.891	0.641
GLV./Week	28.850	0.000	Sugar/ Day	16.408	0.001

4.3.2.4 Seasonal Distribution and Child Feeding Practices/Season

Table 4.5 provides a detailed analysis of child feeding pattern differences across seasons (a more detailed supplementary table is provided in Appendix D4). From Table 4.5 it can be observed that there is no association between seasonal variations in PCM prevalence and child feeding practices in terms of feeding at birth (p=0.693) and breastfeeding at the time of the study (p=0.056). However, there is a significant association between season and feeding practices, including mode of breastfeeding (p=0.041), age of receiving solid food (p=0.000), weaning age (p=0.016), and complementary food (p=0.006). It is observed from the analysis that seasonal association can be linked to the type of breastfeeding in terms of mode of feeding, for instance, greater partial feeding is observed during the dry season than in the wet season. It is also observed that there is an association between wet and dry season with respect to weaning age.

Table 4.5: Seasonal variation and child feeding patterns

Variables	Chi^2	P-value
Breastfeeding at birth	2.479	0.693
Breastfeeding at time of study	3.783	0.056
Breastfeeding mode	4.932	0.041
Weaning age/m	6.271	0.016
Age of solid food/m	36.964	0.000
Type of complementary food	9.397	0.006

It can be argued that there is no seasonal impact on breastfeeding practices or feeding during birth (presence of feeding immediately after birth is 99.3% of children during the wet season and 98.9% during the dry season), breastfeeding at the time of study (absence of feeding is

68.8% of children during the wet season and 60.2% during dry season). In contrast, a seasonal difference is seen with respect to mode of breastfeeding (26.4% of children were exclusively breastfed during the wet season and only 18.3% during the dry season). It is also observed that the age of receiving sold food differed (children less than 4 years of age is higher during the dry season, 24.5% of children). From these results it can be seen that there is no impact of season on the commencement of breastfeeding or sustenance of breastfeeding practices. However, it can be argued that the mode of breastfeeding may have been impacted by the availability of food. Other feeding practices, like the weaning age from breast milk (12-18 months is higher during the dry season, 33.5% of children) are also found to be higher during the dry season. From Table 4.4 it can be argued that there is seasonal availability of food and that products like milk and legumes are available more during the dry season. This may account for the practices of greater partial breastfeeding during the dry season (81.7% of children) compared to the wet season (72.6% of the children). In light of such differences in feeding practices, it is important to discuss why the partial breastfeeding mode is higher during the dry season given that Table 4.4 did not reveal any difference in terms of child milk consumption across both seasons, although it is possible that most of the milk being consumed within a family may be given to the other children. Therefore an association between parity and mode of breastfeeding would provide a clearer assessment of the situation.

It is also interesting to note that complementary food is found to have a greater role in a child's diet during the dry season. These include carbohydrates, and animal and plant proteins (16.6%), as well as carbohydrates and animal proteins (39.8%). This can be associated with the fact that there is a greater availability of legumes and meat during the dry season, as observed in the previous section. It is also observed that the consumption of carbohydrates and plant proteins is higher during the wet season (41.2%), which can be attributed to the greater green vegetable consumption.

4.3.2.5 24-hour Food Recall

***2.3.2.5.1 Seasonal Distribution and 24 hour Dietary Recall (day prior to interview*)**

24-hour food recall is one of the most commonly used methods of dietary assessment within developing countries (Jelliffe, 1966). Rutishauser and Frood, (1973) found a high correlation between the energy and protein intake for 24-hour recalls and direct food analysis. Because the diets of children with PCM tend to be simple and monotonous, the task of recall is not difficult. In this study, 24-hour food recall was conducted by using an open-ended question in which the mother was asked to name all the foods, including fluids that her child had consumed on the day preceding the interview.

The results, presented in Table 4.6 show that children were being fed only a limited number of food items (a more detailed supplementary table is provided in Appendix D5). One of the major problems evident from the baseline survey was that subjects had a monotonous diet. A total of eighteen different foods had been consumed by PCM children the day preceding the interview. It was found that cereal was the most popular food, as it had been consumed by 35.7% of children; however, bread was also a prominent food in Khartoum, consumed by 6.3% of children, and the vast majority of children had also consumed sugar (92.1%). Small percentages of children had consumed meat, fish and eggs. From Table 4.6 the differences in consumption across seasons can be observed. The main food items consumed in the wet and dry seasons were sugar, fruit juice, cereals, milk, milk products and pulses. Cereals remained the commonest food consumed in both seasons, and vegetables were notably not consumed; their consumption was remarkably negligible among the children during both seasons. Potatoes and fruit juice were most consumed during the wet season. As expected, the caloric provision of sugar amongst the study population was high, as it is consumed in almost all meals as sugar is normally added to all types of food, e.g. pulses, rice etc. in Sudan.

Table 4.6: Seasonal distribution and 24 hour dietary recall

Variable	**Chi^2**	**P-value**	**Variable**	**Chi^2**	**P-value**
Bread	0.668	0.716	Eggs	4.000	0.121
Cereals	10.291	0.036	Pulses	18.062	0.000
Rice	5.200	0.156	Potatoes	23.012	0.000
Biscuits	0.629	0.890	Peeled Oranges	2.406	0.493
Milk	26.618	0.000	Fruit juice	2.828	0.587
Yogurt	11.376	0.044	Fizzy drink	0.825	0.364
Meat	1.626	0.202	Sugar	1.712	0.634
Chicken	0.467	0.495	Oil	1.120	0.571
Fish	5.000	0.082	Eggs	4.000	0.121

2.3.2.5.2 Seasonal Variation and Macronutrients Intake (prior to interview)

In order to get as close as possible to the quantity of food a child consumed as to be able to calculate the energy intake of these children, approximate quantities were recorded; small

(100-200g), medium (200-300g) and large (over 300g). The feeding utensils, a child's cup and plate, were requested and examined to give more information on the quantity of food consumed the previous day.

The results of the 24-hour food recall were analysed using Food based software, version 14, and the analysis was undertaken only for children who were not breastfeeding. The energy and nutrients derived from the diet, plus an estimation of the percentage of energy derived from fat, carbohydrate and protein, are given by the analysis.

As can be seen in Table 4.7 (a more detailed supplementary table is provided in Appendix D6), there is no difference in macronutrients intake in terms of seasonality (P-value=>0.050); energy intake (>400 kcal/d), protein intake (>5.4 g/d) and carbohydrate intake (>92g/d) were higher during the dry season than during the wet season; however fat intake was higher during the wet season.

Table 4.7: Seasonal variation and macronutrients intake

Variable	**Chi^2**	**P-value**
Energy intake (kcal/day)	6.214	0.102
Carbohydrates (g/day)	5.331	0.980
Protein intake (g/day)	4.655	0.149
Fat intake (g/day)	0.025	0.619

4.3.3 Bivariate Analysis

4.3.3.1 Influence of Season and Demographic Characteristic on PCM

The analysis of the prevalence of PCM by season and household characteristic is presented in Table 4.8. Significant differences across seasons are observed with respect to gender (p=0.017), child age (p=0.001), birth order (p=0.03), length of residence (p=0.002), type of tribe (p=0.043). When considered at an independent seasonal level, it is observed that seasonal differences are present more during the wet season than the dry. Significant associations are seen in wet season with respect to child age (p=0.000), birth order (p=0.001), and length of residence (p=0.042).

On further bivariate examination, it was found that the season had a significant (Chi-squared=8.137, p=0.017) influence on PCM after controlling for gender (Table 4.8), with female children having higher rate of marasmic kwashiorkor during the wet season. However, season and gender had no significant influence on marasmus nor kwashiorkor, or marasmic kwashiorkor during the dry season. Season was highly significant (p=0.0001) in its influence on SPCM, and even after controlling for child age, season remained significant for both kwashiorkor and marasmus, and for both the wet (Chi-squared=60.813, p=0.000) and dry (Chi-squared=18.768, p =0.045) seasons. In both wet and dry season PCM was observed more often in children aged 12-23 months than younger and older ones

The BMI of the mothers had a non-significant influence on PCM. However, during the wet and dry seasons, children whose mothers had a BMI <18.5 had a higher prevalence of marasmus. None of the children whose mothers had a BMI >30 or above had kwashiorkor or marasmic kwashiorkor. During the dry season none of the children whose mothers had a BMI of 25.0-29.9 had marasmus. Bivariate analysis did find a significant influence on PCM when family size was controlled for seasonal variation, and family size had no significant influence on either the PCM in the wet or dry season. Seasonal variation had no impact on PCM when examined by the number of children <5 years of age within the household, and the number of children <5 years of age in the household had no significant influence on PCM in the wet season, but was significant (Chi-squared=16.169, p=0.013) during the dry season for children who lived in a family with three children aged <5 years where there was a high prevalence of kwashiorkor. In terms of birth order, seasonal variation was significant (Chi-squared=30.299, p=0.003) in influencing PCM, as a larger proportion of children who were classified as the fourth birth were found to have a higher prevalence of marasmus in the wet season than children who were classified as third birth or less.

The length of residence had a significant (p=0.031) influence on PCM for children from families who had resided in Khartoum for less than 10 years, being proportionately more marasmic than children from families who had resided there for more than 10 years. The season had a significant influence on SPCM, and there were significant differences between the wet and dry season (Chi-squared= 20.969, p=0.002). Seasonality had a significant (Chi-squared=42.063, p=0.043) influence on the prevalence of PCM when examined by the type of tribe. During the wet season tribe had no significant influence on levels of PCM but significantly (p=0.050) affected the prevalence of kwashiorkor during the dry season, with children from the Fur tribe showing a high prevalence of kwashiorkor.

Table 4.8: Influence of season and demographic characteristics on prevalence of PCM

Variables	Wet Season			Dry season		
	Marasmus	Kwashiorkor	Marasmic-Kwashiorkor	Marasmus	Kwashiorkor	Marasmic-Kwashiorkor
Gender Overall: Chi-squared = 8.137, p = 0.017						
Male	113(60.4%)	36(54.5%)	8(32.0%)	75(60.0%)	2(62.8%)	75(60.0%)
Female	74(39.6%)	30(45.5%)	17(68.0%	50(40.0%)	16(37.2%)	50(40.0%)
	Chi-squared =7.381, p = 0.025			Chi-squared = 1.928, p = 0.381		
Child Age/month: Chi-squared = 40.234, p = 0.001						
0-5	0(0.0%)	0(0.0%)	6(3.2%)	11(8.8%)	1(5.0%)	7(16.3%)
6-11	47(25.1%)	5(7.6%)	47(25.1%)	26(20.8%)	0(0.0%)	11(25.6%)
12-23	65(34.8%)	58(87.9%)	16(64.0%)	59(47.2%)	9(45.0%)	18(41.9%)
24-35	50(26.7%)	2(3.0%)	2(8.0%)	20(16.0%)	5(11.6%)	8(40.0%)
36-47	13(7.0%)	0(0.0%)	1(4.0%)	5(4.0%)	0(0.0%)	2(10.0%)
49-59	6(3.2%)	1(1.5%)	0(0.0%)	4(3.2%)	0(0.0%)	2(4.7%)
	Chi-squared 60.813, p = 0.000			Chi-squared =18.768, p = 0.045		
Maternal BMI kg/m^2: Chi-squared 4.952, p = 0.550						
<18.5	64(88.8%)	24(25.8%)	5(5.4%)	42(72.4%)	10(17.2%)	6(10.3%)
18.5-24.9	99(64.3%)	37(24.0%)	18(11.7%)	75(65.2%)	27(23.5%)	13(11.3%)
25.0-29.9	22(75.9%)	5(17.2%)	2(6.9%)	8(72.7%)	3(27.3%)	0(0.0%)
30 and above	2(100.0%)	0(0.0%)	0(0.0%)	0(0.0%)	1(50.0%)	1(50.0%)
	Chi-squared 4.955, p = 0.550			Chi-squared = 7.345, p =0.290		
Family Size: Chi-squared = 5.405, p = 0.493						
2-5	65(34.8%)	27(40.9%)	10(40.0%)	74(59.2%)	25(58.1%)	14(70.0%)
6-8	96(51.3%)	31(47.0%)	14(56.0%)	41(32.8%)	15(34.9%)	5(25.0%)
9-11	23(12.3%)	8(12.1%)	0(0.0%)	9(7.2%)	3(7.0%)	1(5.0%)
12-14	3(1.6%)	0(0.0%)	1(4.0%)	1(.8%)	0(0.0%)	0(0.0%)
	Chi-squared = 2.398, p = 0.411			Chi-squared = 1.421, p = 0.965		
Number of children <5 years of age: Chi-squared 10.513, p-value=.105						
1	16(88.9%)	1(5.6%)	1(5.6%)	19(63.3%)	10(33.3%	1(3.3%)
2	60(58.8%)	32(31.4%)	10(9.8%)	42(60.9%)	12(17.4%)	15(21.7%)
3	111(70.3%)	33(20.9%)	14(8.9%)	63(71.6%)	21(23.9%)	4(4.5%)
4				1(100.0%)	0(.0%)	0(.0%)
	Chi-squared = 8.408, p = 0.078			Chi-squared = 16.169, p = 0.013		
Birth Order: Chi-squared = 30.299. p=0.003						
First	18(9.6%)	9(13.6%)	3(12.0%)	23(18.4%)	8(18.6%)	2(10.0%)
Second	32(17.1%)	5(7.6%)	1(4.0%)	33(26.4%)	5(11.6%)	6(30.0%)
Third	19(10.2%)	18(27.3%)	9(36.0%)	18(14.4%)	13(30.2%)	4(20.0%)
Fourth	41(21.9%)	13(19.7%)	2(8.0%)	25(20.0%)	6(14.0%)	4(20.0%)
Fifth	36(19.3%)	11(16.7%)	7(28.0%)	12(9.6%)	5(11.6%)	1(5.0%)
Sixth	27(14.4%)	2(3.0%)	3(12.0%)	2(1.6%)	3(7.0%)	2(10.0%)
>Six	14(7.5%)	8(12.1%)	0(.0%)	12(9.6%)	3(7.0%)	1(5.0%)
	Chi-squared = 33.163, p = 0.001			Chi-squared = 15.171, p = 0.323		
Length of residence: Chi-squared = 20.969, p = 0.002						
Referred	14(7.5%)	2(3.0%)	3(12.0%)	8(6.4%)	6(14.0%)	0(0.0%)

<10 y	134(71.7%)	45(68.2%)	12(48.0%)	99(79.2%)	21(48.8%)	13(65.0%)
10-20	30(6.0%)	14(21.2%)	10(40.0%)	7(5.6%)	3(7.0%)	3(15.0%)
>20	9(4.8%)	5(7.6%)	0(0.0%)	11(8.8%)	13(30.2%)	4(20.0%)
	Chi-squared = 13.071, p = 0.042			Chi-squared = 13.071, p = 0.042		
Tribes: Chi-squared = 42.063, p = 0.043						
Barno	4(2.2%)	1(1.5%)	2(8.0%)	1(.8%)	2(4.7%)	2(10.0%)
Dainka	21(11.3%)	7(10.6%	4(16.0%)	18(14.4%)	3(7.0%)	1(5.0%)
Fur	18(9.7%)	8(12.1%)	0(.0%)	4(3.2%	5(11.6%)	1(5.0%)
Galeen	8(4.3%)	2(3.0%)	0(.0%)	3(2.4%)	6(14.0%)	0(0.0%)
Gawama	3(1.6%)	3(4.5%)	1(4.0%)	3(2.4%)	1(2.3%)	0(0.0%)
Hawsa	18(9.7%)	4(6.1%)	1(4.0%)	9(7.2%)	1(2.3%)	0(0.0%)
Mahas	5(2.7%)	2(3.0%)	0(0.0%)	5(4.0%)	2(4.7%)	0(0.0%)
Masaleet	5(2.7%)	3(4.5%)	0(0.0%)	3(2.4%)	0(0.0%)	0(0.0%)
Neiur	4(2.2%)	1(1.5%)	0(0.0%)	2(1.6%)	2(4.7%)	0(0.0%)
Nuba	15(8.1%)	6(9.1%)	1(4.0%)	18(14.4%)	4(9.3%)	2(10.0%)
Shawayga	9(4.8%)	1(1.5%)	1(4.0%)	3(2.4%)	1(2.3%)	1(5.0%)
Shuluk	6(3.2%)	1(1.5%)	0(0.0%)	6(4.8%)	1(2.3%)	0(.0%)
Tama	3(1.6%)	0(.0%)	0(0.0%)	3(2.4%)	3(7.0%)	0(.0%)
Zabarma	6(3.2%)	2(3.0%)	0(0.0%)	1(.8%)	0(.0%)	0(.0%)
Other tribes	61(32.8%)	25(37.9%)	15(60.0%)	46(36.8%)	12(27.9%)	13(65.0%)
	Chi-squared = 23.901, p = 0.687			Chi-squared = 41.298, p = 0.050		

4.3.3.2 Influence of Season and Socioeconomic Factors on PCM

The analysis of the prevalence of PCM by season and socioeconomic characteristics is presented in Table 4.9. From Table 4.9 it can be observed that there is no association between seasonal variations in PCM occurrence and money spent on food (p=0.256), maternal education (p=0. 682), maternal occupation (p=0.220), time spent outside the home by the mother (p=0.160) and overall family income (p=0.306). However, a significant association is observed with respect to paternal education (p=0.048) and total number of rooms (p=0.043).

Seasonal variation had no influence on the prevalence of PCM after controlling for maternal education. The wet season had no significant influence on the prevalence of PCM but children of mothers with no formal education had proportionately higher rates of marasmus and marasmic kwashiorkor than children from mothers with some formal education. The dry season also had no influence on PCM, although kwashiorkor was more prevalent in children of mothers with no formal education. In contrast, seasonal variation had a significant (Chi squared=12.684, p=0.048) influence on the prevalence of PCM when paternal education was taken into account. The wet season had no significant influence on the prevalence of PCM but children of fathers with secondary education had lower rates of kwashiorkor than children from fathers with only primary or no education. The dry season likewise had no influence on PCM, although no marasmic kwashiorkor was found among children whose fathers had a university degree.

Seasonal variability had no significant effect on PCM after controlling for the occupation of the mother, with more children of employed mothers having kwashiorkor than children of unemployed mothers, but in the dry season, more children of unemployed mothers had kwashiorkor than the children of employed mothers. In terms of paternal education, seasonal variation had a significant (Chi squared=5.659, p =0.050) influence on the prevalence of PCM when paternal occupation was taken into account. The wet season had no significant influence on the prevalence of PCM but children of unemployed fathers had higher rates of kwashiorkor than children with employed fathers. The dry season likewise had no influence on PCM, although the kwashiorkor rate was higher among children whose fathers had no employment. The number of hours a household spent outside the home had a non-significant influence on PCM, with none of the children whose mothers spent 2-4 hours outside home during the wet season being marasmic.

Seasonality significantly (Chi squared=7.759, p=0.256) did not influence PCM when the economic status of a family was taken into account, with children during the wet season from very low economic status families showing a greater prevalence of kwashiorkor than those with a lower or middle level economic status. The dry season had a non-significant influence on PCM, with children from lower economic status households showing a greater prevalence of kwashiorkor during dry season than those from higher economic status households. Regarding the amount of money spent on food, seasonal variation had no influence PCM (Chi squared=7.759, p=256*)*, when money spent on food controlled for, however, the dry season became significant (Chi squared=15.624, p=0.016), with children from very low economic status families having more kwashiorkor than those from households of lower or middle level economic status. The wet season had a non-significant influence on PCM, with children from families who spent low amount of money on food being more marasmic than those from families who spent a higher amount of money on food. When seasonal variability was taken into account with the number of rooms in a household then it was found to significantly (Chi squared=13.002, p=0.043) affect the levels of PCM in children. During the dry season there was proportionately more kwashiorkor in children whose families had one bedroom compared to families who had three bedrooms (Chi squared= 14.114, p=0.028).

Table 4.9: Influence of season and socioeconomic factors on the prevalence of PCM

Variables	Wet Season			Dry season		
	Marasmus	Kwashiorkor	Marasmic-Kwashiorkor	Marasmus	Kwashiork or	Marasmic-Kwashiorkor
Mother Education: Chi squared = 3.963, p = 0.682						
None	98(52.4%)	32(48.5%)	13(52.0%	64(51.2%)	25(58.1%)	11(55.0%)
Primary	74(39.6%)	31(47.0%)	9(36.0%)	42(33.6%)	13(30.2%)	5(25.0%)
Secondary	15(8.0%)	3(4.5%)	2(8.0%)	16(12.8%)	5(11.6%)	4(20.0%)
University	0(0.0%)	0(0.0%)	1(4.0%)	3(2.4%)	0(0.0%)	0(0.0%)
	Chi squared = 11.931, p = 0.069			Chi squared = - 3.503, p = 0.802		
Father Education: Chi squared = 12.684, p = 0.048						
None	54(28.9%)	525(37.9%)	12(48.0%)	37(29.6%)	15(34.9%)	10(50.0%)
Primary	94(50.3%)	32(48.5%)	8(32.0%)	52(41.6%)	19(44.2%)	6(30.0%)
Secondary	31(16.6%)	4(6.1%)	4(16.0%)	29(23.2%)	7(16.3%)	4(20.0%)
University	8(4.3%)	5(7.6%)	1(4.0%)	7(5.6%)	2(4.7%)	0(0.0%)
	Chi squared = 9.726, p = 0.137			Chi squared = 4.814, p = 0.568		
Mother Occupation: Chi squared = 0.027, p = 0.220						
Employed	118(65.2%)	50(76.9%)	17(68.0%)	22(17.7%)	10(23.3%)	4(20.0%)
Unemployed	63(34.8%)	15(23.1%)	8(32.0%)	102(82.3%)	33(76.7%)	16(80.0%)
	Chi squared = 3.038, p = 0.219			Chi squared = 0.633, p = 0 .729		
Father Occupation: Chi squared = 5.659, p = 0.050						
Employed	45(24.7%)	11(16.9%)	5(20.0%)	34(27.2%)	5(11.6%)	7(35.0%)
Unemployed	137(75.3%)	54(83.1%)	20(80.0%)	91(72.8%)	38(88.4%)	13(65.0%)
	Chi squared = 1.769, p = 0.412			Chi squared = 5.541, p = 0.062		
Number of hours household spent outside: Chi squared = 3.662, p = 0.160						
2-4 hr (at home)	4(2.1%)	3(4.5%)	0(0.0%)	9(7.2%)	6(14.0%)	1(5.0%)
>4 hr (outside home)	183(97.9%)	63(95.5%)	25(100%	116(92.8%)	37(86.0%)	19(95%)
	Chi squared = 1.860, p = 0.394			Chi squared = 2.228, p = 0.328		
Family Income/ Sudanese Pound: Chi squared = 7.159, p=0.306						
<300	108(57.8%)	45(68.2%)	16(64.0%)	57(45.6%)	28(65.1%)	11(55.0%)
300-400	52(27.8%)	13(19.7%)	5(20.0%)	31(24.8%)	9(20.9%)	6(30.0%)
400-500	18(9.6%)	6(9.1%)	4(16.0%	25(20.0%)	4(9.3%)	1(5.0%)
>500	9(4.8%)	2(3.0%)	0(0.0%)	12(9.6%)	2(4.7%)	2(10.0%)
	Chi squared = 4.937, p = 0.552			Chi squared = 7.888, p = 0.246		
Money spend on Food: Chi squared = 7.759, p = 256						
<300	146(78.1%)	50(75.8%)	17(68.0%	89(71.2%)	37(86.0%)	17(85.0%)
300-400	32(17.1%)	12(18.2%)	7(28.0%	30(24.0%)	4(9.3%)	0(.0%)
400-500	4(2.1%)	2(3.0%)	1(4.0%)	4(3.2%)	1(2.3%)	3(15.0%)
>500	5(2.7%)	2(3.0%)	0(0.0%)	2(1.6%)	1(2.3%)	0(0.0%)
	Chi squared = 2.837, p = 0.829			Chi squared = 15.624, p = 0.016		
Number of Rooms: Chi squared = 13.002, p = 0.043						
1	60(32.1%)	27(40.9%)	5(20.0%)	42(33.6%)	25(58.1%)	11(55.0%)
2	103(55.1%)	33(50.0%)	17(68.0%)	57(45.6%)	14(32.6%)	9(45.0%)
3	23(12.3%)	6(9.1%)	3(12.0%)	19(15.2%)	4(9.3%)	0(0.0%)
4	1(.5%)	0(0.0%)	0(0.0%)	7(5.6%)	0(0.0%)	0(0.0%)
	Chi squared = 4.567, p = 600			Chi squared =14.114, p = 0.028		

4.3.3.3 Influence of Season and Household Food Consumption Factors on PCM

Table 4.10 presents the association between the prevalence of PCM by season and the household consumption of various food items. From Table 4.10 it is clear that a significant association can be found between the consumption of sugar and PCM (p=0.000). From these values it is important to note that there is no difference across diseases with respect to most food consumption patterns. From Table 4.4 it was clear that there is a seasonal availability to food consumption. From Table 4.10 result, it can be contended that the consumption of most food products is related to this seasonal availability and that there is no significant impact of food consumption on individual disease attributes.

In the case of a wet season, the consumption of sugar (p=0.000) and green leafy vegetables (p=0.034) was found to have a significant association in relation to PCM. It is seen that the consumption of sugar during the wet season is highest across all three diseases, whilst during the dry season there is commonly consumption of sugar both twice and three times daily in protein calorie malnourished children. It is also interesting to see that green leafy vegetable consumption during the wet season is mostly seen twice and three times a week, which decreases during the dry. This may be associated with greater availability during the wet season.

In the case of the dry season, the consumption of legumes (p=0.050) was found to have a strong association with regard to the prevalence of PCM. No child affected by PCM reported three times a day consumption during the wet season.

Table 4.10: Prevalence of PCM by season and household food consumption

Variables	Wet Season			Dry season		
	Marasmus	**Kwashiorkor**	**Marasmic-Kwashiorkor**	**Marasmus**	**Kwashiorkor**	**Marasmic-Kwashiorkor**
Bread/day: Chi squared = 5.436, p = 0.489						
None	27(14.4%)	7(10.6%)	2(8.0%)	8(6.4%)	5(11.6%)	2(10.0%)
Once	44(23.5%)	12(18.2%)	2(8.0%)	40(32.0%)	8(18.6%)	6(30.0%)
> once	102(54.5%)	39(59.1%)	16(64.0%)	68(54.4%)	27(62.8%)	12(60.0%)
Three times	14(7.5%)	8(12.1%)	5(20.0%)	9(7.2%)	3(7.0%)	0(.0%)
	Chi squared = 8.447, p = 0.207			Chi squared = 5.806, p = 0.533		
Cereals/day: Chi squared = 5.805, p = 0.445						
None	1(.5%)	1(1.5%)	0(.0%)	3(2.4%)	0(.0%)	0(.0%)
Once	44(23.5%)	19(28.8%)	12(48.0%)	44(35.2%)	17(39.5%)	8(40.0%)
Twice	103(55.1%)	33(50.0%)	10(40.0%)	63(50.4%)	21(48.8%)	10(50.0%)
Three times	39(20.9%)	13(19.7%)	3(12.0%)	15(12.0%)	5(11.6%)	2(10.0%)
	Chi squared = 7.783, p =0.254			Chi squared = 1.817, p = 0.936		

Legumes /day: Chi squared = 5.368, p = 0.498						
None	8(4.3%)	2(3.0%)	2(8.0%)	2(1.6%)	5(11.6%)	1(5.0%)
Once	105(56.1%)	40(60.6%)	17(68.0%)	31(24.8%)	14(32.6%)	3(15.0%)
Twice	74(39.6%)	24(36.4%)	6(24.0%)	75(60.0%)	17(39.5%)	13(65.0%)
Three times	0(.0%)	0(.0%)	0(.0%)	17(13.6%)	7(16.3%)	3(15.0%)
	Chi squared = 3.106, p = 0.540			Chi squared = 12.217, p = 0.050		
Oil/Day: Chi squared= 2,237, p = 0.692						
Once	67(35.8%)	28(42.4%)	7(28.0%)	42(33.6%)	11(25.6%)	8(40.0%)
Twice	116(62.0%)	38(57.6%)	18(72.0%)	81(64.8%)	32(74.4%)	11(55.0%)
Three times	4(2.1%)	0(0.0%)	0(0.0%)	2(1.6%)	0(0.0%)	1(5.0%)
	Chi squared = 3.702, p = 0.448			Chi squared = 4.022, p = 0.403		
Sugar/Day: Chi squared = 39.004, p = 0.000						
Once	82(43.9%)	13(19.7%)	2(8.0%)	31(24.8%)	6(14.0%)	2(10.0%)
Twice	67(35.8%)	17(25.8%)	8(32.0%)	45(36.0%)	16(37.2%)	6(30.0%)
Three times	15(8.0%)	13(19.7%)	9(36.0%)	26(20.8%)	15(34.9%)	6(30.0%)
> three times	23(12.3%)	23(34.8%)	6(24.0%)	23(18.4%)	6(14.0%)	6(30.0%)
	Chi squared = 44.651, p = 0.000			Chi squared = 7.923, p = 0.243		
Green Leafy Vegetables/Week: Chi squared = 14.746, p =0. 064						
Once	73(39.0%)	28(42.4%)	1(44.0%)	40(32.0%)	9(20.9%)	5(25.0%)
Twice	66(35.3%)	14(21.2%)	4(16.0%)	34(27.2%)	15(34.9%)	5(25.0%)
Three times	42(22.5%)	18(27.3%)	6(24.0%)	32(25.6%)	11(25.6%)	5(25.0%)
> three times	10(4.2%)	12(9.1%)	4(16.0%)	18(15.2%)	8(18.7%)	35(25.0%)
	Chi squared = 16.686, p = 0.034			Chi squared = 8.570, p = 0.38		
Other Vegetables/Week: Chi squared = 9.284, p = 0.319						
None	76(40.6%)	22(33.3%)	11(44.0%)	33(26.4%)	9(20.9%)	6(30.0%)
Once	58(31.0%)	21(31.8%)	4(16.0%)	26(20.8%)	11(25.6%)	5(25.0%)
Two times	44(23.5%)	17(25.8%)	8(32.0%)	45(36.0%)	14(32.6%)	6(30.0%)
Three times	1(.5%)	5(7.6%)	1(4.0%)	4(3.2%)	2(4.7%)	0(0.0%)
> three times	8(4.3%)	1(1.5%)	1(4.0%)	17(13.6%)	7(16.3%)	3(15.0%)
	Chi squared = 16.161, p = 0.078			Chi squared = 2.258, p = 0.971		
Fruits/Week: Chi squared = 11.015, p = 528						
None	5(2.7%)	4(6.1%)	0(0.0%)	3(2.4%)	1(2.3%)	1(5.0%)
Once	129(69.0%)	45(68.2%)	13(52.0%)	77(61.6%)	27(62.8%)	14(70.0%)
Twice	40(21.4%)	13(19.7%)	6(24.0%	34(27.2%)	9(20.9%)	3(15.0%)
Three times	7(3.7%)	4(6.1%)	5(20.0%)	8(6.4%)	3(7.0%)	1(5.0%)
> three times	6(3.1%)	0(0.0%)	1(4.0%)	3(9.6%)	3(7.0%)	1(5.0%)
	Chi squared = 16.834, p = 0.078			Chi squared = 9.003, p = 0.703		

4.3.3.4 Influence of Season and Child Feeding Practices Factors on PCM

Table 4.11 represents the association between the prevalence of PCM by season and child feeding practices. From Table 4.11 a significant association could be found between the prevalence of PCM and MF at birth (p=0.003). In addition to this, the breastfeeding mode (p=0.000), age at introduction of solid food (p=0.000), weaning age (p=0.016) and weaning food (p=006) were also factors that were found to show a strong association with the prevalence of PCM. Breastfeeding at the time of the study (p=0.695) showed no significance in relation to the prevalence of PCM.

For the wet season, the breastfeeding mode (p=0.05), age of introduction of solid food (p=0.026), weaning age (p=0.022) and weaning food (p=0.005) were all child feeding factors that showed a significant association with regard to the prevalence of PCM. The mode of breastfeeding was found to show a greater significance in both the wet and dry seasons, as children affected by PCM during the wet season were found to be engaged in the partial breastfeeding mode. It can be argued from Table 4.10 that there is seasonal availability of food, and therefore, it can be contended from the above bivariate analysis that there is a significant association between the mode of breastfeeding and PCM occurrence in terms of the mode of breastfeeding.

Similarly, it can also be argued that the weaning age shows an association with wet season attributes. For example, the weaning age is found to be less than 12 months and 12-18 months during the wet season; however, in the dry season the weaning age was more spread out. Another interesting observation is that a weaning age of greater than 24 month was found for marasmus affected children (1 child in the wet season and 3 children in the dry season). Similarly, the age of introducing solid food is found to be greatest at less than 4- 6 months during the wet season, whilst during the dry season the age for introducing solid food is found to be distributed in a much more concentrated fashion.

From the above analysis, the primary issue that should be noted is that there is no difference across diseases with respect to most food consumption patterns, although there is a strong link between feeding practices and food availability. From the results it can be contended that the consumption of most food products is related to the seasonal availability of feeding and that there is no significant impact of feeding practices on individual disease attributes.

Table 4.11: Prevalence of PCM by season and child feeding practices

Variables	Wet Season			Dry season		
	Marasmus	Kwashiorkor	Marasmic-Kwashiorkor	Marasmus	Kwashiorkor	Marasmic-Kwashiorkor
Maternal Feeding at birth: Chi squared = 13.002, p = 0.003						
Yes	186(67.4%)	65(23.6%)	25(9.1%)	123(66.1%)	43(23.1%)	20(10.8%)
No	1(50.0%)	1(50.0%)	0(0.0%)	2(100.0%)	0(0.0%)	0(0.0%)
	Chi squared = 856, p = 652			Chi squared = 1.019, p =0.601		
Breastfeeding at the time of the study: Chi squared = 0.227, p = 0.695						

Yes	64(74.4%)	16(18.6%)	6(7.0%)	45(60.8%)	22(29.7%)	7(9.5%)
No	122(64.2%)	49(25.8%)	19(10.0%)	78(69.6%)	21(18.8%)	13(11.6%
	Chi squared = 2.811, p-value=245			Chi squared = 3.040, p =0.219		
Breastfeeding mode: Chi squared = 16.134, p = 0.000						
Exclusive	38(52.1%)	26(35.6%)	9(12.3%)	18(52.9%)	14(41.2%)	2(5.9%)
Partial	148(72.9%)	39(19.2%)	16(7.9%)	105(69.%)	29(19.1%)	18(11.8%
	Chi squared = 10.772, p = 0.005			Chi squared = 7.881, p = 0.019		
Age/m at introduction of solid food: Chi squared = 21.571, p = 0.000						
				7(50.0%)	6(42.9%)	1(7.1%)
<4	27(81.8%)	3(9.1%)	3(9.1%)	36(78.3%)	5(10.9%)	5(10.9%)
4-6	137(67.5%)	46(22.7%)	20(9.9%)	68(66.7%)	22(21.6%)	12(11.8%
>6	23(54.8%)	17(40.5%)	2(4.8%)	14(53.8%)	10(38.5%)	2(7.7%)
	Chi squared = 11.058, = 0.026			Chi squared = 10.834, p- = 0.094		
Weaning Age/ m Chi squared = 15.620, p = 0.016						
<12	65(67.7%)	19(19.8%)	12(12.5%)	32(74.4%)	10(23.3%)	1(2.3%)
12-18	41(52.6%)	31(39.7%)	6(7.7%)	34(61.8%)	11(20.0%)	10(18.2%
18-24	15(88.2%)	2(11.8%)	0(0.0%)	11(91.7%)	0(0.0%)	1(8.3%)
>24	1(100.0%)	0(.0%)	0(0.0%)	3(75.0%)	0(0.0%)	1(25.0%)
	Chi squared = 14.750, p = 0.022			Chi squared = =11.099, p = 0.085		
Weaning Food: Chi squared = 21.538, p = 006						
CHO+ animal + plant proteins	22(62.9%)	7(20.0%)	6(17.1%)	22(73.3%)	4(13.3%)	4(13.3%)
CHO+ animal protein	18(62.1%)	8(27.6%)	3(10.3%)	11(50.0%)	8(36.4%)	3(13.6%)
CHO+ plant protein	87(76.3%)	22(19.3%)	5(4.4%)	54(75.0%)	11(15.3%)	7(9.7%)
CHO	43(53.1%)	28(34.6%)	10(12.3%)	33(62.3%)	15(28.3%)	5(9.4%)
Animal or plant proteins	17(94.4%)	1(5.6%)	0(.0%)	1(25.0%)	2(50.0%)	1(25.0%)
	Chi squared = 22.025, p = 0.005			Chi squared = 11.189, p = 0.191		

4.3.3.5 24 Hour Dietary Recall

Table 4.12 shows that the energy and macronutrients intake was very low among children with SPCM. It can be seen that the difference in energy intake and energy requirement was significant ($P < 0.05$), and the difference in carbohydrate, protein and fat were significant ($p < 0.05$) between nutrient intake and recommended dietary allowance. The percentages of adequacy were low for energy (22.16%), proteins (33.7%), carbohydrate (39.9%) and fats (10.18%), and the contribution of carbohydrate, protein and fat to energy was 85.4%, 8.14% and 13.8%, respectively.

Table 4.12: Observed and required nutrient intake of children with PCM

Energy and dietary nutrients	Mean ± SD (intake)	Mean ± SD (requirement)	p-value	% of adequacy
Energy Kcal	220.59±86.520	995.25±241.621	0.028	22.16
Carbohydrate intake/g/d	47.159±22.6554	118.53±20.027	0.005	39.9
proteins g/day	4.495±3.2387	13.307±1.8624	0.000	33.7
Fats g/day	3.39±2.821	33.29±2.786	0.020	10.18

4.3.3.6 Observed and Required Nutrient Intake of Children with PCM by Age

The intake of energy and macronutrients of Sudanese children aged 0-59 months is presented in Table 4.13. The mean energy intake was 225.99±89.682kcal (23% of the energy requirement), and the average intakes of carbohydrate, protein and fat were 47.159±22.6554g (39.8% of the recommended daily allowance, RDA), 4.495±3.2387g (33.8% of RDA) and 3.52±3.556g (10.5% of RDA), respectively. On average, children aged 0-6, 7-11 months, 1-3 years and 4-5 years consumed low levels of energy relative to the RDA (DRI, 2005). A higher intake of energy and carbohydrate were consumed by the 7-11 months and 1-3 years age groups compared to the 0-6 months or 4-5 years groups. The mean intake of energy and carbohydrate increased with age, but the only difference observed was between the 1-3 year old children and the intake of the younger ones concerning their carbohydrate intake (p=0.000). In contrast, protein and fat intake decreased with age and the difference was significant for both protein (p=0.020) and fat (p=0.002).

Table 4.13: Observed and required nutrient intake of children with PCM by age

Nutrient value	Age	Mean ± SD Intake	p-value	Mean ± SD Requirements	Mean percentage of adequacy
Energy kcal/day	0-6 months 7-11m 1-3 year 4-5 year	219.00±97.124 227.28±85.079 227.48±90.872 205.50±92.859	0.427	543.33±57.757 711.47±33.691 1046.93±0.711 1742.00±.000	40.3 31.9 21.7 11.8
Carbohydrates/g /d	0-6 months 7-11m 1-3 year 4-5 year	39.300±23.4375 45.187±21.003 48.587±23.134 44.243±22.085	0.000	60.00±00 94.49±4.114 130.00±00 130.00±00	65.5 47.8 37.4 34
Protein/g/d	0-6 months 7-11m 1-3 year 4-5 year	5.967±3.6728 5.085±3.218 4.212±3.1414 4.193±3.7954	0.020	9.100±15 11.484±.100 13.856±.0853 18.636±1.363	66.2 44.25 30.4 22.5

Fat/g/d	0-6 months 7-11m 1-3 year 4-5 year	7.80±9.745 4.06±2.895 3.09±2.657 2.45±3.139	0.002	31.00±.000 30.37±1.315 35.00±.000 25.00±.000	22.6 13.2

The mean percentage of adequacy of energy, carbohydrates, proteins and fats was high for children aged 0-6 months. The mean percentages of energy adequacy was lower for children aged 4-5 months (11.8%) compared with the group of children aged 0-6 months (40.5%), although there was no significant differences with respect to energy intake/day. The mean percentages of carbohydrates, protein and fats were significantly higher in children aged 0-6 months compared to children aged 4-5 years old. The composition of foods was continuously changing over time, depending on the age of the children. Very thin maize porridge was prepared for children aged less than 6 months, with increasing viscosity to that of custard or composite flour porridge was prepared for children aged 6-11 months. Older children received much thicker composite flour porridge and family foods.

4.3.3.7 Relationship between Mean Intakes of Nutrients and Children with Marasmus, Kwashiorkor and Marasmic Kwashiorkor

Table 4.14 shows the relationship between mean intakes of nutrients and children with marasmus, kwashiorkor and marasmic kwashiorkor. From Table 4.14 it can be seen that in the case of children with marasmus, kwashiorkor and marasmic kwashiorkor, the percentage of energy intake from carbohydrates is 82.2%, 84.6% and 88.6%, respectively. The overall p-value is 0.050, which shows that there is a significant relationship between the carbohydrate intake and children suffering from marasmus, kwashiorkor and marasmic kwashiorkor. This is also the reason for the lack of a significant difference between the carbohydrate intakes among children suffering from the various disorders. In the case of the percentage of energy derived from the intake of proteins among the various children who had marasmus, kwashiorkor and marasmic kwashiorkor, it was found to be 8.3%, 7.5% and 6.4%, respectively. Table 4.14 also reveals that for children with marasmus, kwashiorkor and marasmic kwashiorkor, the percentage of energy intake from fat is 15.1%, 12.8% and 10.2%, respectively. The intake of energy via fat or proteins does not show any significant difference.

Table 4.14: Relationship between mean intakes of nutrients and children with marasmus, kwashiorkor and marasmic kwashiorkor

Parameter	Mean± Std.				P-value
	Marasmus	Kwashiorkor	Marasmic kwashiorkor	Total	
Energy	219.50±85.336	240.51±101.308	236.13±88.605	225.99±89.682	0.235
Carbohydrate	45.114±22.414	50.828±24.043	52.272±19.824	47.159±22.655	0.050
% energy	82.2	84.6	88.6	72.7	
Protein	4.585±3.466	4.556±2.582	3.794±2.991	4.495± 3.238	0.520
% energy	8.3	7.5	6.4	7.9	
Fat	3.69±3.927	3.40±2.639	2.68±2.601	3.52±3.556	0.787
% energy	15.1	12.8	10.2	13.9	

4.3.3.8 Relationship between Mean Energy and Dietary Intakes and requirements for Children with Marasmus, Kwashiorkor and Marasmic Kwashiorkor

Table 4.15 depicts the relationship between the mean energy and dietary intakes of children with marasmus, kwashiorkor and marasmic kwashiorkor. It is evident that for energy with respect to marasmic children, there is a significant difference between the energy requirements and intake (p=0.009), the requirement and intake of carbohydrates (p=0.033), the requirement and intake of proteins (p=0.000) and the requirement and intake of fat (p=0.001). A significant difference could also be seen for marasmic kwashiorkor children and their requirement and intake of fat (p=0.047).

The diet leading to kwashiorkor is characterized by a high carbohydrate and very low protein and fat content (Table I5). The average consumption of calories was 240 cal./day, and of protein, 1.68 g./day. The calorie intake was 25% of the recommended intake per day. Carbohydrates contributed to more than 84% of the calories, and protein only 2.8 %. Whether excess carbohydrate intake in the presence of protein deficiency is responsible for the prevalence of kwashiorkor has yet been determined by this study.

In Marasmus, the average consumption of calories was 226 cal. /day, and of protein 4.5 g. /day. The calorie intake was less than one-fourth of the recommended intake per day. The difference in the dietetic intakes in kwashiorkor and marasmus was impressive. Whereas the protein intake in kwashiorkor was one third of that in marasmusm while the fat intake per day in marasmus was 9% of the requirment, in kwashiorkor it was only 3% of the requirement.

In marasmic kwashiorkor, the average consumption of calories was 236 cal./day, and of protein 3.8 g./day. The diet closely resembles the diet in marasmus, and differs from kwashiorkor in having a smaller calorie and a higher protein intake per day. Children on this diet will form the classic picture of protein calorie malnutrition.

Table 4.15: Relationship between mean energy and dietary intakes and requirements for children with marasmus, kwashiorkor and marasmic kwashiorkor

Macronutrients	Marasmus	P-value	Kwashiorkor	P-value	Marasmic Kwashiorkor	P-value
Energy intake/Kcal	225.99±89.68	0.009	240.51±101.30	0.235	236.13±88.60	0.175
Energy requirement/kcal	978.61±237.19		956.24±237.82		922.72±194.0	
Carbohydrate intake/g	47.159±22.65	0.033	50.828±24.04	0.171	52.272±19.82	0.274
Carbohydrate requirement/g	118.53±20.02		117.13±18.04		115.78±23.28	
Protein intake/g	4.495±3.23	0.000	1.68±.701	0.676	3.794±2.99	0.273
Protein requirement/g	13.765±1.51		13.216±1.82		12.791±1.69	
Fat intake/g	3.52±3.55	0.001	1.03±.17	0.926	2.68±2.60	0.047
Fat requirement/g	33.29±2.78		33.03±2.87		33.53±2.22	

4.3.3.9 Observed and Required Nutrient Intakes by Season

Table 4.16 represents the observed and required nutrient intakes during both the wet and dry seasons. It can be seen that for macronutrients such as carbohydrates, protein and fat, a significant difference could be perceived between the requirement and intake values (carbohydrate, p=0.044); (protein, p=0.005); (fat, p=0.000). The results showed that the percentages of adequacy were higher in the wet season with regards to energy and carbohydrate, while those for protein and fat were higher in the dry season. However, children did not meet the full macronutrient requirements in either season.

Table 4.16: Observed and required nutrient intakes by season

Macronutrients intake	Wet season	Dry season	Total	p-value
Energy intake Energy requirement % of adequacy	229.89±91.017 977.53±228.068 23.5%	219.38±87.374 980.44±252.971 22.4%	225.99±89.682 978.61±237.196 23.1%	0.105
Carbohydrate intake Carbohydrate requirement % of adequacy	49.474±22.7544 119.13±18.478 41.5%	43.232±22.0344 117.50±22.461 36.8%	47.159±22.6554 118.53±20.027 39.8%	0.044
Protein intake Protein requirement % of adequacy	4.199± 3.1934 13.321±1.8009 30.2%	4.996± 3.2676 13.285±1.8624 37.6%	4.495± 3.2387 13.307±1.8624 33.8%	0.005
Fat intake Fat requirement % of adequacy	3.03±2.793 33.24±2.778 9%	4.34±4.461 33.38±2.810 13%	3.52±3.556 33.29±2.786 10.6%	0.000

4.3.3.10 Relationship between Mean Intakes of Nutrients by Season and Children with Marasmus, Kwashiorkor and Marasmic Kwashiorkor

Table 4.17 shows the energy and nutrients intake in the wet and dry seasons for children with marasmus, kwashiorkor and marasmic kwashiorkor. For kwashiorkor children, a significant difference could be observed between their energy and carbohydrate intake during the wet and dry seasons (p=0.049, p=0.050, respectively). There were also no major differences in consumption of protein and fat in the various protein calorie malnutrition groups; marasmus, kwashiorkor and marasmic kwashiorkor

Table 4.17: Relationship between mean intakes of nutrients by season and children with marasmus, kwashiorkor and marasmic kwashiorkor

Macronutrients	Marasmus	P-value	Kwashiorkor	P-value	Marasmic Kwashiorkor	P-value
Energy/kcal						
Wet season Dry season	227.95±87.30 209.03±84.522	0.279	229.42±100.236 267.15±101.390	0.049	244.56±94.409 225.29±82.709	0.477
Carbohydrate /g/d						
Wet season	48.689±22.7819	0.404	48.606±23.3312	0.050	57.194±20.6490	0.173
Dry season	40.205±21.7016		56.160±25.4861		45.943±17.4040	
Protein/g/d						
Wet season	4.213±3.3933	0.139	4.565±2.7184	0.775	3.133±2.8382	0.489
Dry season	5.154±3.5039		4.535±2.2894		4.643±3.0701	
Fat/g/d						
Wet season	3.12±2.890	0.508	3.19±2.643	0.508	1.96±2.381	0.551
Dry season	4.10±2.838		3.90±2.627		3.61±2.661	

4.3.3.11 Prevalence of PCM by Energy and Micronutrients Intake/Season

Table 4.18 depcts the prevalence of PCM by energy and micronutrients intake according to the season. From Table 4.18 it can be seen that there is a strong association between the energy intake and carbohydrate intake among children with PCM and the dry season.

The deficit in overall energy intake was found to be associated with PCM, the association was nearly significant (0.06). The deficit in calories intakes was significantly higher (P < 0.037) in dry season as compared to wet season This may be due to the typical harsh environmental conditions of drought where children are exposed to extreme environmental conditions rapidly occurring drought leading to poor economy affecting their dietary intake in turn. The deficit in protein (49.9%) and carbohydrates (70%) intakes was high in wet season which might be responsible for the increase of prevalence of marasmus, although the association was not significantly so.

Overall consumption of carbohydrates was responsible for the prevalence of PCM. The association was nearly significant (0.08). High consumption of carbohydrates (35%) was signicantly assocated with kwashiorkor (0.005), and low consumption of protein (5%) was found to be associated with the prevalence kwashiorkor, although the association was not significant.

Table 4.18: Prevalence of PCM by energy and macronutrients intake/season

	Wet season			Dry season		
	Marasmus	Kwashiorkor	Marasmic-Kwashiorkor	Marasmus	Kwashiorkor	Marasmic-Kwashiorkor
Energy intake (kcal/day): chi squared = 10.763, p = 0.069						
<200	52(41.9%)	18(37.5%)	7(38.9%)	35(45.5%)	73(35.0%)	5(35.7%)
200-300	46(37.1%)	20(41.7%)	5(27.8%)	30(39.0%)	9(45.0%)	7(50.0%)
300-400	25(20.2)	8(16.7%)	5(27.8%)	10(13.0%)	0(0.0%)	2(14.3%)
>400	1(0.8)	2(4.2%)	1(5.6%)	2(2.6%)	4(20.0%)	0(0.0%)
	chi squared = 4.657, p = 0.588			chi squared = 13.415, p = 0.037		
Carbohydrates intake (g/day): chi squared = 8.331, p = 0.088						
<60	92(74.2%)	31(64.6%)	10(55.6%)	63(83.3%)	13(65.0%)	12(85.7%)
60-95	30(24.4%)	16(33.3%)	7(38.9%)	16(16.7%)	4(20.0%)	2(14.3%)
>95	2(1.6%)	1(2.1%)	1(5.6%)	0(0.0%)	3(15.0%)	0(0.0%)
	chi squared = 4.108, p = 0.392			chi squared = 14.695, p = 0.005		
Protein intake (g/day): chi squared = 4.321, p = 0.633						
>4	62(50.0%)	20(41.7%)	11(61.1%)	28(35.9%)	10(50.0%)	7(50.0%)
4-8	44(35.5%)	22(45.8%)	6(33.3%)	37(47.4%)	9(45.0%)	6(42.9%)
8-12	15(12.1%)	5(10.4%)	1(5.6%)	8(10.3%)	1(5.0%)	0(0.0%)
>12	3(2.4%)	1(2.1%)	0(0.0%)	5(6.4%)	0(0.0%)	1(7.1%)
	chi squared = 3.248, p = 0.777			chi squared = 4.386, p = 0.625		
Fat intake (g/day): chi squared = 0.945. p = 0.624						
<10	119(97.5%)	46(97.9%)	18(100.0%)	73(98.6%)	19(95.0%)	13(100.0%)
10-15	3(2.5%)	1(2.1%)	0(0.0%)	1(1.4%)	1(5.0%)	0(0.0%)
	chi squared = 0.453, p = 0.797			chi squared = 1.425, p = 0.491		

4.3.4 Multinomial Logistic Regression Analysis

4.3.4.1 Risk Factors for Protein Calorie Malnutrition of Children in Sudan/Season

4.3.4.1.1 Risk of Marasmus

In Table 4.19, it can be seen that the wet season was 59% less likely to influence marasmus, and the dry season was 62% less likely to influence marasmus when gender was taken into account. The dry season was also 37% less likely to influence marasmus when the length of residence was taken into account. The bivariate model utilised the quantities of food consumed on the day before the interview as a co-factor for PCM. The children who consumed sugar in the wet season had a higher risk of marasmus relative to those who consumed sugar in dry season, whilst those children who consumed fizzy drinks and cereals in the wet season were more likely to have marasmus. This further supports the functional limitations of starch-based weaning foods that need to be consumed in bulk in order to satisfy the daily energy and nutrient requirements. The number of children who consumed vegetables in the wet season is lower than those who consumed them during the dry season (5 times in the wet season and 13 times in the dry season). In Sudan, food availability is not constant throughout the year, and experience various food-insecure periods during each season. Seasonal variations in food production and fluctuations in prices of foods contribute to transitory food insecurity in poor households, which over time escalates into chronic food insecurity and nutritional deterioration (Huss-Ashmore, 1988).

Table 4.19: Regression coefficients and odds ratios for the risk factors for marasmus

Variables	B	SE	Sig	Exp	Variables	B	SE	Sig	Exp
Household characteristics					**Household food consumption**				
Child gender					**Sugar consumption**				
Intercept	3.321	0.548	0.000		Intercept	3.457	0.679	0.000	
Wet season/	-0.889	0.338	0.008	0.411	Wet season	-0.148	0.062	0.017	0.862
Dry season/	-0.956	0.349	0.006	0.384	Dry season	-0.165	0.064	0.010	0.848
Length of residence					**24 hr food consumption**				
Intercept	2.863	0.525	0.000		Fizzy drink				
Wet Season	-0.369	0.229	0.107	0.691	Intercept	0.693	1.225	0.571	
Dry Season	-0.455	0.213	0.032	0.634	Wet season	0.155	0.010	0.000	1.168
Father education					**Cereals**				
Intercept	1.164	0.404	0.004		Intercept	9.638	2.562	0.000	
Wet Season	0.443	0.227	0.050	1.558	Wet season	-0.283	0.085	0.001	0.754
Dry Season	0.377	0.224	0.093	1.548	Dry season	-0.332	0.094	0.000	0.718

4.3.4.1.2 Risk of Kwashiorkor

From Table 4.20, it can be seen that the dry season was 30% less likely to influence kwashiorkor when child age was taken into account, and the wet season was 54% less likely to impact when examined by gender. The dry season likewise was 59% less likely to influence kwashiorkor when gender was taken into account and 2% less likely to influence kwashiorkor when tribes were taken into account. The wet and dry seasons are more likely to influence kwashiorkor when fat intake was taken into account. In general, regression coefficients did not determine any differences between the wet and dry seasons for influencing kwashiorkor. Both seasons were less likely to influence kwashiorkor when gender, child age, tribes were taken into account, and were more likely to influence kwashiorkor when fat consumption was taken into account

Table 4.20: Regression coefficients and odds ratios for the risk factors for kwashiorkor

Variables	**B**	**SE**	**Sig**	**Exp**	**Variables**	**B**	**SE**	**Sig**	**Exp**
Child age					**Tribes**				
Intercept	2.123.	0.734	0.004		Intercept	1.798	0.489	0.000	
Wet season	0.178	0.768	0.139	0.768	Wet season	0.014	0.008	0.087	0.986
Dry season	-0.369	0.182	0.043	0.691	Dry season	0.019	0.008	0.023	0.981
Child gender					**Fat intake**				
Intercept	2.129	0.597	0.000		Intercept	-15.728	0.353	0.000	
Wet season	0.769	0.373	0.039	0.463	Wet season	16.644	0.447	0.000	1.691
Dry season	0.889	0.389	0.022	0.411	Dry season	16.159	0.000	0.000	1.041

4.3.5 Covariance Analysis

4.3.5.1 Prevalence of PCM by Season and Cofactors

In Table 4.21 the coefficient of the season with the length of residence statistically affected the prevalence of PCM during the rainy season. This implies that season had an effect for families who had immigrated to Khartoum, exhibiting an increased prevalence of PCM.

Table 4.21 also presents the results of the ANCOVA and the coefficients of the interactions of paternal education. This shows that season did not significantly affect the prevalence of PCM ($p>0.05$). While the results of the coefficients demonstrate that the wet season and dry season significantly affected the prevalence of PCM when the father’s education was taken into account. The ANCOVA results for investigating the effect of season and whether the number of rooms affects PCM show that the wet season was significant in affecting PCM, while the dry season also had an influence on PCM. The coefficient of the interaction of season and the presence of latrines was also significant in affecting PCM, both in the wet season and the dry season.

The coefficients of the wet and dry seasons and their interaction with breastfeeding status reveal that the wet season statistically affected the dependent variable, while the dry season did not have a statistically significant affect. This implies that breastfeeding in the wet season were more likely to affect the prevalence of PCM.

The results of the ANCOVA, investigating the effect of season and sugar consumption in affecting PCM show that wet season was significant in affecting PCM when examined by sugar consumption. Sugar consumption was statistically significant affecting the prevalence of PCM during both the wet and dry seasons.

The coefficient of the association of season and rice consummation was critical in influencing PCM, both during the wet and dry seasons, and the wet season statistically affected the presence of PCM when cereals consumption was taken into account. This implies that the wet season is more likely to affect the existence of PCM.

The results of the generalised linear model shown in Table 4.21 provide the coefficients of the seasons and their interaction with carbohydrate intake, revealing that the dry season did not statistically affect the prevalence of PCM. In contrast, the wet and dry season statistically affect the prevalence of PCM when Carbohydrate intake is taken into account.

Table 4.21: Parameter estimates for risk factor by season and cofactors

Variables	95% Wald Confidence					
	Interval				Hypothesis Test	
	B	Std Error	Lower	Upper	Chi-Square	P-value
Years of residence						
Wet season	0.120	0.0451	0.032	0.209	7.092	0.000
Dry season	0.134	0.0438	0.049	0.220	9.421	0.002
Father education						
Wet season	-0.088	0.0392	-0.164	-0.011	4.998	0.025
Dry season	-0.080	0.0398	-0.158	0.002	4.027	0.045
Number of rooms						
Wet season	-0.100	0.0457	-0.190	-0.011	4.826	0.028
Dry season	-0.118	0.0457	-0.207	-0.028	6.628	0.010
Breastfeeding mode						
Wet season	-0.230	0.0785	-0.384	-0.076	8.563	0.003
Dry season	-0.152	0.0829	-0.314	0.011	3.352	0.067
Sugar consumption						
Wet season	0.170	0.0300	0.111	0.228	32.056	0.000

Dry season	0.147	0.0301	0.088	0.206	23.670	0.000
Rice consumption/d						
Wet season	0.042	0.0190	0.004	0.079	4.818	0.028
Dry season	0.046	0.0210	0.004	0.087	4.729	0.030
Cereals consumption/d						
Wet season	0.056	0.0110	0.035	0.078	26.574	0.000
Dry season	0.067	0.0128	0.042	0.092	27.115	0.000
Carbohydrate intake/g/d						
Wet season	0.166	0.0785	0.012	0.319	4.453	0.035
Dry season	0.160	0.0900	-0.016	0.337	3.167	0.045

4.3.5.2 Summary of the Finding for t he Generalised Linear Model

Table 4.21 presents the final models in the wet and dry season, showing that there is a significant difference in the prevalence of PCM during the dry and wet seasons. The analysis of covariance investigated wet and dry season risk factors while interacting with the covariate. The only covariates which had a significant relationship with the wet and dry seasons in influencing PCM, were the length of residence, father’s education, number of rooms, breastfeeding mode, fish consumption, sugar consumption, rice, cereals, meat and carbohydrate intake.

4.3.5.3 Magnitude Results

Table 4.22 illustrates the results of the bivariate, multinomial logistic regression and generalised linear model analysis. Overall, the factors that were significant in the bivariate analysis were length of residence, tribes, father’s education, mother’s occupation, father’s occupation, number of rooms, healthy latrines, birth order, breastfed at birth, breastfeeding mode, age when receiving solid food, age at weaning, weaning food, fish consumption per month, sugar consumption per day, energy intake per day and carbohydrate intake per day.

Factors that were significant in the wet season identified by the bivariate analysis were length of residence, birth order, breastfeeding mode, age when receiving solid food, age at weaning, weaning food, and sugar consumption. Factors that were significant in dry season identified by the bivariate analysis were, number of children aged less than 5 years, length of residence, tribes, money spent on food, number of rooms, breastfeeding mode, legumes consumption, energy intake and carbohydrate intake per day.

Factors that remained significant during the wet and dry seasons in the multinomial logistic regression were tribes, father’s education, presence of latrines, and sugar consumption. Factors that remained significant in the wet and dry seasons in the generalised linear model were length of residence, father's education, mother's occupation, number of rooms, healthy latrines, , sugar consumption, and carbohydrate intake.

The multinomial logistic regression and generalised linear model analysis showed that in the wet season significant factors included father's education, presence of latrines and sugar consumption, while for the dry season only the presence of latrines and sugar consumption were identified. In the wet season, only one significant factor was identified using all three statistical methods, sugar consumption, while for the dry season, tribes was the only common significant factor identified.

Table 4.22: Summary of the results of the bivariate, multinomial logistic regression and generalised linear model analyses

	Bivariate			MLR		GLM	
	Overall	WS	DS	WS	DS	WS	DS
HH characteristics							
Number of <5 years	10.513	8.408	16.169*				
Length of residence	20.969**	13.071*	13.071*			7.092***	9.421**
Tribes	42.063*	23.901	41.298*				
Kwashiorkor-tribes					-0.019*		
Socioeconomic							
Father education	12.684*	9.726	4.814			4.998*	4.027*
Marasmus - Father education				0.443*			
Mother occupation	6.340*	4.836,	1.733			5.878*	6.222*
Father occupation	5.659*	1.769	5.541				
Money spent on food	7.759	2.837	15.624*				
Number of rooms	13.104**	4.567	14.114*			4.826*	6.628*
Presence of latrines	5.980 *	3.080	3.007			5.904*	4.689*
Marasmus - Presence of latrines				0.852*	0.852*		
Birth order	30.299**	33.163**	15.171				
Child feeding practice							
Breastfed at birth	13.002**	0.856	1.019,	.			
Breastfeeding mode	16.134***	10.772**	7.881*				
Age at receiving solid food	21.571**	11.058*	10.834				
Age at weaning	15.620*	14.750*	11.099				
Weaning food	21.538**	22.025**	11.189				
HH food consumption							
Legumes/day	5.368	3.106	12.217*				
Sugar/day	39.004***	44.651***	7.932			32.056***	23.670***
Marasmus-Sugar				-0.648*	-0.612*		
GLV/day	14.746.	16.686*	8.570				
24 hr nutrients intake							
Energy intake/kcal/d	0.056	4.657	13.415*				
Carbohydrate intake/g/d	0.048	4.108	14.695*			4.453*	3.167*

4.4 Discussion of the Findings

4.4.1 Prevalence of Protein Calorie Malnutrition

This study found that PCM affected 1.15% of Sudanese children <5 years old who attended CEH and KTH. This finding is consistent with other studies which have stated that severe malnutrition affects 1-2% of pre-school children in developing countries. This study observed that the prevalence of marasmus (66.9%) was much more frequent than kwashiorkor (23.4%), and food scarcity leading to inadequate intake may be the cause. This finding was in agreement with other studies from Sudan (Omar et al., 1975; Taha, 1979), and other countries such as Turkey (Wray, 1961) and Peru (Graham & Morales, 1963). However, kwashiorkor seems to be more prevalent than marasmus in some countries, such as in Nigeria, where a higher incidence of kwashiorkor has been reported (Hamidu et al., 2003).

In terms of seasnality, there is a significant difference between the prevalence of PCM in the wet and dry seasons which indicates that the prevalence of PCM in Khartoum demonstrates seasonal variability. The extant literature (Black et al., 1983; Beaten et al., 1983; Rajakumar et al., 2011) has identified the daily and seasonal variation in dietary intake among individuals; however, most of this literature is limited to industrialised nations. The impact of seasonal variation in developing countries has been examined with respect to children and young adults (Jafar et al., 2010; Rajakumar et al., 2011), where the positive role played by seasonal variation in the overall energy uptake of an individual has been noted (Arabi et al., 2010).

Many low income rural communities in tropical countries experience seasonal variation in the availability of food, which results in periodic food scarcity (Chambers et al., 1981). Most tropical countries have the same climates, and as there is little variation in temperature throughout the year, the seasons are differentiated by rains into the wet and dry seasons. The harvesting of crops stars a few months into the rainy season and lasts into the first few months of the dry season. In the pre-harvest period food scarcity occurs (Walsh, 1981), and food becomes less varied and more expensive (Schofield, 1974).

It has been estimated that one billion people live in environments which are prone to food seasonal shortages (Chambers, 1982). Young children are vulnerable during this time as they need a constant supply of adequate food for growth and development (Chambers, 1982), although Leonard (1991) indicated that children are mostly protected from food scarcity during this period and in some communities food scarcity occurs during the harvest season

when mothers are busy with agriculture (Graham, 1981). These findings exhibit the complexity of the problems and the need to examine PCM and its determinants (demographic characteristics) during the wet and rainy seasons.

4.4.1.1 Household Characteristics

4.4.1.1.1 Number of Children Under Five Years of Age in the Family

In the bivariate analysis the prevalence of PCM was found to be high among children in households with more than one under five year olds. During the dry season a high prevalence of kwashiorkor was significantly associated the number of under five year old children in the family, whilst during wet season marasmic kwashiorkor was higher in this population. This is consistent with the fact that younger children are expected to be more vulnerable to the dispersion of precious household resources and caretaker time when there is a greater number of young, dependent children (Das et al., 2008). The multivariate analysis also revealed that large numbers of pre-school aged children are significantly associated with a higher prevalence of PCM. Most children presented with PCM during the wet season, suggesting that an increase in infectious diseases may be more responsible for PCM than issues of food availability.

4.4.1.1.2 Length of Residence

Household characteristics were discussed in relation to the occurrence of PCM and the impact of seasonal variation. The results showed that the dry season influenced the prevalence of marasmus when residency length of a family was considered. It was observed by Asali et al. (1978) that in Beirut, the longer the residence in a region the greater the chances of the occurrence of marasmus, and this correlates with the findings of this study. However, Ahmed et al. (2011) obtained results which contradict this view, as a study among children in Assiut University Hospital in Egypt identified that the only household characteristic which impacted on the occurrence of PCM was whether a household was rural or urban. Furthermore, this study found that the dry season was less likely to influence kwashiorkor when the tribes were considered. These results are comparable with those of Myatt et al. (2006) who found that the community/tribe of a child was associated with the occurrence of PCM. However, the effect of seasonality with tribe and PCM has not been studied and so this result cannot be compared.

4.4.1.1.3 Tribe

Tribes had a significant association with PCM, as the prevalence of marasmus was significantly higher among the Dainka (14.4%) and Nuba (14.4%) during the dry season. The highest level of kwashiorkor was also found in dry season, for children belonging to the Galeen tribe (14.0%), while a better picture was observed for Zabarma tribes in the dry and wet seasons. Sudan continues to be a country characterised by diversity, and numerous tribes have been found in the northern Arabic and southern African regions along with eastern and western tribes. The different tribes contribute to a country with multi-cultural and ethnic features (Abdella & Sulieman, 2009). Entire ethnic groups may be subjected to discrimination and intimidation, or even violence and abuse (Torún & Chew, 1994; Torún, 2006). Mothers may have to take up completely different roles within the household. For example, when a household income decreases, women have to try to find a job for extra money, forcing mothers to spend long hours outside the home in order to obtain food, water and fuel.

4.4.1.2 Socioeconomic Characteristics

4.4.1.2.1 Parental Occupation

Maternal occupation was found to be seasonal, with a greater number of respondents employed during the wet season than during the dry season. This is comparable to a study by Alredaisy (2010) in Eastern Sudan, which identified that during the wet season the mother in agricultural households is often expected to help out on farm related activities. Furthermore in his dissertation, Earl (2011) identified that occupational seasonal variation is due to rural families assuming different jobs throughout the year in order to ensure an adequate supply of food. Similarly, the number of hours a mother spends outside the home was also quite high among respondents during the dry season. Grosegner (2010) proposed that the amount of time spent by a mother outside of the home during the dry season is high, as she often seeks non-agriculturally related income for the family. In their examination of the occurrence of kwashiorkor among Sudanese children, Hendrickse et al. (1992) identified that there was a positive impact of seasonal variation, as well as type of parental occupation, on the occurrence of PCM.

4.4.1.2.2 Family Income and Money Spent on Food

The growth of infants and younger children throughout the world is related to the socioeconomic environment in which they live. The findings here reflect that the fact that children in wealthier families are less likely to be malnourished than those of poorer families.

***4.4.1.2.3* Size of Household**

There is a positive association between seasonal variation, number of rooms and the occurrence of PCM. It was observed that the difference in the number of rooms children use by season is also related to the occurrence of PCM. In a study by Abdullah and Wheeler (1985) it was observed that the seasonal variation of nutrition in a Bangladeshi village was dependent on the size of a household. The authors reported that smaller houses had a lower income and lower hygiene levels, and that therefore the children from these houses were undernourished.

4.4.1.2.4 Presence of a Latrine

The occurrence of PCM and the presence of a latrine was higher during the wet season compared to the dry season. The results of this study are comparable to those of Gross et al. (1989), whose study identified that the seasonal variation in water supply impacted upon the sanitation facilities of homes in Brazil. Furthermore, Phetsouvanh et al. (1999) examined the seasonal variation in the occurrence of diarrhoea among children and its causative agents, identifying that the leading cause of diarrhoea during the dry season was unclean toilets, which rarely had enough water.

4.4.1.3 Household Food Consumption

The dietary assessment of the children included a household food consumption and 24 hour food intake survey. For the majority of the foods there were no statistical differences in the frequency of food consumption and marasmus, kwashiorkor and marasmic kwashiorkor children. A few foods however, showed significant differences between the various PCM diseases; in the dry season the prevalence of marasmic kwashiorkor was significantly associated with legumes consumption, while marasmic children had significantly lower sugar consumption.

A possible mechanism for an increase in legumes consumption and the prevalence of marasmic kwashiorkor is postulated to be impairment in the general metabolism of the children, in particular the metabolism of energy yielding nutrients. However, it was not possible to validate this and efforts to ask the mothers during the survey about the amount of food consumed yielded little meaningful information.

4.4.1.4 Child Feeding Practices

Apart from the sociocultural, economic and demographic factors, infant-feeding practices constitute a major component of child caring practices. Yet somehow, these practices constitute one of the most neglected areas of study. This section presents a discussion of child feeding practices with respect to seasonal variation and its impact on the occurrence of PCM.

4.4.1.4.1 Breast Feeding Patterns

No seasonal variation in breastfeeding which occurred at the time of birth was identified; however, differences in breastfeeding patterns were observed at the time of the study and with respect to the mode of breastfeeding. Van Steenbergen et al. (1981) studied the lactation performance of Akamba mothers in Kenya, and their results confirmed the presence of seasonal variations in breastfeeding practices, with mothers breastfeeding their children completely during the wet season and only partially during the dry season. This correlates with the results of this study. This notion is reinforced by the results of Zoohori et al. (1993), who observed seasonal variations in breastfeeding patterns among mothers in the Philippines. Furthermore, the results indicate that the occurrence of PCM is related to breastfeeding at the time of birth, as well as the mode of breastfeeding. A study by Kumar et al. (2006) examined maternal breastfeeding practices and identified that a lack of colostrum is a significant factor which impacts upon the nutrition of a child and can result in an underweight, stunting and malnourished status among children under five years old.

4.4.1.4.2 Age at Receipt of Solid Food

It was observed that the age at which children received solid food was different between the two seasons, with a greater number of children starting to receive solid food during the dry season compared to the wet season. Thompson & Rahman (1967) examined the feeding pattern of infants in Africa and identified that the availability of solid food and the introduction of infants to solid food was strongly dependent upon the seasonal availability of food. This is in agreement with the results obtained in this study. These results are augmented by the finding that the occurrence of PCM is strongly related to the age of a child when the introduction to solid food is considered in a seasonal manner. This finding can be compared to the results of Ibrahim et al. (1992), which identified that children in Somalia often suffered from undernourishment during droughts due to a lack of available solid food.

4.4.1.4.3 Weaning Practices

When weaning practices were considered, it was observed that the number of children who had been recently weaned from breast milk was higher during the wet season compared to the dry season, a finding which is echoed in the literature. A study by Padmadas et al. (2002) identified that the weaning initiation patterns among children in India were found to depend upon the seasonal availability of solid food in a family. Furthermore, the association between weaning age, seasonal variation and PCM was established in this study. A study by Motarjemi et al. (1993) observed that the degree of contaminated weaning food was higher during the wet season due to a lack of hygiene, and this resulted in an increased risk of diarrhoea, which can cause PCM.

4.4.1.4.4 Complementary Food Patterns

When the type of complementary food patterns were observed, it was seen that most of the children received a greater amount of complementary food during the dry season compared to the wet season, which is in agreement with the views on solid food consumption. The results from a study by Ibrahim et al. (1992) identified that there was seasonal variation with respect to complementary feeding patterns in infants. Furthermore, Underwood and Hofvander (1982) reported that the introduction of complementary food into the diet of an infant is vital, and that any variations or delays will cause problems of undernourishment. In addition to this, Caulfield et al. (1999) identified the need for interventions to improve the intake of complementary food among infants, stating that a lack of complementary foods results in PEM. About 12% of the infants started a complementary feeding programme early (<4 month of age) and 57.3% were in the age range between four to six month old (Abdella &Sulieman, 2009).

4.4.1.4.5 The 24-hour Food Recall

The results of the 24 hour food recall survey showed that a limited variety of foods had been consumed on the day preceding the interview. Cereals dominated as the staple food (35.7%), and although animal products were consumed, included milk and meat, the quantities were very small. The consumption of fruit and vegetables was found to be very low, while the consumption of fizzy drinks was found to be too high for children of this age, and the vast majority of children consumed sugar (92.1%).

There was no difference in the macronutrients intake in terms of seasonality; energy, protein and carbohydrate intakes were higher during the dry season than during wet season, while fat intake was higher during the wet season. A significant relationship was found between the carbohydrate intake and children suffering from marasmus, kwashiorkor and marasmic kwashiorkor. The generalised linear model analysis revealed that carbohydrate intake had a significant relationship with the wet and dry seasons in influencing the prevalence of PCM.

4.4.1.5 Magnitude of the Study

The final model for seasonal variation and its impact on PCM revealed that seven covariates significantly influenced PCM: the length of residence, father's education, number of rooms, presence of latrines, breastfeeding mode and sugar consumption, and the results of all the previous analyses clearly supported this result. The overall findings of this study can be compared to those of Chen et al. (1979) in rural Bangladesh, which indicated that homes, family income and food patterns were associated with seasonal variation, and were found to impact upon the occurrence of PCM.

Chapter 5 - Risk Factors for Protein Calorie Malnutrition: Demographic Characteristics

5.1 Introduction

This chapter discusses the demographic characteristics, which are factors that can be used to help promote better health and prevent PCM among infants and young children. The causes of malnutrition are multiple, and complex factors arise both from the individual and the environment. At the macro-level, the causes of malnutrition involve socioeconomic, nutritional (food security), educational, and health factors. However, at the micro-level, malnutrition is a direct result of the inadequate intake and/or utilisation of food and nutrients.

Demographic factors raise much larger problems than may be anticipated. Low immunological resistance caused by demographic factors may facilitate the occurrence of common childhood diseases, such as diarrhoea, measles and whooping cough, which can in turn contribute to PCM, marasmus, kwashiorkor and marasmic kwashiorkor in children. Whereas the high prevalence of PCM is well recognised, there is less information on the effect of demographic factors. Because of the difficulty in improving demographic factors directly, interventions try to act on the other elements of the web of causation, such as socioeconomic and environmental factors, whose negative interaction with PCM has been confirmed by many studies (Jones, 1998; Kandala et al., 2011). Despite the complex nature of the basis for PCM, it is also possible to examine specific risk factors which are characteristic among children, and such an analysis forms the basis of the study.
This research aims to address many of these attributes and to examine the occurrence of different forms of PCM.

Widespread PCM with the resulting negative effects on health and productivity is likely to place serious restrictions upon a child's development. Thus the need to combat the prevalence of PCM has not only an ethical, but also an economic justification. If children are protected from PCM, then they have an increased chance of growing a healthy body and mind, reaching their genetic, physical and intellectual potential, and contributing to higher productivity in the future. Although PCM among children has been a problem in Sudan for a long time, demographic factors have not always been given the importance and priority they deserve. There has always been a general lack of understanding among decision makers and the public at large of the strong relationship that exists between demographic factors and PCM. There has been inadequate research into the area of childhood malnutrition in Sudan, and poor coordination and publication of all the research efforts on the subject. There has also been a lack of understanding of the nature and magnitude of the malnutrition problem. This section examines the demographic characteristics of the households and children, and also other selected variables in order to provide a complete picture to decision makers who are in a position to take action towards combatting PCM.

5.1.1 Objective

To investigate the effect of maternal age, teen marriage and pregnancy, birth spacing, birth order, parity, family size, ethnicity, tribe, child age, gender and nutrition deficiency on PCM.

5.2 Subjects and Methods

This study is based on data collected from children aged 0-59 months in Khartoum in order to assess the effect of demographic factors on PCM (marasmus, kwashiorkor and marasmic kwashiorkor). These parameters were used to describe the PCM in children and the relationship between maternal factors and child development. Apart from obtaining information on demographic factors, the questionnaire was expanded to elicit descriptive information. The aim of this study was to obtain comprehensive information on the prevalence of PCM and to investigate the degree to which demographic factors contribute to PCM. See (Figure 4.1) simplified methodological framework for prevalence and seasonal variation of PCM in Sudan

5.2.1 Data Collection

See section 4.2.1

5.2.2 Sample Size

See section 4.2.1.1

5.2.3 Data Analysis

Both bivariate and multivariate analyses were employed to identify the determinants of PCM in children. The chi-squared test was utilised to investigate the relationship between each of the independent variables and PCM in children, namely marasmus, kwashiorkor and marasmic kwashiorkor (based on the Welcome classification), and p-values of less than 0.05

were considered to be significant. The net effects of each independent variable were estimated by determining the relative importance of a factor's influence on the nutritional status of a child using a multinomial logistic regression multivariate analysis. The odds ratio, which is determined from the logistic regression coefficients, provides information on the increased or decreased chance of PCM given a set level of independent variables while controlling for the effects of other variables within the model. Estimates of odds greater than 1.0 indicate that the risk of PCM is greater than that for the reference category, while estimates of less than 1.0 indicate that the risk of malnutrition is less than that for the reference category of each variable. Please *see secton 3.10*

5.3 Results of Background Characteristics

A total of 466 children were studied in detail using the methods described in Chapter 4. Some background characteristics, especially those concerning the mother, the child, the household and the environment the child is living in can have a considerable influence on PCM in a child below five years of age.

5.3.1 Baseline Child Profile

5.3.1.1 Children's Characteristics and the Prevalence of PCM

Table 5.1 presents the bivariate analysis of the disease diagnosis against the demographic characteristics. It is evident that significant relationships are observed between the diagnosis of the various diseases and gender (p=0.017), age (p=0.0001), between weight at birth (p=0.013), height for age (p=0.037), weight for height (p=0.001), weight for age (p=0.001), MUAC (p=0.004), vaccine status (p=0.036) and place of delivery (p=0.033).

When it comes to the diagnosis of various diseases, it can be seen that the majority of the diseases affected boys (57.5%). In addition, Table 5.1 also reveals that the majority of children who were diagnosed with PCM were between the ages of 12 and 23 months (48.3%), while those aged between 48 and 59 months were the least affected by PCM (2.8%). When considering any link between weight at birth and the prevalence of disease, it can be seen that the majority of children (64.2%) had a normal weight at birth yet were still affected by PCM. Similarly, when height for age was considered as a factor in the prevalence of PCM, it was found that 5.6% of children who had PCM were severely under the average height for their age, 63.3% had a severely abnormal weight for their heights, and 77.5% of children were found to have a severely abnormal weight for their age. Although 81.1% of children had been vaccinated during the early stages of their life for various diseases, they were still affected by PCM. Finally, among the children diagnosed with PCM, about 53.6% of them were found to have had a home based delivery.

Table 5.1: Demographic characteristics of children and the prevalence of PCM

Variable	Marasmus	Kwashiorkor	Marasmic Kwashiorkor	Total	P-value
Gender					
Boys	188 (60.3%)	63 (57.8%)	17 (37.8%)	268 (57.5%)	0.017
Girls	124 (39.7%)	46 (42.2%)	28 (62.2%)	198 (42.5%)	
Age in months					
0-5	17 (5.4%)	7 (6.4%)	1 (2.2%)	25(5.4%)	0.001
06-11	73 (23.4%)	16 (14.7%)	6 (13.3%)	95 (20.4%)	
12-23	124 (39.7%)	76 (69.7%)	25 (55.6%)	225 (48.3%)	
24-35	70 (22.4%)	7 (6.4%)	10(22.2%)	87 (18.7%)	
35-47	18 (5.8%)	0 (0%)	3 (6.7%)	21 (4.5%)	
48-59	10 (3.2%)	3 (2.8%)	0 (0%)	13 (2.8%)	
Weight at birth					
Normal	186 (59.6%)	81 (74.3%)	32 (71.1%)	299 (64.2%)	0.013
Abnormal	126 (40.4%)	28 (25.7%)	13 (28.9%)	167 (35.8%)	
Height-for-Age					
Very severe	0 (0%)	1 (0.9%)	0 (0%)	1 (0.2%)	0.037
Severe	177 (56.7%)	51 (46.8%)	22 (48.9%)	250 (53.6%)	
Moderate	77 (24.7%)	24 (22.0%)	13 (28.9%)	114 (24.5%)	
Mild	41(13.1%)	17 (15.6%)	4 (8.9%)	62 (13.3%)	
Normal	17 (5.4%)	16 (14.7%)	6 (13.3%)	39 (8.4%)	
Weight-for-Height					
Severe	21 (69.9%)	52 (47.7%)	25 (55.6%)	295 (63.3%)	0001
Moderate	39 (12.5%)	13 (11.9%)	6 (13.3%)	58 (12.4%)	
Mild	29 (9.3%)	17 (15.6%)	9 (20.0%)	55 (11.8%)	
Normal	26 (8.3%)	27 (24.8%)	5 (11.1%)	58 (12.4%)	
Weight-for-Age					
Severe	256 (84.9%)	64 (58.7%)	3 (71.1%)	361 (77.5%)	0.001
Moderate	25 (8.0%)	24 (22.0%)	8 (17.8%)	57 (12.2%)	
Mild	15 (4.8%)	9 (8.3%)	3 (6.7%)	27 (5.8%)	
Normal	7 (2.2%)	12 (11.0%)	2 (4.4%)	21 (4.5%)	
Vaccine Status					
Yes	263 (84.3%)	80 (73.4%)	35 (77.8%)	378 (81.1%)	0.036
No	49 (15.7%)	29 (26.6%)	10 (22.2%)	88 (18.9%)	
Place of Delivery					
Hospital	157 (50.3%)	41 (37.6%)	18 (40.0%)	216 (46.4%)	0 .033
Home	155 (49.7%)	68 (62.4%)	27 (60.0%)	250 (53.6%)	

5.3.1.2 Maternal Factors and the Prevalence of PCM

Table 5.2 presents the demographic characteristics of mothers and the prevalence of PCM. It is evident that significant relationships are observed between the prevalence of PCM and the mother's BMI category (p=0.05), mother's marriage age (p=0.005), mother's age at the time of her first year (p=0.005), birth spacing between ill child and younger sibling (p=0.035), birth order PCM (p=0.003), number of years in Khartoum (p=0.002) and tribes (p=0.043). It is also clear that there is no association between the prevalence of PCM and the age of a mother when she had her youngest child (p=0.326), size of a family (p=0.493), number of children under five (p=0.105) and parity (p=0.679).

When considering the prevalence of PCM, it can be seen that the majority of disease was present in children whose mothers had a BMI of 18.5 to 25 (61.9%). The majority of the mothers had been married between the ages of 19 and 24 (41.6%), and mothers who were pregnant before they turned 18 were the most likely to have children affected by PCM (40.8%). In addition, mothers who had their youngest child between the ages of 25 and 34 were most likely to have children affected by PCM (44%), and a family size of two to five members resulted in a child being more likely to be affected by PCM (46.1%).

Table 5.2 also shows that 50.8% of the mothers with a child affected by PCM had a birth spacing of 12 to 23 months between their ill child and a younger sibling. Furthermore, mothers who had lived for fewer than 10 years in Khartoum were the most likely to have children affected by PCM (56.0%), while children whose mothers belonged to different tribes were the most affected by PCM (37.6%).

Table 5.2: Demographic characteristics of mothers and the prevalence of PCM

Variables	Marasmus	Kwashiorkor	Marasmic Kwashiorkor	Total	P-value
Mother BMI kg/m^2					
<18.5	75(23.8)	33(30.6%)	8(17.7%)	115(24.8%)	0.001
18.5-25	199 (63.8%)	58 (53.7%)	31 (68.9%)	288 (61.9%)	
25.1-30	37 (11.9%)	16 (14.8%)	5 (11.1%)	58 (12.5%)	
>30	2 (0.6%)	1 (0.9%)	1 (2.2%)	4 (0.9%)	
Mother Marriage Age/year					
<18	133 (42.6%)	46 (42.2%)	10 (22.2%)	189 (40.6%)	0.005
19-24	135 (43.3%)	39 (35.8%)	20 (44.4%)	194 (41.6%)	
25-34	44 (14.1%)	24 (22.0%)	15 (33.3%)	83 (17.8%)	
Mother Age/year at First Pregnancy					
<18	135 (43.3%)	45 (41.3%)	10 (22.2%)	190 (40.8%)	0.005
19-24	127 (40.7%)	39 (35.8%)	18 (40.0%)	184 (39.5%)	

>24	50 (16.0%)	25 (22.9%)	17 (37.8%)	92 (19.7%)	
Mother Age/year at Youngest Child					
<19	15 (4.8%)	7 (6.4%)	1 (2.2%)	23 (4.9%)	0.326
20-24	89 (28.5%)	29 (26.6%)	8 (17.8%)	126 (27.0%)	
25-34	139 (44.6%)	47 (43.1%)	19 (42.2%)	205 (44.0%)	
>35	69 (22.1%)	26 (23.9%)	17 (37.8%)	112 (24.0%)	
Family Size					
02-05	139 (44.6%)	52 (47.7%)	24 (53.3%)	215 (46.1%)	0.493
06-08	137 (43.9%)	46 (42.2%)	19 (42.2%)	202 (43.3%)	
09-11	32 (10.3%)	11 (10.1%)	1 (2.2%)	44 (9.4%)	
12-13	4 (1.3%)	0 (0%)	1 (2.2%)	5 (1.1%)	
Number of children under five					
1	35 (11.2%)	11 (10.1%)	2 (4.4%)	48 (10.3%)	0.105
2	102 (32.7%)	44 (40.4%)	25 (55.6%)	171 (36.7%)	
3	174 (55.8%)	58 (49.5%)	18 (40.0%)	246 (52.8%)	
4	1 (0.3%)	0 (0.0%)	0 (0.0%)	1 (0.2%)	
Birth spacing between ill child and Younger Sibling/month					
<12	98 (33.8%)	18 (18.0%)	7 (15.6%)	123 (28.3%)	0.035
12-23	134 (46.2%)	61 (61.0%)	26 (57.8%)	221 (50.8%)	
24-35	43 (14.8%)	14 (14.0%)	10 (22.2%)	67 (15.4%)	
36-47	13 (4.5%)	5 (5.0%)	2 (4.4%)	20 (4.6%)	
48-70	2 (7%)	2 (2.0%)	0 (0%)	4 (0.9%)	
36-47	11 (3.8%)	5 (5.0%)	1 (2.2%)	17 (3.9%)	
48-70	2 (0.7%)	2 (2.0%)	0 (0.0%)	4 (0.9%)	
Birth order					
1	41 (13.1%)	17 (15.6%)	5 (11.1%)	65 (13.5%)	0.003
2	65 (20.8%)	10 (9.2%)	7 (15.6%)	82 (17.6%)	
3	37 (11.9%)	31 (28.4%)	13 (28.9%)	81 (17.4%)	
4	66 (21.2%)	19 (17.4%)	6 (13.3%)	91 (19.5%)	
5	48(15.4%)	16 (14.7%)	8 (17.8%)	72 (15.5%)	
6	29 (9.3%)	5 (4.6%)	5 (11.1%)	39 (8.4%)	
>6	26 (8.3%)	11 (10.1%)	1 (2.2%)	38 (8.2%)	
Parity					
<3	93 (39.8%)	34 (31.2%)	19 (40.0%)	145 (31.1%)	0.679
3-4	106 (34.0%)	43 (39.4%)	13 (28.9%)	162 (34.8%)	
5-6	93 (39.8%)	23 (21.1%)	12 (26.7%)	128 (27.5%)	
7-8	16 (5.1%)	7 (6.4%)	2 (4.4%)	25 (5.4%)	
>8	4 (1.3%)	2 (1.8%)	0 (0.0%)	6(1.3%)	
Number of years in Khartoum					
Not living in Khartoum	8 (7.3%)	3 (6.7%)	33 (10.7%)	44 (9.4%)	0.002
<10	66 (60.6%)	25 (55.6%)	170 (54.4%)	261 (56.0%)	
10-20	17 (15.6%)	13 (28.9%)	67 (21.5%)	97 (20.8%)	
>20	18 (16.5%)	4 (8.9%)	42 (30.4%)	64 (13.7%)	
Tribes					
Barno	5 (1.6%)	3 (2.8%)	4 (8.9%)	12 (2.6%)	0.043
Dainka	39 (12.5%)	10 (9.2%)	5 (11.1%)	54 (11.6%)	
Fur	22 (7.1%)	13 (11.9%)	1 (2.2%)	36 (7.7%)	
Galeen	11 (3.5%)	8 (7.3%)	0 (0%)	19 (4.1%)	

Gawama	6 (1.9%)	4 (3.7%)	1 (2.2%)	11 (2.4%)	
Hawsa	25 (8.0%)	5 (4.6%)	1 (2.2%)	31 (6.7%)	
Mahas	10 (3.2%)	4 (3.7%)	0 (0%)	14 (3.0%)	
Masaleet	8 (2.6%)	3 (2.8%)	0 (0%)	11 (2.4%)	
Neiur	6 (1.9%)	3 (2.8%)	0 (0%)	9 (1.9%)	
Nuba	32 (10.3%)	10 (9.2%)	3 (6.7%)	45 (9.7%)	
Shawayga	12 (3.9%)	2 (1.8%)	2 (4.4%)	16 (3.4%)	
Shuluk	12 (3.9%)	2 (1.8%)	0 (0%)	14 (3.0%)	
Tama	6 (1.9%)	3 (2.8%)	0 (0%)	9 (1.9%)	
Zabarma	7 (2.3%)	2 (1.8%)	0 (0%)	9 (1.9%)	
Different tribes	110 (35.4%)	37 (33.9%)	28 (62.2%)	175 (37.6%)	

5.3.1.3 Household Characteristics and the Prevalence of PCM

Table 5.3 presents the household/environmental characteristics and the prevalence of PCM in Sudanese children. It is evident that significant relationships are observed between the prevalence of PCM and paternal education (p=0.048), maternal occupation (p=0.042), paternal occupation (p=0.05), maternal source of income (p=0.0), family income in Sudanese Pounds (p=0.047), number of rooms in the house (p=0.038), household building materials (p=0.026), sources of water (p=0.039), household waste disposal (p=0.004) and the presence of latrines (p=0.016).

It is also clear that there is no association between the prevalence of PCM and maternal education (p=0.886), sources of electricity (p=0.054) and paternal source of income a (p=0.614).

When regard to the prevalence of PCM, it can be seen that the highest prevalence of PCM was observed in children whose mothers had received no education (52.4%). Table 5.3 also reveals that children whose fathers who had a primary education had the highest prevalence of PCM (45.5%), together with those whose mothers were unemployed (75.1%). In addition, paternal employment also affects the prevalence of PCM in children (76.7%), and mothers of PCM affected children whose source of income was their husband also demonstrated a high prevalence of PCM (70.6%). Paternal occupation revealed that the children with the highest prevalence of PCM had fathers (31.8%) who were street sellers, whilst families whose source of income was less than 300 Sudanese Pounds per month were most likely to be affected by PCM (56.9%), together with those families whose source of water is a public supply (39.7%), and disposed of their garbage in the public garbage (49.6%). Finally, children whose families had a latrine in their household were not affected by PCM (56.2%).

Table 5.3: Household/environmental characteristics and the prevalence of PCM

Dependent Variable	Marasmus	Kwashiorkor	Marasmic Kwashiorkor	Total	P-value
Maternal education					
None	163 (52.2%)	57 (52.3%)	24 (53.3%)	244 (52.4%)	0.886
Primary	117 (37.5%)	44 (40.4%)	14 (31.1%)	175 (37.6%)	
Secondary	29 (9.3%)	8 (7.3%)	6 (13.3%)	43 (9.2%)	
University	3 (1.0%)	0 (0%)	1 (2.2%)	4 (0.9%)	
Paternal education					
None	92 (29.5%)	39 (35.8%)	21 (46.7%)	152 (32.6%)	0.048
Primary	146 (46.8%)	51 (46.8%)	15 (33.3%)	212 (45.5%)	
Secondary	59 (18.9%)	12 (11.0%)	8 (17.8%	79 (17.0%)	
University	15 (4.8%)	7 (6.4%)	1 (2.2%)	23 (4.9%)	
Maternal occupation					
Employed	88 (28.2%)	22 (20.2%)	6 (13.3%)	116 (24.9%)	0.042
Unemployed	224 (71.8%)	87 (79.8%)	39 (86.7%)	350 (75.1%)	
Paternal occupation					
Unemployed	79 (25.7%)	16 (14.8%)	12 (26.7%)	107 (23.3%)	0.050
Employed	228 (74.3%)	92 (85.2%)	33 (73.3%)	353 (76.7%)	
Maternal source of Income					
Government employee	8 (2.6%)	1 (0.9%)	0 (0.0%)	9 (1.9%)	0.001
Hairdresser	5 (1.6%)	1 (0.9%)	0 (0.0%)	6 (1.3%)	
Housekeeper	15 (4.8%)	2 (1.8%)	1 (2.2%)	18 (3.9%)	
Cleaner	68 (21.8%)	18 (16.5%)	7 (15.6%)	93 (20.0%)	
Husband	216 (69.2%)	78 (71.6%)	35 (77.8%)	329 (70.6%)	
Tea seller	0 (0%)	9 (8.3%)	2 (4.4%)	11 (2.4%)	
Paternal sources of income					
Government employee	48 (15.6%)	16 (14.7%)	7 (15.6%)	71 (15.4%)	0.614
Skilled labour	90 (29.2%	33 (30.3%)	17 (37.8%)	140 (30.3%)	
Water trader	16 (5.2%)	1 (9%)	2 (4.4%)	19 (4.1%)	
Street seller	96 (31.2%)	40 (36.7%)	11 (24.4%)	147 (31.8%)	
Do not have income	55 (17.9%)	17 (15.6%)	8 (17.8%)	80 (17.3%)	
Cleaner	3 (1.0%)	2 (1.8%)	0 (0%)	5 (1.1%)	
Family income in Sudanese Pounds per month					
<300	165 (52.9%)	73 (67.0%)	27 (60.0%)	265 (56.9%)	0.047
300-400	83 (26.6%)	22 (20.2%)	11 (24.4%)	116 (24.9%)	
400-500	43 (13.8%)	10 (9.2%)	5 (11.1%)	58 (12.4%)	
>500	21 (6.7%)	4 (3.7%)	2 (4.4%)	27 (5.8%)	
Number of rooms in the house					
One room	100 (32.1%)	51 (46.8%)	16 (35.6%)	167 (35.8%)	0.038
2 rooms	169 (54.2%)	48 (44.0%)	25 (55.6%)	242 (51.9%)	
3 rooms	38 (12.2%)	10 (9.2%)	4 (8.9%)	52 (11.2%)	
4 rooms	5 (1.6%)	0 (0.0%)	0 (0.0%)	5 (1.1%)	
Household building materials					
Mud	191 (61.2%)	62 (56.9%)	20 (44.4%)	273 (58.6%)	0.026
Brick	112 (35.9%)	45 (41.3%)	23 (51.1%)	180 (38.6%)	
Paste Board	7 (2.2%)	2 (1.8%)	0 (0.0%)	9 (1.9%)	
Stone	2 (0.6%)	0 (0%)	1 (2.2%)	3 (0.6%)	
Other	0 (0.0%)	0 (0.0%)	1 (2.2%)	1 (0.2%)	

Sources of Water					
Public supply to tap	116 (37.2%)	48 (44.0%)	21 (46.7%)	185 (39.7%)	0.039
Public supply outside	65 (20.8%)	28 (25.7%)	10 (22.2%)	103 (22.1%)	
Water Trader	131 (42.0%)	33 (30.3%)	14 (31.1%)	178 (38.2%)	
Sources of Electricity					
No electricity	33 (10.6%)	17 (15.6%)	10 (22.2%)	60 (12.9%)	0.054
Public supply	105 (33.7%)	43 (39.4%)	12 (26.7%)	160 (34.3%)	
Through neighbour	17 (5.4%)	3 (2.8%)	4 (8.9%)	24 (5.2%)	
Lamp	157 (50.3%)	46 (42.2%)	19 (42.2%)	222 (47.6%)	
Household Waste disposal					
Public garbage	171 (54.8%)	39 (35.8%)	21 (46.7%)	231 (49.6%)	0.004
Collection	78 (25.0%)	38 (34.9%)	10 (22.2%)	126 (27.0%)	
Buried	50 (16.0%)	25 (22.9%)	9 (20.0%)	84 (18.0%)	
Burned	13 (4.2%)	7 (6.4%)	5 (11.1%)	25 (5.4%)	
Presence of Latrine					
No	165 (52.9%)	65 (59.6%)	32 (71.1%)	262 (56.2%)	0.016
Yes	147 (47.1%)	44 (40.4%)	13 (28.9%)	204 (43.8%)	

5.3.1.4 Child Feeding Practice and the Prevalence of PCM

Table 5.4 illustrates child feeding practice, and reveals that nearly all children with PCM (99.1%) were breastfed when they born, but that only 33.2% of them were breastfed exclusively up to the recommended six months, and about two thirds (64.8%) of the children were not breastfeeding at the time of the study. The study found that 17% of children had received solid food before they reached four months of age, while 14% had received solid food after they were six months old; one quarter of mothers had introduced solid food to their children because they had little breast milk, and 21.5% were pregnant. Nearly half (45.4%) of the SPCM affected children were weaned before they reached their first birthday, while only 1.6% continued breastfeeding beyond 24 months, and half of the mothers weaned their children at the usual time. Almost 29.3% of mothers had relied on starchy food as a source of weaning food for their PCM affected children.

In terms of feeding practice, it is evident that significant relationships are observed between the prevalence of PCM and breastfeeding mode from birth to the first six months (p=0.0), age at the introduction of solid foods (p=0.001), reasons for introducing solid food (p=0.05), age at weaning (p=0.016), reasons for weaning (p=0.010) and the nature of weaning food (p=0.005). Breastfeeding when a child was born and breastfeeding at the time of the study were not found to be risk factors for PCM. Bivariate analysis found no significant difference between PCM and breastfeeding when the child was born. Children who were not breastfed at the time of the study had a high prevalence of PCM (marasmus 64.7%, kwashiorkor

62.4%, marasmic kwashiorkor 71.1%). Breastfeeding mode emerged as a predictor of PCM in this study, and partial breastfeeding also contributed to the prevalence of PCM.

Children who received solid food after six months of age had a lower prevalence of PCM compared to those children who received solid food when they were four months old; about 17.3% of children suffered from PCM when complementary food was introduced at 4-6 months compared to 65.5% when complementary food was introduced at 4 months. Almost 28.1% of mothers introduced solid food because there was no satisfactory growth, and 20.5% because they were pregnant. Children who were weaned before the age of 12 months had a higher risk of marasmus (48.0%) while children who consumed food composed mainly of carbohydrates had a higher risk of kwashiorkor (40.6%). Concerning breastfeeding, about 20% of mothers terminated breastfeeding their children because they were pregnant, while half terminated breastfeeding because it was the usual time to do so. When considering weaning food, 40.6% of malnourished children had consumed carbohydrate and plant protein, 29.3% had consumed carbohydrate alone, and 4.8% had consumed animal or plant proteins alone.

Table 5.4: Characteristics of child feeding and the Prevalence of PCM

Variables	Marasmus	Kwashiorkor	Marasmic Kwashiorkor	Total	P-value
BF status at child's birth					
Yes	309 (99.0%)	108 (99.1%)	45 (100.0%)	462 (99.1%)	0.805
No	3 (1.0%)	1 (0.9%)	0 (0%)	4 (0.9%)	
BF status at time of Study					
Yes	109 (35.3%)	38 (35.2%)	313 (28.9%)	160 (34.6%)	0.695
No	200 (64.7%)	70 (64.8%)	32 (71.1%)	302 (65.4%)	
BF mode from birth to 6 months					
Exclusive BF	56 (18.1%)	40 (37.0%)	11 (24.4%)	107 (23.2%)	0.001
Partial BF	253 (81.9%)	68 (63.0%)	34 (75.6%)	355 (76.8%)	
Age at receiving solid food					
Not started	7 (2.2%)	6 (5.5%)	1 (2.2%)	14 (3.0%)	0.001
< 4 months	205 (65.7%)	68 (62.4%)	32 (71.1%)	305 (65.5%)	
4-6 months	63 (20.2%)	8 (7.3%)	8 (17.8%)	79 (17.0%)	
> 6 months	37 (11.9%)	27 (24.8%)	4 (8.9%)	68 (14.6%)	
Reason for receiving solid food					
No satisfactory growth	78 (25.5%)	27 (25.7%)	23 (52.3%)	128 (28.1%)	0.05
Little/week breast milk	81 (26.5%)	29 (27.6%)	4 (9.1%)	114 (25.1%)	
Advice	57 (18.6%)	21 (20.0%)	4 (9.1%)	82 (18.0%)	
Work	16 (5.2%)	6 (5.7%)	1 (2.3%)	23 (5.1%)	
Breast problem	6 (2.0%)	0 (0%)	1 (2.3%)	7 (1.5%)	
Pregnancy	66 (21.6%)	21 (20.0%)	11 (25.0%)	98 (21.5%)	
Refusal after bottle	2 (0.7%)	1 (1.0%)	0 (0.0%)	3 (0.7%)	

Child weaning age/month					
< 12 months	97 (48.0%)	29 (39.7%)	13 (41.9%)	139 (45.4%)	0.016
12-18	75 (37.1%)	42 (57.5%)	16 (51.6%)	133 (43.5%)	
18-24	26 (12.9%)	2 (2.7%)	1 (3.2%)	29 (9.5%)	
>24	4 (2.0%)	0 (0.0%)	1 (3.2%)	5 (1.6%)	
Reasons for Weaning					
Usual time	107 (52.2%)	38 (50.0%)	12 (37.5%)	157 (50.2%)	0.01
Low milk production	40 (19.5%)	15 (19.7%)	6 (18.8%)	61 (19.5%)	
Mother was sick	11 (5.4%)	13 (17.1%)	7(21.9%)	31 (9.9%)	
Pregnancy	47 (22.9%)	10 (13.2%)	7 (21.9%)	64 (20.4%)	
Weaning food					
Carbohydrate + animal + plant proteins	44 (14.3%)	11 (10.4%)	10 (22.7%)	65 (14.2%)	0.006
Carbohydrate + animal protein	29 (9.4%)	16 (15.1%)	6 (13.6%)	51 (11.1%)	
Carbohydrate + plant protein	141 (45.8%)	33 (31.1%)	12 (27.3%)	186 (40.6%)	
Carbohydrate	76 (24.7%)	43 (40.6%)	15 (34.1%)	134 (29.3%)	
Animal or plant proteins	18 (5.8%)	3 (2.8%)	1 (2.3%)	22 (4.8%)	

5.3.2 Multinomial Logistic Regression

The extent to which all the variables were significant, independent predictors of childhood PCM was assessed through multinomial logistic regression. The estimated odds ratios were obtained by exponentiating the regression coefficients in the logistic regression model (Collett, 1991). The regression coefficients and the odds ratios of the risk factors identified by the regression model are presented in Tables 5.5 and 5.6.

Table 5.5 and 5.6 reveal that some of the selected variables which were found to influence the prevalence of PCM using bivariate analysis remained significantly associated with PCM when submitted to multinomial evaluation. The age of the mother when she delivered her youngest child, family size, parity, mother's education, father's source of income, source of electricity, breastfeeding status at birth, and breastfeeding status at the time of the study, were all excluded from the regression analysis because they did not attain the statistical significance required for them to remain in the model.

5.3.2.1 Risk Factors for PCM

5.3.2.1.1 Risk of Marasmus

Table 5.5 illustrates the child characteristics variables that were significantly associated with marasmus, namely child age, child gender, severe stunting and mid upper arm circumference. The remainder of the factors were not detected by the multinomial logistic regression as a risk factor. Boys were observed to be 2.4 and 2.2 times more likely to have marasmus compared to girls, and UNICEF (1991) stated that more than 50% of all boys are at high risk of malnutrition compared to 25% of all girls. The risk of marasmus was found to be low for children who were breastfed up to 12 months of age relative to those who were breast beyond 12 months, where the continuation of breastfeeding beyond 12 months and up to 18 months increased the risk of marasmus. Both these findings have been observed in other countries, including Uganda (Vella et al., 1992), India (Rao and Kanade, 1992) and Zambia (Ng'andu and Watts, 1990). Severely stunted children were 2.8 times more likely to be marasmic, and children with a MUAC of less than 12.5 mm were 2.9 times more likely to become marasmic.

Turning to the maternal characteristics, the mother’s age at marriage, her age at first pregnancy, interval between ill child and younger children, and tribe were all significant factors associated with the occurrence of marasmus. Mothers who married before they were 18 years old were 4.5 times more likely to have marasmic children, while mothers aged between 18 and 24 were 2.3 more likely to have marasmic children. Conversely, years of residence in Khartoum was not identified as a factor associated with marasmus. Ill children of mothers who had a birth interval between themselves and a younger sibling of less than two years, were 8.9 times more likely to be marasmic compared to those where the birth interval was two years or more. The logistic model shows that a significant difference in the prevalence of marasmus was observed only for the Mahas tribe, and the likelihood of a child being marasmic was the lowest in the Galeen (1.16) and Tama (1.24) tribes and higher in the Zabarma (1.43) tribes.

Household characteristics, such as maternal occupation, building materials, household waste disposal, sources of water, household waste disposal and the presence of a healthy latrine were all significantly associated with marasmus. However, paternal education, paternal occupation, family income, source of electricity, source of water, and number of rooms were found not to be significant risk factors for marasmus. Employed mothers had a 2.5 times higher likelihood of having marasmic children, with mothers who worked as housekeepers being 4.2 times more likely to have children with marasmus, whilst cleaners were 57% less likely to have children with marasmus. Although the coefficients indicated that paternal occupation was not an indicator of PCM, a father sources of income did influence the risk of their children being affected by marasmus. Families which lived in houses built of mud had a 2.5 times higher likelihood of having marasmic children, while those who lived in houses built of bricks had an increased risk factor of 1.3. Children of families deprived of electricity were 67% less likely have marasmus, whilst when household waste disposal was by public garbage collection, children were 3.1 times more likely to have marasmus. Finally, the presence of latrines reduced the probability of child being affected by marasmus by 55%.

When considering child feeding practices, breastfeeding at child's birth, age at introduction to solid food, reasons for introducing solid food, weaning age, and reasons for weaning, were all found to be significantly associated with PCM. The remaining variables, such as breastfeeding at the time of the study, breastfeeding mode and weaning food were not associated with marasmus. Children whose mothers had received advice regarding the introduction of solid food were 8 times more likely to have marasmus, and 6.5 times more likely when their mothers had breast problems.

Table 5.5: Regression coefficients and odds ratios for the risk factors for marasmus

Variable	**B**	**SE**	**EXP(B)**
Child characteristics			
Gender			
Male	0.915**	0.329	2.49
Female	0		
Child age/month			
0-5	-18.305	1.317	1.123
6-11	-18.639***	0.926	8.037
12-23	-19.537***	0.851	3.277
24-35	-19.192***	0.768	4.624
36-47	-19.346***	1.032	3.964
48-59	0		
Height-for-Age			
Very sever	0.895	0	2.447
Severe	1.044*	0.526	2.84
Moderate	0.737	0.562	2.09
Mild	1.286	0.707	3.618
Normal	0		
MUAC			
<12.5	-15.034***	0.681	2.956
12.5-13.5	004	1675.900	0.966
>13.5	0		
Mother marriage age			
<18	1.512**	0.444	4.534
18-24	833*	0.383	2.301
25-34	0		
Birth spacing between the ill and younger child			
<12	-15.235***	1.361	-2.419
12-23	-16.234***	1.321	8.90
24-35	-16.415***	1.350	7.428
36-47	-16.002***	1.130	1.123
48-70	0		

Parity			
<3	-17.369***	1.208	2.863
3-4	-16.912***	1.216	4.519
5-6	-16.963***	1.219	4.295
>6	0		
Tribes			
Barno	-1.145	0.703	0.318
Dainka	0.686	0.52	1.985
Fur	1.723	1.044	5.6
Galeen	18.575***	0.502	1.167
Gawama	0.423	1.101	1.527
Hawsa	1.851	1.042	6.364
Mahas	18.693***	0	1.26
Masaleet	18.710***	0.703	1.335
Neiur	18.640***	0.732	1.246
Nuba	0.999	0.64	2.715
Shawayga	0.423	0.793	1.527
Shuluk	18.91	7309	1.632
Tama	18.640***	0	1.246
Zabarma	18.780***	0.824	1.433
Different tribes	0		
Household Characteristics			
Mother occupation			
Yes	.937**	0.456	2.554
No	0		
Mother source of income			
Government employee	32.454	2.058	.b
Hairdresser	32.354	2.477	.b
Housekeeper	17.823***	1.049	4.297
Cleaner	17.389***	0.437	8.386
Husband	16.935	0	2.263
Tea seller	0		
Building materials			
Mud	21.676***	1.247	2.593
Bricks	21.003***	1.246	1.322
Paste board	33.57	4.468	3.796
Stone	20.113	0	5.431
Others	0		
Sources of Electricity			
No electricity	-0.918*	0.435	0.399
Public supply	0.057	0.39	1.059
Via neighbour	-0.665	0.606	0.514
Lamp	0		
Household waste disposed			
Public garbage	1.142*	0.575	3.132
Collection	1.099	0.624	3
Buried	0.759	0.639	0.235
Burned	0		
Presence of latrines			

Yes	-0.785*	0.348	.456
No	0		
Reasons for introducing complementary food			
No satisfactory growth	-15.790***	1.302	1.78
Little/week breast milk	-14.003***	1.379	1.236
Advice	-14.355***	1.381	8.728
Work	-14.239***	1.643	1.641
Breast problem	-15.220***	1.675	6.543
Pregnancy	-15.220***	1.25	2.846
Refusal after bottle	0		
Reasons for weaning			
Usual time	0.284	507	3.586
Low milk product	-0.007	0.596	3.196
Mother was sick	-1.452**	.631.	0.806
Usual time	0.284	507	3.586
Pregnancy	0		

Reference category of dependant variable is marasmic kwashiorkor
*** p<0.001; ** p<0.01; * p<0.05

5.3.2.1.2 Risk of Kwashiorkor

Table 5.6 illustrates the variables that were significantly associated with kwashiorkor. In terms of child characteristics, boys were observed to be 2.4 and 2.2 times more likely to have kwashiorkor compared to girls, children aged 0-5 months were less likely to have kwashiorkor than children aged 6-11 months, while children aged 12-23 months were 6.7 more likely to have kwashiorkor than older children.

When considering the maternal characteristics, the mother's age at marriage, her age at first pregnancy, interval between index and younger children, parity and tribe were all significant factors associated with the occurrence of kwashiorkor. Mothers who married before they were 18 years old were 2.8 times more likely to have children with kwashiorkor, while mothers in the age groups of 15, 16-18, 19-24, and 25-30 years had a 3.5, 7.7, 5.8 and 3.3 times higher risk respectively, of having children with kwashiorkor than mothers who were aged between 31-47 years. Children with a birth interval between themselves and a younger sibling of less than 12 months were 4.4 times more likely to have kwashiorkor compared to those children with a birth interval of 2 years or more. Households with six or more children had a 3.8 times greater risk of having marasmus and kwashiorkor. Only the Fur tribe was associated with the prevalence of kwashiorkor.

Mothers with no education and mothers with a primary education had a high risk of having children with kwashiorkor, while secondary educated mothers had no risk at all. A father's source of income was found to influence the risk of their children getting kwashiorkor, whilst children were 4.6 more likely to have kwashiorkor when their mothers had to work. In terms of age of weaning, the risk of children being kwashiorkor was 1.5 times higher for children weaned at <12 months and 1.7 times higher for those weaned between 12 and18 months of age.

Table 5.6: Regression coefficients and odds ratios for the risk factors for kwashiorkor

Variable	B	SE	EXP(B)
Gender			
Male	813*	0.364	2.25
Female	0		
Child age/month			
0-5	-17.988***	1.17	1.54
6-11	-18.953***	0.687	5.87
12-23	-18.822***	0.544	6.69
24-35	-20.291	.000	1.54
36-47	-38.609	6,555	1.70
48-59	0		
Mother marriage age/year			
<18year	1.056*	0.48	2.875
19-24	1.198	0.429	1.219
25-34	0		
Mother age at first birth			
15	19.701***	1.318	3.596
16-18	18.160***	0.888	7.706
19-24	17.892***	0.867	5.893
25-30	17.330***	0.896	3.359
31-35	18.16	0	7.706
>**35**	0		
Birth spacing between the ill and younger child			
<12	-16.930***	0.948	4.442
12-23	-17.021***	0.869	4.053
24-35	-17.538***	0.943	2.419
36-47	-16.958***	0.00	4.319
40-70	0		
Parity			
<3	-17.682***	.853	2.094
3-4	-17.121***	.862	3.666
5-6	-17.667***	.833	2.124
>6	0		
Tribes			
Barno	-0.566	0.804	0.568
Dainka	414	0.602	0.514
Fur	2.286*	1.068	9.838
Galeen	19.346	0	2.524
Gawama	1.108	1.146	3.027
Hawsa	1.331	1.124	3.784

Mahas	18.867	0	1.562
Masaleet	18.818	0	1.489
Neiur	19.037	0	1.852
Nuba	0.925	0.704	2.523
Shawayga	-0.2791	0.031	0.757
Shuluk	18.208	7309	8.086
Tama	19.037	0	1.852
Zabarma	18.617	0	1.21
Other tribes	0		
Age at introducing solid food/month			
Not started	-0.118	1.206	0.889
<4	-1.156**	0.577	0.315
4-6	-1.910***	0.733	0.932
>6	0		
Reasons for introducing complementary food			
No satisfactory growth	-16.158***.	468	2.404
Little/week breast milk	-14.337***	650	2.123
Advice	-14.660***	660	1.568
Work	-14.527***	1.142	4.609
Breast problem	-31.004	1.544	0.984
Pregnancy	-15.672	0	1.562.
Refusal after bottle	0		
Age at weaning/month			
<12	18.837***	1.269	1.517
12-18	19.000***	1.259	1.785
18-24	18.728	1.161	1.36
>24	0		

Reference category of dependant variable is marasmic kwashiorkor

*** p<0.001; ** p<0.01; * p<0.05.

5.4 Summary of the Findings

This summary of the findings of this study is presented as two sections, the bivariate analysis and the multinomial logistic regression.

5.4.1 Bivariate Analysis

Mothers who married and became pregnant as teenagers had an increased likelihood of having a child with malnutrition, and low birth weight babies were more prone to developing PCM. Child age and gender were found to be independently related to the prevalence of PCM. When considering nutritional deficiencies, the majority of children with PCM were severely stunted, wasted, were underweight and had severe low MUAC. The current study also identifies that getting married and becoming pregnant as a teenager in Sudan is predictive of infant and child malnutrition. Associations were observed between PCM and a mother's age at marriage and pregnancy, and PCM in children seems to be a consequence of early motherhood. Other indicators of poor maternal health and factors such as family size and birth interval were all significantly linked to the prevalence of PCM. These data offer some support to the growing evidence of the effects that the adolescent marriage of girls has on infants and childhood PCM. Variables concerning a mother's education had no significant effect; however, a father's education and occupation had a significant influence on PCM. Although the income of a family had no significant influence on the prevalence of PCM, a larger proportion of the children who were malnourished were from lower and very low economic classes. The number of rooms in a household and the building materials was directly linked to a child becoming malnourished, while waste disposal and presence of a latrine also significantly influenced the prevalence of PCM. When considering child feeding practices, their breastfeeding status had no effect, while breastfeeding mode and food consumed by the child had a significant influence on the prevalence of PCM.

5.4.2 Multinomial Logistic Regression

Multinomial logistic regression was carried out on the twenty variables considered to be the most important for influencing the prevalence of PCM in Sudanese children. It was found from that the odds of marasmus were higher for boys, children aged 6-11 months, children who had severe stunting, children with a MUAC of less than 12.5 cm, children of mothers with a chronic energy deficiency, children of mothers aged <18 years when they were married, children born within two years of a subsequent birth, fourth born children, tribe, children of unemployed mothers, father's income, children who lived in houses built of mud and bricks, children who lived in houses without electricity, children whose household used public garbage for waste disposal, children whose families did not have latrines, and children whose mothers gave them solid food due to advice they were given or due to breastfeeding problems.

The likelihood of developing kwashiorkor was increased among boys, children aged 12-23 months, children of mothers who were still teenagers when they were married, children of mothers which were still teenagers when they delivered their first child, sixth born children, children born before a two year birth interval, children from the Fur tribe, children who received solid food at when aged less than 4 months or between 4 and 6 months due to unsatisfactory growth and little breast milk, and children who were weaned before they reached 18 months of age. The largest risk for PCM was found to be belonging to the Fur tribes, where children had a ten times higher risk of developing kwashiorkor (Table 5.6).

5.5 Discussion of the Findings

5.5.1 Factors Identified in the Bivariate Analysis

5.5.1.1 Gender

Overall, the prevalence of PCM was highly influenced by gender (p=0.017), and was higher among males compared to females. Similar results have also been reported in the Khartoum area (Alredaisy, 2012), Gorgan, Iran (Reza, 2007) and in the Kalahandi district of Orissa (Mahapatra et al., 2000). In contrast, the vulnerability of females to developing PCM was indicated in Pakistan (World Bank, 2005), Bangladesh (Choudhury et al., 2000), and Tanzania (Mbago & Namfua, 1992). However, not all studies have reported a gender difference; for example, Al-Mekhlafi et al. (2005) found no significant difference in the prevalence of SPCM by gender in Malaysia, whilst some studies have suggested that perhaps males and females exhibit different relationship patterns between nutritional adequacy and malnutrition (Neumann et al., 1992). These differences could be random phenomena or they could be associated with specific nutritional (e.g. differential adequacy of intake) or cultural characteristics. Correlational studies would seem an appropriate starting point for identifying specific parameters that are systematically associated with gender differences in terms of nutritional intake.

5.5.1.2 Child Age

Overall, a child's age had a significant (p=0.001) influence on PCM. The relationship between a child's age and the prevalence of malnutrition was shown by the observation that during the first six months of life, the prevalence of all forms of PCM in children under five years was found to be lower than in other age groups. This finding is consistent with studies from different countries, which indicate that children in the youngest age group, 0-5 months, were at a significantly lower risk of PCM compared with children in older age groups (Yimer, 2000; Genebo, 1999; Samson & Lakech, 2004). This low prevalence of PCM may also be due to the protective effect of breastfeeding, since almost all Sudanese children are breastfed and most continue to be fed for their first year of life.

One explanation for this finding may be that breastfed babies from a poor socioeconomic environment are protected against nutritional inadequacies when their mothers breastfeed their infants exclusively during the first six months. As has been seen, children in their second year of life are most prone to malnutrition, so the prevalence increases, peaking between the ages of 6-11 months. This might suggest that children begin to move independently by age one and are more likely to be cared for by older siblings some of the time. The prevalence of PCM was reported to be higher between 12 and 23 months of age than in other age groups; however, cases of kwashiorkor (69.7%) outnumbered marasmus (39.4%) during the second year of life. This is probably due to inadequate and inappropriate complimentary feeding. The period between the ages of 6 and 18 months of life is critical, especially with regard to feeding practices. This is the time when complimentary feeding is started (Monte & Giugliani 2004) and a child encounters many more problems in obtaining food, especially during the period following weaning. If the caloric content of weaning foods is inadequate or the preparation and storage of food in the home is not hygienic, PCM may develop (Ingrain, 1992).

The 12-23 months age group showed a significantly higher prevalence of marasmus, kwashiorkor and marasmic kwashiorkor. However, Saxena et al. (1997) reported a higher prevalence in the age range 0-1 year and Prasot et al. (2012) indicated a higher prevalence in the 1-3 year age group, while another study reported that children in the second and third year of life were most vulnerable to malnutrition (Wray & Aguirre, 1969). In contrast, Taha (1979) stated that marasmus and marasmic kwashiorkor occurred more in older children than kwashiorkor. The age incidence of marasmus and marasmic kwashiorkor obtained in this study is consistent with other studies from Sudan (Shakir et al., 1972; Omar et al., 1975; Taha, 1976). An explanation for this result is that mothers may introduce complementary feeding earlier, exposing infants and young children to pathogens and increasing their risk of infection, thus possibly contributing to PCM. However, the prevalence of PCM among exclusively breastfed children was 70.9%, probably because of prolonged exclusive breastfeeding beyond 6 months and a lack of complementary feeding being initiated.

5.5.1.3 Birth Weight

Child birth weight significantly (p=0.013) affected PCM in children. This study found that children who were larger in size when born had a higher prevalence of PCM than those who were very small at birth, but this finding is contradicted by the results of studies from Brazil (Lima, 2004) and Bangladesh (Rayhan, 2006). In a study in Kerala, India, it was shown that low body weight was a significant risk factor for malnutrition (Sanghvi et al. 2001). In Brazil, low birth weight contributed to a growth deficit and breastfeeding failure (Carvalho et al., 2004), and there is considerable evidence that low birth weight children are more vulnerable to prolonged infections with a subsequent greater weight loss (Hobcraft, 1983). The association between PCM in this study and a child's birth weight may either overestimate or underestimate the true prevalence, as 53.6% of mothers delivered their babies at home and the babies were not properly weighed.

5.5.1.4 Nutritional Deficiency

When concerning other nutritional deficiencies, children who were stunted had significantly (p=0.037) higher chances of being affected by PCM, and more than half (56.7%) of the children who were marasmic were severely stunted. Similar finding has been observed in Karachi, where 42% of severely malnourished children also had severe stunting (Ejaz and Latif, 2010). Stunted children frequently suffer from acute malnutrition, but it is misleading to think that stunting is a chronic condition; in fact it is an active and continuous process. Although the process of stunting may be acute, the process underlying a child's stunting may have been present for a long time, and this process could be persistent malnutrition instead of chronic malnutrition (Golden, 2009). In addition, children who were wasted had an increased chance (p=0.0001) of developing PCM, and more than two thirds (69.9%) of marasmic children exhibited severe wasting. Children with marasmus had a very low weight for their height and exhibited wasting. If children are not receiving sufficient food over a period of time, the body will start digesting its own fat and protein reserves. In the later stages, all the muscles will be affected, including vital organs such as the heart, which may ultimately result in death.

Underweight children were significantly (p=0.0001) associated with PCM, and the majority of children affected by marasmus and marasmic kwashiorkor were severely underweight. Being underweight is a composite form of under nutrition that includes elements of marasmus and kwashiorkor, and this presents itself as a weight for age which is below three standard deviations from the median weight for age of the standard reference population. The regression analysis found that children with a low MUAC were significantly more likely (p=0.001) to develop SPCM, and 100% of the marasmic kwashiorkor children had low MUAC results (<12.4 cm). A Low MUAC (<11.0 cm) is an indicator of marasmic kwashiorkor (Z-score < -3, WHO; Choudhury et al., 2000).

5.5.1.5 Immunisation

The vaccine status of a child significantly influenced (p=0.036) the prevalence of PCM. Community vaccination programmes can therefore substantially contribute to a child's health in early childhood (Lima, 2004). This study showed that all but 18.9% of the malnourished children had outstanding immunisations, and such children are more prone to illnesses and infections, resulting in a higher chance of developing PCM. Other studies have also found that incomplete immunisations are directly associated with malnutrition, such as in children younger than five years old in Ethiopia (Getaneh et al., 1998) and in Uganda (Owor et al., 2000), and in children aged 3-36 months in Kenya (Ayaya et al., 2004). Immunisation is a public health measure that has an essential impact on the nutritional status of children because it avoids the negative effects of serious diseases like measles and whooping cough (Lima et al., 2004).

5.5.1.6 Maternal Age at Marriage and During Pregnancy

There was a significant (p=0.005) positive relationship between a mother's age and the prevalence of PCM among children. It was found that the adolescent age group (<18) and young women in the 19-24 years age group were at a significantly higher risk of having children with PCM. This finding is in agreement with a study in India which found malnutrition to be higher among young children born to mothers who had married at a young age compared to those born to women who had married when older (Raj et al., 2010). Adolescent mothers and their children are at a higher risk of malnutrition (Hechtman, 1989), while teenage mothers tend to have lower than average birth weight babies (Botting et al., 1998).

The prevalence of PCM was found to be highly significant (p=0.005) for the mother's age during her first pregnancy, and the distribution of PCM was higher among first born children whose mothers were younger than 18 years old, and lower among first born children whose mothers were older than 24 years. Extensive studies have noted that pregnancies before the age of 19 and after 35 may result in low birth weight babies (Akın et al., 1995; Sezgin et al., 1998; Klima, 1998). The reasons for this are that the mother may still be growing herself, and that the nutritional and metabolic stresses of lactation will be severe. Consequently, mothers would only be able to produce poor or little breast milk for their children. Additionally, adolescent mothers are less likely to gain adequate weight during their pregnancy, leading to babies with a low birth weight (Botting et al., 1998). Furthermore, teenage mothers may not be able to take care of a child, while older mothers have more experience in childcare (Kariuki, 2002). In fact, in some developing countries children of young mothers are cared for by their grandmothers.

5.5.1.7 Maternal BMI

The prevalence of PCM among children of mothers with a chronic energy deficiency was statistically significant (p=0.05). A similar result was reported in Bangladesh, where children who had malnourished mothers suffered from a higher prevalence of malnutrition than those which had nourished mothers (Rayhan, 2006; Sanghvi et al., 2001). Women of reproductive age are among the most vulnerable to malnutrition for both biological and social reasons, and an increased risk of low birth weight babies is a consequence of chronic energy deficiency in women (Kulasekaran, 2012).

These results show that the greatest proportion of children with a normal birth weight lived in households with mothers who had a chronic energy deficiency, thus suggesting that maternal care is good despite food shortages. The fact that only a small proportion of marasmic and kwashiorkor children have mothers with an adequate BMI indicates that public health issues are less of a priority than food security. However, the relationship noted in this study between maternal BMI and PCM among children indicates that other factors play an important role in the aetiology of PCM in addition to food availability.

5.5.1.8 Birth Interval

The birth interval duration between the child with PCM and a younger sibling is another important demographic variable which significantly (p=0.035) contributes to PCM in Sudanese children. The highest prevalence of PCM (79.1%) was associated with a birth interval of less than 2 years, while the lowest prevalence (25.7%) was associated with an interval of more than 2 years. The current survey demonstrates good evidence that PCM in children was decreased when the birth interval was increased. This finding is in conformity with a study carried out by Ahmed et al. (1982) who stated that the prevalence of PCM was 75.8% when the birth interval was less than 2 years and 24.2% when the interval was more than 2 years. Kumar (1976) reported that when the birth spacing was less than 1 year, then the incidence of malnutrition was 65.2%, but when the interval was 3-4 years and more than 4 years, the incidence fell to 37% and 28.6%, respectively. Wray and Aguirre (1969) in their study of Columbian children stated that there was less malnutrition when the birth interval was three years or more.

This finding indicates that when the interval is less than 2 years, the ill children were found to be particularly vulnerable to kwashiorkor and marasmic kwashiorkor. Moreover, a short birth interval may force a mother to concentrate on her new baby, and lead to a shorter duration of breastfeeding and earlier weaning of children, while children are still unable to feed themselves independently. Kwashiorkor has been found to be compounded when another child was born before the ill child had reached their second birthday (Torûn, 2006).

5.5.1.9 Birth Order

This study identified that a child's birth order is one of the demographic variables which influences the prevalence of PCM in children, and a significant relationship between birth order and the prevalence of PCM (p=0.003) was revealed. The lowest prevalence of PCM was observed in children who were first in the birth order (13.5%), while the highest prevalence of PCM was found in those whose birth order was fourth (19.5%). However, this finding is not consistent with a number of other studies, specifically within Africa in Nigeria (Morely et al., 1986) and South Africa (Saloojee et al., 2007). Additionally, studies in Bangladesh and India have indicated that the highest proportion of severely malnourished children was found when the birth order was equal to or more than five (Swenson, 1984).

The low prevalence of PCM in first and second birth order children may be due to the fact that children born earlier receive more attention and care, and hence experience better health. However, the higher risk of PCM in first birth order children could be due to a mothers' low level of experience of child care and feeding, which are important factors in preventing PCM. Surprisingly, the prevalence of kwashiorkor among first born children was higher than among sixth born children. It could be expected that these children would exhibit more cases of kwashiorkor within the family.

5.5.1.10 Tribe

Sudan is a multi-ethnic country, with more than 150 ethnic minorities living in different areas. The study enrolled participants from more than 50 tribes, although details on only 19 tribes have been analysed and reported, since there was less than seven patients for the other individual tribes. Nevertheless, PCM in Sudan was significantly influenced by tribes (p=0.042). The Dainka, Fur and Hawsa tribes had a high prevalence of PCM, possibly as a result of changing traditions, isolated habitats and monotonous food habits (Basu, 1993). Cultural and religious food customs may also play a role. Among some tribes there is a general low awareness of health related issues, due to the lack of, or very low levels of education, inadequate feeding and childcare practices which include the discarding of colostrum. Maternal and child care is an important aspect of health seeking behaviour which is largely neglected among the tribal groups.

5.5.1.11 Length of Residence in Khartoum

Another determinant of the prevalence of PCM among children in Sudan which appears to be significant (p=0.002) was the length of residence in Khartoum, and Sudanese families who had resided in Khartoum for less than 10 years exhibited a high risk for developing PCM. Correlations between the length of stay in Khartoum and different parameters have shown that the length of time in Khartoum correlated significantly with marasmus, kwashiorkor and marasmic kwashiorkor. These results suggest that a rapid switch to an urban lifestyle may help to explain the high prevalence of PCM in this area.

5.5.1.12 Maternal Education

The results indicate that the education level of mothers was not significantly associated with PCM (p=0.886). This finding differs from the results of several other studies from Khartoum (Coulter et al., 1988) which have found a positive association between maternal education and the presence of marasmus and kwashiorkor in their children, although they are in agreement with a study conducted in Harare, Zimbabwe, where Owor et al. (2000) reported there was no association between the level of formal education and severe malnutrition. Doan (1988) and Reed et al. (1996) observed a significant effect of maternal education on child nutrition, while a study in Nigeria showed that despite high education levels of the mothers, their children still had severe forms of malnutrition (Oyedejo, 1996). Other studies have also found that children of uneducated mothers have a higher prevalence of malnutrition than children of educated mothers (Caldwell, 1979). Solon et al. (1985) found that maternal education was associated with a lower prevalence of malnutrition among children under five in the richest households, whereas the relationship between maternal education and child malnutrition was not significant among the poorest households.

It is difficult to explain why a mother's education was not significant in influencing PCM in this study, although only 9.2% of the women had a secondary education and 0.9% had a university education, which was too small to produce significant results. Moreover, this study found that marasmus, kwashiorkor and marasmic kwashiorkor were strongly connected with the family's socioeconomic background, as there was no difference in maternal education among these groups of children.

5.5.1.13 Paternal Education

There was a significant association between a fathers education and PCM (p=0.048). Surprisingly, children of fathers who had no education had a lower prevalence of SPCM than fathers with a primary education. It seems the effect of education is relevant at levels beyond primary school. An explanation of this result could be due to the fact that primary education is extremely basic among this population. The finding that the children whose fathers had secondary and university level education had a lower prevalence of PCM than those of illiterate fathers is in agreement with a study which showed that children whose fathers had a higher level of education exhibited a reduced weight deficiency than those with illiterate fathers (Rayhan & Khan, 2006).

Typically in developing countries, the father is the main earner and decision maker within a family and fathers with higher levels of education can ensure a better nutritional status for their children, as education helps fathers to acquire better knowledge (Rayhan & Khan, 2006). In some societies within developing countries, fathers are able to correct certain behaviours and practices regarding child health and nutrition (Kuate-Defo & Diallo, 2002; Fotso & Kuate, 2005b). They may be able to influence mothers' decisions with regards to preventive medicine, such as immunisation, how to use health facilities, and to share family resources more equally, especially for children. A more educated father is able to recognise the severity of infectious diseases and to take proper action, and can also positively influence weaning practices, thus limiting the prevalence of diarrhoea and the subsequent consequences. Educated fathers are able to direct mothers in terms of hygiene and sanitation, such as using clean vessels to collect water, and to wash their hands and utensils before preparing foods.

5.5.1.14 Maternal Occupation

Mothers' occupation was significantly (p=0.042) associated with PCM. Glick and Sahn (1998) found that maternal self-employment and wage employment in urban Guinea statistically affected child height. This result contradicted other studies which have reported that there was no association between a mother's employment and malnutrition in children (Leslie, 1988; Smith et al., 1980; Vial & Muchnick, 1989). The study found that a large proportion (70.6%) of children of housewives were more likely to become marasmic, because their mother relied on their husband's income, and this was not enough to meet the household requirements, with the associated risk of malnutrition and marasmus. Employed mothers can increase the total household income and have a higher chance of getting better quality and more food; however, the workload of a mother may prevent them from giving their children the care they need at the time they need it most.

5.5.1.15 Paternal Occupation

The occupation of the fathers appears to be a major factor influencing the prevalence of PCM (p=0.05), while sources of income were found not to be significant. Fathers who were water traders had less than 1% of children with kwashiorkor, and cleaners had no children with marasmic kwashiorkor; however, the association was not significant (p=0.614). This finding could be due to the fact that water trading and cleaning jobs generate a higher income than other jobs in the Khartoum area.

Unemployment and low wages mean that individuals are not able to buy foods with a high nutritive value; consequently, low wage families eat cheaper food, which is less nutritious, leading to weight loss and malnutrition (Dorothy et al., 2015). Meat, milk and milk products are expensive, and children's intake of animal proteins is often less than their requirements due to family poverty (Christiaensen & Alderman, 2001).

The type of employment is presumed to be important because of differences in the compatibility of work and caring for children. Informal sector activity is usually considered to be more compatible with childcare than formal employment, due to greater flexibility in the working hours or the possibility of combining work and child supervision. Work in or near the home should be more childcare compatible than work outside or far from the home. The influence of a father's occupation on PCM in this study suggests that it is possible that fathers with a high income had greater purchasing power and were thus able to provide their families with better living conditions.

5.5.1.16 Household Income

Family income was found to significantly (p=0.0001) influence the prevalence of PCM in this study; those families with a very low income had children with a higher prevalence of SPCM. This finding corresponded with the findings of another study which stated that households with a high income have a better nutritional status for their children (Nnyepi, 2007; Vella, 1994). Other studies in both developed and developing countries have indicated that the type of food purchased by a household varies according to income (Furtrell et al., 1975; Abdel, Ghany et al., 1978), as households with higher incomes are able to buy food with a high nutritive value, and children from high socioeconomic groups in developed countries were found to have a better nutritional status than children from low socioeconomic groups (Garn et al., 1978). Families with an income of less than 300 Sudanese Pounds per month negatively had a higher prevalence of PCM (marasmus, kwashiorkor and marasmic kwashiorkor) compared to households living on higher incomes ($p<0.05$), and kwashiorkor was more prevalent than marasmus and marasmic kwashiorkor.

5.5.1.17 Number of Rooms

A significant difference was found between household room density and the prevalence of PCM ($p=0.038$). The association between PCM and the number of occupants per room is similar to finding from a study in Lagos, which was ascribed to rapid urbanisation (Abidoye & Ihebuzor, 2001). Children diagnosed with kwashiorkor lived in households with a slightly higher room density than children with marasmus: 46.8% of children with kwashiorkor lived in households with one room compared to 32.1% with marasmus and 35.8% marasmic kwashiorkor; although the coefficient showed no relationship between the number of rooms and kwashiorkor or marasmus. The provision of adequate and proper housing is essential for the normal growth and development of a child. In Sudan, the population growth rate is very high (more than 4%) compared with that of the developed world where population growth rate is 0.6% (Rao & Kanade, 1992).

5.5.1.18 Sources of Water and the Presence of a Latrine

This study showed that 39.7% of households used water from public supplies (running tap water) in the house, which was clean water used for food preparation and domestic activities. This was followed by water from a tap water trader (38.2%) and from a water supply outside the house (22.1%) constructed for the public. This means that 60.3% of households of malnourished children used unclean water. The use of unclean water for food preparation and daily activities causes digestive diseases which are direct causes of PCM. Water supplies are often contaminated, but even when it is pure at the source, water can easily become contaminated within a household. Personal hygiene, child rearing and feeding practices are other routes of transmission of diarrhoeal diseases. Usually, weaning foods take a long time to prepare, and so they are prepared in large quantities to avoid wasting time, meaning that the leftovers are used many hours after their preparation, with the subsequent proliferation of bacteria within the food. Often, weaning foods, besides being contaminated, are bulky and of low caloric density, thereby failing to adequately supplement the breast milk component of the diet.

The use of sanitary latrines was significantly associated with (p=0.016) the prevalence of PCM. This study found that among children living in households without latrine, 43.8% of them were affected by PCM. This finding has also been observed by Lima et al., (2004). It is possible that appropriate environmental conditions, which are essential for preventing infectious diseases, are more important than the location of a home for ensuring satisfactory growth (Lima et al., 2004), and the consumption of food is conditioned by access to water, sanitation and hygiene (Osei et al., 2010).

5.5.1.19 Breast Feeding Mode

The rate of breastfeeding was found to be very high in this studied population in Khartoum, as indeed it is for the rest of the country. Breast feeding at birth was universal, and more than 90% of mothers breastfed their children, but of these, only 34.6% breastfed their children exclusively. This finding is in agreement with a study in Sub-Saharan Africa which found that only 30% of children were exclusively breastfed (UNICEF, 2005). The reasons for this may be due to cultural and educational factors (Fabian et al., 2005), as some women do not give their children colostrum because they believe that it is harmful and may cause discomfort and jaundice for their babies (Saka et al., 2005). Normally, women who do not breastfeed their children exclusively give their children water too early (Saka et al., 2005; Kulsoom & Saeed, 1997; Lipsky et al., 1994).

This study found that almost half (55.6%) of the mothers breastfed their children for prolonged periods (>18 months), similar to in Northern Uganda, where a large proportion of children were found to be breast fed for more than 18 months (Vella et al., 1994). Inappropriate breastfeeding practices and the low dietary quality of complementary foods are recognised as major causes of under nutrition in infants and young children. In Sudan, one third of infants are exclusively breastfed and 55.8% of children aged 6-12 months receive complementary foods. Dietary diversity is limited and cultural food proscriptions prevent pregnant and lactating mothers and young children from consuming accessible nutritious foods (SHHS, 2007).

Health seeking behaviours by mothers and children remain inadequate, and environmental health and hygiene are also problematic, with only 56.1% of households having access to improved sources of drinking water and only 31.4% of households using improved sanitation facilities (SHHS, 2007).

5.5.1.20 Age at the Introduction of Solid Food

Age at the introduction of solid food had a significant (p=0.001) effect on the prevalence of PCM, with the results revealing that 65.5% of malnourished children had received solid food before they reached 4 months of age, compared to 17% of children who had received solid food at 4-6 months of age. When solid food was introduced between 4-6 months of age, the children were 80% less likely to be affected by kwashiorkor than when solid food was introduced at <4 months. However, the age at introducing solid food had no influence on the prevalence of marasmus.

5.5.1.21 Weaning Age

Children who were weaned beyond 24 months of age had a lower prevalence of PCM in comparison with their peers who stopped breastfeeding before 12 months of age. This result contradicts a study in Ghana where breastfeeding beyond 12 months was found to be associated with malnutrition (Brakohiapa et a1., 1988). This study found that weaning before 18 months increased the risk of kwashiorkor, a finding which contradicts studies from Uganda (Kikafunda et al., 1998), Uganda (Vella et al., 1992), India (Rao & Kanade, 1992) and Zambia (Ng'andu & Watts, 1990), where the continuation of breastfeeding beyond 18 months and up to 24 months increased the risk of stunting. In contrast, another study from Zambia confirmed that the continuation of breastfeeding >24 months decreased the risk of stunting (Ng'andu & Watts, 1990). This result is further supported by the WHO suggestion that breastfeeding should be greatly encouraged up to 2 years of age, as delayed weaning reduces the risk of marasmus. The explanation could be that the mothers' practice of prolonged breastfeeding (beyond 18 months) is possibly because a child is able to consume family food and breast milk gives the child proteins that are needed for growth and development. This study found that 29.3% of the children consumed starch as weaning foods, and that the continuation of breastfeeding supports the child with nutrient requirements.

5.5.1.22 Reasons for Weaning

Half of the malnourished children were weaned because their mothers' thought it was the usual time, and this indicates that the complementary food was deficient in protein and calories or that the weaning foods had been based on starchy gruels. Children are also influenced by adult eating habits, where food components cannot be used for growth building tissue, which results in PCM in children. About 20 percent of mothers reported that they were pregnant, and 10% of mothers were sick. Mothers who did not have enough milk accounted for 20%, and such mothers might use bottle feeding instead. It is possible that breast milk production after 12 months is decreased and therefore a child receives less protein and energy intake. It is also possible that a child who is on the breast is not accustomed to other food and is unwilling to accept foods in sufficient amounts. Timing of weaning could be due to socioeconomic factors, which force mothers to stop breastfeeding early, thus leading to a high prevalence of PCM in the future. Maramus is often seen in infants below 6 months, and is often widespread when a child is weaned early or when the breast milk is inadequate and little or no other food is given. Children whose mothers were sick were 20% less likely to be marasmic.

5.5.1.23 Reasons for Introducing Solid Foods

The study found that reasons for introducing solid food were a determinant factor of PCM. Some of the malnourished children had received complementary food because they had no satisfactory growth, whilst other women said there had little or weak breast milk, a large number of women were pregnant, and some children received solid food because their mothers had received advice to do so. In total, 65.7% of the children had been given solid food before they reached four months of age, and it is possible that the mothers misguidedly introduced complementary foods very early to help their children to grow healthily and prevent them from being sick. It is also possible that mothers who were worried about the adequacy of their milk flow might be wrongly advised about the early introduction of complementary food, and might assume that breast milk alone does not satisfy their baby's hunger and so solid food was introduced to supplement breast milk. Introducing supplements before four months, especially under unhygienic conditions, could be an important cause of malnutrition (Kariuki et al., 2002). A study in India where the prevalence of malnutrition was 60.7%, reported that not exclusively breastfeeding a child until at least four months of age and undesirable practices of discarding colostrum were related to child malnutrition (Khokhar et al., 2003), similar to the findings of this study.

5.5.1.24 Solid Foods

The majority of children (40.6%) had begun the weaning process by consuming carbohydrates and animal proteins, while 29.3% were weaned on carbohydrates alone, The majority of families are too poor to afford animal protein, and they were found to be consumed by less than 5% of children. Although the majority consumed carbohydrates and plant proteins, the starchy staples themselves have very little protein. The high protein they are combined with (especially the plant proteins) enhances the protein content of the weaning foods. It is important to note that if the protein content of weaning foods is adequate quantitatively, the quality of plant protein is low and this could result in poor digestibility and the utilisation of the protein. It is important to note that children in developing countries are malnourished, not because their mothers do not give them enough food but because the food is so bulky that most children cannot consume enough to meet their daily energy and nutrient needs (Morley & Love, 1986).

5.5.2 Factors Identified in the Multinomial Logistic Regression

In order to determine the relative importance of the factors that influence the prevalence of PCM, multinomial logistic regression analysis was carried out on all the important variables identified in the bivariate analysis and some factors were found to remain significant: being male, aged between 6-11 and 12-23 months of age, severe stunting, a MUAC less than 12.5cm, underweight mothers, maternal marriage age (both <18, and 18-24 years of age), mothers age during first pregnancy (<18), birth spacing of <24 months, birth order, belonging to the Fur tribe, maternal employment status, maternal source of income, building materials, source of electricity, waste disposal, healthy latrines, age at receiving solid food (<4 months and 4-6 months of age), reasons for receiving solid foods, and reasons for weaning.

5.5.2.1 Age and Gender

In Sudan, males were more likely to be affected by marasmus and kwashiorkor. PCM affects all age groups but children aged 6-11 months were eight times more likely to become marasmic. This might suggest a relationship with feeding practices, likely to be when almost all children are introduced to solid and semi-solid foods, and the 12-23 months age group was 6.7 more likely to have kwashiorkor than older children. It is general practice among Sudanese mothers to wean their children abruptly, maybe in a period of time shorter than six months, when another pregnancy immediately follows. This is in agreement with the results of Jitta et al. (1992) and Vella et al. (1992) in Uganda, where the risk of older children being stunted relative to younger children are high for those aged 12-18 months and >18 months.

5.5.2.2 Nutritional Deficiencies

Children who had a severely low height-for age were 2.8 times more likely to be marasmic and all the children who exhibited very severe stunting were affected by marasmic kwashiorkor. Children who were classified with low MUAC values in clinical examinations were 2.9 times more likely to become marasmic than those classified as having a normal MUAC value.

5.5.2.3 Maternal BMI

The multinomial results found that only marasmus, was indicated by the logistic regression, to exhibit a relationship with mothers with a BMI <18.5. This can be explained by the fact that breastfed babies in Sudan with a poor socioeconomic background are protected against nutritional inadequacies because their mothers breastfeed their infants exclusively during the first 6 months. However, it has been reported that malnourished mothers cannot provide sufficient breast milk (Rayhan, 2006), and a poor nutritional status may result in low birth weight babies (Akın et al., 1995; Sezgin et al., 1998; Klima, 1998).

5.5.2.4 Maternal Age at Marriage

The results show that when the mother is <18 years old when she marries, then there is a higher risk of her child developing marasmus and kwashiorkor, and as the mother's age at marriage reduces, then the prevalence of marasmus and kwashiorkor increases. In terms of a higher maternal age, the children of women having their first child in their early and mid-thirties, were at a high risk of being affected by kwashiorkor. Marasmus was higher among children whose mother had married before the age of 25, with children being 2.3 more likely to become marasmic, while the highest rate of kwashiorkor was among children whose mothers had married when younger than 18. Extensive studies have supported this finding, and adolescent women are more likely than those marrying in adulthood to contribute to an increased risk for infant and child malnutrition because the adolescent mothers are more likely to remain poor, uneducated, and to have low access to health care (Raj et al., 2010). An undernourished first born is 2.5 times more likely to have an adolescent mother (Lima et al., 1990).

5.5.2.5 Mothers' Age at First Child

Children of mothers aged <16 years were 1.3 more likely to have marasmus, while those with mothers aged 19-24 were 3.1 and 2.7 times more likely to have marasmus and kwashiorkor, respectively, and mothers aged 25-30 were 2.2 times more likely to have marasmus.

5.5.2.6 Birth Spacing

Birth spacing predisposed children to kwashiorkor; those with a birth spacing of 16-18 months and 19-24 months were 7.7 and 5.8, respectively, more likely to have children affected by kwashiorkor.

5.5.2.7 Birth Order

Third born children appear to be 90% less likely to be marasmic, while sixth born children were 91% less likely to have kwashiorkor. Polllu (1973) reported that 37% of children who were fifth or earlier born were affected by marasmus, while a study of marasmic children in Peru reported that 41% were sixth or later born (Graham & Morales, 1963), suggesting that the experiences mothers gain in childcare may tend to reduce adverse natural effects that might contribute to higher birth order infants. However, it could also be related to the total number of children a woman bears during her lifetime.

5.5.2.8 Tribe

Galeen, Mahas, Masaleet, Neiur and Nuba tribe children were 1.1, 1.2, 1.3 and 2.3, respectively, more likely to become marasmic. No tribes were at risk for kwashiorkor except the Fur tribe (9.8%).

5.5.2.9 Maternal Employment

The occupation of the mother was a major factor influencing the prevalence of marasmus. A mother's source of income may explain this, as a child whose mother was a government employee, hairdresser or tea seller had a better nourished child than one whose mother was a housekeeper, housewife or cleaner. However, the association was strongly significant only for occupations such as housewife and cleaner, which could be because government workers and hairdressers earn a higher income than other jobs. The children of cleaners were also more likely to be malnourished than the children of tea sellers, possibly because mothers who leave home to work or undertake other economic activities often leave their young children in the care of older siblings, neighbours or relatives, who often do not provide optimal childcare.

5.5.2.10 Paternal Employment

Children of government employees, skilled labourers and street sellers were 38%, 48% and 46%, respectively, less likely to have kwashiorkor than children whose fathers were water traders, while children of fathers who had no specific work were 100% less likely to have kwashiorkor. In terms of marasmus, children of fathers who had all types of occupations were more likely to be marasmic. This could be due to the fact that in developing countries, mothers who leave home to farm or undertake other economic have children more likely to develop marasmus and kwashiorkor. Children whose fathers were water traders had a lower prevalence of marasmus and kwashiorkor, while street seller fathers had a higher prevalence of kwashiorkor. The association for the prevalence of PCM was significant for all occupations except those which had no specific source of income, and these had no influence on kwashiorkor.

5.5.2.11 Building Materials, Number of Rooms and Presence of Latrine

There was no relationship between the number of rooms and kwashiorkor and marasmus, although children who lived in mud and paste boarded houses were 2.9 and 1.5, respectively more likely to suffer from marasmus. These findings are consistent with other studies from Bangladesh, where children living in mud and brick house were more likely to be marasmic (Perry et al., 2013). Households with a latrine were 55% less likely to have marasmic children. The status of no latrine in a house confirmed the existence of open defecation, consequently causing polluted surroundings, and spreading worms, parasites and microbes into the environment, leading to gastroenteritis infections and PCM. A study has shown that the incidence of underweight children may reduce from 10% to 0% if households use hygienic latrines (UNICEF, 2011).

Chapter 6 - The Implications of Protein Calorie Malnutrition on Brain Function

6.1 Introduction

An EEG is a test that measures and records the electrical activity of the brain and was a technique discovered by the German psychiatrist, Hans Berger in 1929 (Smith, 2005). Although the use of detailed imaging today, such as computerised tomography (CT) and magnetic resonance imaging (MRI) is increasing, the EEG still has a central place in the diagnosis and management of patients with seizures, epilepsy, and an altered mental status (Fahoum et al., 2012). The EEGs recorded today still exhibit the same variety of focal abnormalities as in the past, and a framework for analysing these abnormalities is necessary in order to interpret and articulate the clinical implications of a recording.

6.1.1 Definition of Abnormal EEG

Abnormal can have two meanings: firstly, it can mean that the finding is not expected in most patients but has no clinical implications; and secondly, abnormal can mean that the finding has clinical implications such that the brain is not functioning in the way that it should. These are two very different meanings, for example, a sharply-contoured slow wave might be considered to be normal, but is still unexpected (Mackdonal, 2003).

6.1.1.1 Slowing Activity

Slow activity is frequently normal, such as theta during drowsiness and delta during sleep. However, focal delta during the waking state or theta for a posterior dominant rhythm in the waking state is clearly abnormal. Slowing can be divided into three classifications (Misulis and Head, 2006).

6.1.1.2 Generalised Slowing

Generalised slowing includes slow activity which would be characteristic of encephalopathy, with slowing of the posterior dominant rhythm, disorganisation of the rhythm, and excessive theta activity (Morgane et al, 1978).

6.1.1.3 Regional Slowing

Regional slowing consists of slow activity which would only affect one portion of the brain yet does not occur focally to a single area. Examples of encephalopathy would be frontal intermittent rhythmic delta activity (FIRDA) or slowing of the posterior dominant rhythm. These two patterns are often associated with slowing outside of these regions, but the background may otherwise be normal (Misulis and Head, 2006).

6.1.1.4 Focal Slowing

Focal slowing is usually indicative of a structural lesion, and includes focal theta activity and polymorphic delta activity (Misulis and Head, 2006).

6.1.1.5 Focal vs. Generalised Abnormalities

Abnormal patterns can be focal or generalised, and the clinical implications depend on the exact pattern and location; however, there are some generalizations (Smith, 2008). Focal slowing usually suggests a focal structural lesion underlying the scalp electrodes, while focal spikes or sharp waves can correlate with a focal structural lesion but more commonly suggests a partial seizure disorder. The type of seizure correlates with location, although it should be noted that not all sharp activity indicates seizures. Diffuse slowing is usually associated with encephalopathy, which can have many potential causes, including toxic, metabolic, degenerative, and multifocal vascular disease. Diffuse spikes or sharp waves correlate with a generalised seizure disorder, but a secondary generalisation cannot be ruled out (Smith, 2008).

6.1.1.6 Abnormal Frequency Composition

The interpretation of an EEG is a complex assessment of frequency composition and localisation. An abnormal frequency composition can consist of either slowing of the background or excessive fast activity (Fahoum et al., 2012). The effects of malnutrition on cognitive development have been studied in both humans and animals, although animal studies began much earlier than human studies and are more abundant within the literature (Laus et al., 2011). Research involving humans concerns mainly children in developing countriesand the highest prevalence of disadvantaged children can be found in sub-Saharan Africa and South Asia (Grantham-McGregor et al., 2007).

Electroencephalography activities have been found to be abnormal in several studies which involve malnourished animals and humans. Alterations in the cortical and hipocampal electrical activity have been observed in the EEGs of malnourished rats, and EEG abnormalities have been observed to be high among human patients too (Zhou et al., 2004). The study of electrical cerebral activity is important because it exerts control over a variety of developmental processes, such as neuronal differentiation, migration, synaptogenesis, neurotransmitter specification and synaptic plasticity (Rakik, 1994; Zhou et al., 2004). Consequently, it is important to study the influence of the nutritional status on the development of electrical cerebral activity during different stages of life.

A neuropsychological estimation will be able to elucidate the performing standard of the activities of the brain in correlation to the impact of malnourishment. A shortfall in behavioural patterns, emotional balance and intellect are correlated to the constitutional malformation of various areas of the human brain. The brain and its circuits handle diverse constituents of cognitive procedures (Raven et al., 1998), and malnourishment has lifelong consequences in the spheres of intelligence and actions, yet cognitive procedures, such as decision-making performances, have not been completely elucidated (Kar and Rao, 2004).

The differential quality of a cognitive shortfall correlated to undernourishment illustrates that diverse regions of the brain are involved at various levels, and a neuropsychological evaluation can define the outline of a brain malfunction. Undernourishment is a serious setback in Sudan, as approximately 50% of the children are undernourished. The consequence of PCM is merged in an inseparable manner with the outcomes of societal drawbacks.

The purpose of the research conducted in CEH in Khartoum State, Sudan in July 2011, was to explore the relationship between PCM and brain development among pre-school children.

6.1.2 Objectives

i) To localise the site of pathological lesions in the brain by abnormalities
ii) To evaluate the relationship between nutritional assessments and EEG abnormalities
iii) To study the relationship between clinical signs and EEG abnormalities
iv) To evaluate the relationship between neuropsychological signs and EEG and severe malnutrition changes
v) To assess improvements

6.2 Subjects and Methods

6.2.1 Population under Study

The impact of PCM on brain development in children was evaluated using a case controlled study, which was selected because longitudinal data are necessary to evaluate the outcomes of nutritional recovery. A randomised control trial for PCM was not ethically possible as PCM cannot be randomised, and whilst the mode of the treatment could have been randomised, this would have been an additional variable which could have confounded the effect of PCM on brain development. A prospective cohort study was also not possible because the predicted sample size was not large enough to conduct such a study.

It is unlikely that the control children would experience a significant change in their nutritional status during the short period of time (6 months) the study was collected. Therefore it was deemed unnecessary to subject the control children and their mothers to multiple data collection

From October 2010 to February 2011, the clinical research (third survey) was planned. Within this period the process was discussed with a paediatrician, neurologist and psychiatrist. Between July 2011 and July 2012, the questionnaires were answered by the mothers of the children (children with PCM and a control group), and during the same period, nutritional, clinical, EEG and neuropsychological assessments were carried out. The assessments were repeated after 4 and 12 weeks for malnourished children. Methodological framework for the effect PCM on brain development (Figure 6.1) summarises the study design

Figure 6.1 A methodological framework of PCM and cognitive function study

Activity	2010			2011												2012												2013
	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J→
Preparation of proposal, study protocol and approval by university research committee																												
Consultation with hospital administrators and clinicians*																												
Questionnaire design development and piloting																												
Ethical approval																												
Training interviewers																												
Pilot																												
Interview and data collection																												
Re-interview																												
Data entry and analyses																												
Thesis writing																												

* Paediatrician, Neurologist, Psychiatrist

6.2.1.1 Sample Size

The sample size is calculated using the following formula (Kadam & Bhalerao, 2010):

$$n = \frac{2(Za+Z1-\beta)^2 * p(1-p)}{\Delta 2}$$

where *n* is the required sample size. For

Z_α, *Z* is a constant (set according to the accepted α error and whether it is a one-sided or two-sided effect) as shown below:

α- error	5%	1%	0.1%
2- sided	1.96	2.5758	3.2
1-sided	1.65	2.33	

For Z1-,β,*Z* is a constant set according to power of the study as shown below:

Power	8%	85%	90%	95%
Value	0.8416	1.0364	1.2816	1.6449

In the above-mentioned formula σ is the standard deviation (estimated) and Δ the difference in effect of two interventions which is required (estimated effect size). This gives the number of sample per group.

As seen above, the study needs the following values: $Z_{\alpha,}$ $Z_{1-\beta,}$σ, standard deviation (estimated), and Δ, the difference in effect of PCM on brain impairment. It will accept a $p<0.05$ as acceptable and a study with 80% power; using the above tables, it gets the following values: $Z_{\alpha,}$ is 1.96 (in this case it will be using a two-tailed test because the results could be bidirectional). $Z_{1-\beta,}$ is 0.8416. The standard deviation would be approximately 0.0188 (using UNICEF global database on child malnutrition 2001, approximately 2% children suffer from PCM; marasmus, kwashiorkor and marasmic kwashiorkor). For Δ, thus, the effect size would be 15% (0.15).

The sample size for the study will be

$$N = \frac{2(1.96 +0\text{-}084)^2\, p(1-p)}{(0.15)}$$

$$N = \frac{2(1.96+ 0.84)^2\, (0.0188)}{(0.15)}$$

$$N = \frac{15.68 \times 0.02}{(0.022)} \quad = 14 \text{ patients for each group}$$

Calculating for a 15% drop-out rate one would need to complete approximately 16 patients each group to be able to say with any degree of confi dence whether a difference exists between the two treatments.

Sample size 14 + 15/100 x 14 = 16 pateints for each group

The children under study were 16 underweight children, 16 with marasmus, and 16 with kwashiorkor, together with 16 control children, who at the time of testing were not and never had been malnourished (4 control children refused to participate, so the number of control children has reduced to 12). Nearly all the children were aged between 12-36 months. Interview and testing usually occurred within the first three days of admission to the hospital using a combination of structured questionnaires and the collection of anthropometric data. Written consent to join the study was obtained from the mothers, and the mother of each child with PCM was interviewed. The first test was carried out within the first three days of admission, after a child had recovered from a threatening condition, such as hypoglycaemia, hypothermia and dehydration. Children remained in the hospital until they reached nutritional recovery, defined as >85% weight for height and no oedema for ten days, which usually took about three weeks. A second test was conducted one month after discharge and a third and final test three months after discharge. In contrast, the control children were submitted to only one EEG, neuropsychological assessment, clinical assessment and nutritional assessment.

6.2.1.2 Limitation of the Calculated Sample Size

The sample size calculated using the above formula is based on some conventions (Type I and II errors) and few assumptions (effect size and standard variation).

The sample size has to be calculated before initiating a study and as far as possible should not be changed during the study course.

The sample size calculation is also then influenced by a few practical issues, e.g., administrative issues and costs.

6.2.1.3 Inclusion Criteria

Every patient who met the inclusion criteria was included in the study. If the patient refused to come for a second assessment or died, then they were dropped from the study and replaced by another patient (*see* ***section 3.3****).*

6.2.2 Experimental Design

Three types of comparison were conducted:

a) Severe protein calorie malnourished subjects versus matched adequately nourished subjects
b) Severe protein calorie malnourished subjects on admission compared to when they came for follow up after a 4 and 12 week period of discharge
c) Relationships between clinical, EEG and neuropsychological findings

This design allowed the study to conduct a statistical evaluation and made it possible to study the effects of each syndrome (marasmus, kwashiorkor and underweight) independently of one another. The analysis consisted of the comparison of brain and intellectual development of PCM children with normal children at corresponding ages in order to ascertain whether those who have had PCM demonstrate significantly different results from those who have not had PCM (controls).

The study highlighted the importance of making an assessment on the effects of brain and secular change on the undernourished children. The hypothesis was tested to determine whether there was a difference in development between undernourished children and children who have had PCM. This should provide good evidence on whether certain kinds of malnutrition can result in severe mental illness and also enable the measurement of how severe the malnutrition needs to be in order to contribute to these changes. It also enables an investigation as to what effect this would have on the mental performance of these children, what kind of PCM has a greater impact, and to assess whether a small degree of malnourishment can lead to a lack of socialising skills and more behavioural problems. In addition, it enables the determination of whether learning abilities and concentration are also significantly lower in malnourished children compared to properly nourished children. Finally, the design allowed the study to identify if any factor other than under-nutrition could contribute to brain impairment, although as the control children came from relatively stable home conditions, environmental factors may have accounted for any differences in outcomes between undernourished children and the control group.

6.2.3 Teams Undertaking Separate Sub-Studies

For conducting this study in Khartoum Hospital, three teams were established:

(1) Nutrition and paediatric team

(2) Neurology team

(3) Psychology team

These teams worked in close cooperation and pooled their data which was then analysed by the researcher and a statistical team. These teams were also undertaken some separate sub-studies:

(a) The nutrition and health team undertook a number of investigations on childhood diet before admission to hospital and four weeks after discharge. A complete general physical examination, including the measurement of height, weight and head circumference of each child was performed. Additionally, data on behavioural problems obtained via their mothers and through direct observations was documented.

(b) Neurological examinations were conducted for all the patients.

(c) The psychology team began to develop a conceptual test that suited the needs of the research. This test was based on the fact that in several parts of the world malnourished children had been found to have a lower than average neuropsychological development when tested with a variety of standard instruments. The test carried out to study the effects of PCM and mental development were selected from several of the standard tests that have been used in industrialised countries.

6.2.4 Employed Questionnaire

The full questionnaire is presented in Appendix B. The questionnaire consisted of five sections and was seven pages in length.

Section 1*:* Characteristics of the Mother and Child

This section was designed to collect information on the characteristics of the mother and child for children 2-3 years of age. This included a child's age and gender, maternal age, maternal age when pregnant with the ill child, country and place of delivery, mode and presentation of delivery, the baby's birth order, maternal obstetrics, type of complications, number of children, whether the mother and father were blood relatives, number of years in Khartoum and tribal origin.

Section 3*:* Medical History

Section two dealt with the medical history of a patient, including gestational age, birth weight, past infections, type of infection, duration of infection, and history of past admissions. This section also obtained information on other historical illnesses, any other medical problems, whether a child had suffered from an infection before becoming malnourished, the type of infection a child had, and the length of their present illness before admission. Vaccination history was included in this section.

Section 4: Clinical Examination at Admission

This section sought child-related medical information, such as child weight, skin folds thickness, behaviour, apathy and diagnosis.

Section 5: Nutritional Assessment at Admission

The section sought to collect data about food practices of a child before their admission, such as food consumed by a child, food sources and frequency of consumption. This section also included information on haemoglobin, protein and serum albumin..

Section 6, 7 and 8

These sections sought to collect data about clinical examination 4 weeks after discharge, nutritional assessments: 4 weeks after discharge and clinical examination 12 weeks after discharge

6.2.5 Anthropometric Measurements

The measurements collected were those described earlier in section 3.4.1.

6.2.6 Clinical Assessment

Every child included in the study was subjected to a clinical examination, focusing on their general condition at the time of admission, weight, appetite, skin condition and evidence of PCM.

6.2.7 EEG Assessment

An EEG was carried out by a specialist.

6.2.8 Neuropsychological Assessment

This assessment was conducted by a psychologist, who measured learning, cognitive and intellectual capacities.

6.2.9 Criteria of Progress

Changes in body weight, ease of feeding as an indication of the degree of anorexia, loss of pitting oedema, healing of skin lesions, and improvement of temperament were recorded. The children's body weight was measured daily and weight gain, the main outcome measure, was compared between the groups during hospitalisation and follow up. During the **r**ecover**y** phase which lasted a few weeks, it was expected that the EEG of malnourished children would improve to more closely resemble the EEG of healthy children, and a child's psychological condition is also expected to improve over the same period.

6.2.10 Testing Methods

6.2.10.1 Clinical Assessment

See section 3.4.5

6.2.10.2 EEG Assessment

An EEG was carried out by a specialist for sixteen undernourished children, sixteen marasmic children, sixteen children with kwashiorkor and sixteen normal children of the same age (12 months - 36 months). The electroencephalographic recording of the subjects was undertaken at a private hospital in Khartoum. An electrophysiology assessment was performed and a sleep EEG was indicated in some cases to improve the detection of abnormalities. A sleep EEG may be achieved spontaneously by a period of sleep deprivation or by the administration of sedative.

The EEG recording was made using a Neurofax, Made 2000, Nishon Kohden Windows 2000, and Version 1990, with the scalp electrode placement in accordance to the 10-20 system. The recording was carried out in a recording room devoid of environmental distractions as much as possible. Children were held by their caregivers (in most cases their mothers) on their laps. The recording EEG technologist was not informed of the clinical diagnoses of the subjects and pre-recording instructions were provided, aimed at minimising artefacts in the recording. The cooperation of children who had developed test anxiety or fear was secured as much as possible. A can be expected EEG recording on children from this young age group posed some practical difficulties; however, obvious body movement noticed during the EEG recording was indicated as artefacts on the tracing. Furthermore, the recording was usually suspended during child movements, and the suspension time was noted and added to ensure an average of 45 minutes recording in total. Where this could not be achieved it was necessary to sedate the subject by administering an oral sedative in order to carry out the recording. Each recording session lasted 40-50 minutes (average 45 minutes).

The EEG reporting was performed independently by a neurologist who specialised in EEG interpretation with inter-rate reliability of 0.89. The neurologist reviewed all the EEG recordings in a random order and was therefore blind to all clinical data. The reporting was based on the EEG classification by Luders and Noachter (2000), and included normal or non-specific EEG changes such as an abnormal slow background rhythm, as well as generalised discharges, focal discharges and multifocal discharges.

EEG is a relatively cheap, fast, and safe way to check functioning of different areas of the brain. It illustrates a more complete picture of brain activity, however it can only measure activity in general areas, not specific neural connections. Moreover Localization with EEG source models is less precise (Ebersole, 2011). However, large sample for evaluation purposes in this study was very costly because it entailed the collection of long and detailed nutritional surveys, the cost of EEG and neuropsychological assessment and, more importantly the logistics of patients follow up. According to the empirical literature reviewed here, the effect of this set of activities was expected to take one year of participation in the program.

6.2.10.3 Neuropsychological Assessment

The neuropsychological assessment was conducted by a psychologist using the Denver Developmental Screening Test, which can be used for children from birth (in practice 2 months) to 6 years of age.

First developed by Frankenburg (1967), the Denver test evaluates a child's level of development from direct observations of a child's performance using items pertaining to four developmental domains:

(1) Social/personal
(2) Fine motor function
(3) Language
(4) Gross motor functions

The test consists of up to 125 items, although all 125 items are not administered to each child, as the number of items administered depends on how much time is available and whether the goal of the screening is only to determine if a child is at risk, or to evaluate a child's relative strengths. A typical assessment session takes about 20-60 minutes and depends on the age and developmental level of a child. The 125 items are arranged in approximate chronological order according to the ages at which most children can be expected to interact with them. A special feature of the test is the provision of age norms for each item, which are represented on the form by a bar that spans the ages at which 25%, 50%, and 90% of the standardisation sample. This provides a comparison of a child's performance to other children of the same age for each of the test items. There is also a scale for rating a child's behavioural characteristics during the test, such as compliance, alertness, fearfulness, attention span, and typical behaviour.

An age scale is used to determine the starting point of the test. A child's age is calculated and shown as a line on the test form, and each item that is intersected by the age line determines the starting point of the test. The assessment uses several terms for the scores for each item, and children 'pass' an item if they interact with it correctly and 'fail' an item if they do so incorrectly. Children are scored 'normal' for an item if they fail or refuse to interact with it correctly and it is an item that is indicated to be much above their age level (25-75%). Conversely, children are scored 'caution' for an item if they fail or refuse to interact with it correctly and 75-90% of children their age do so. These percentages are based on the developmental norms described earlier. Finally, children are scored 'delay' for an item if they fail or refuse to interact with it and it is at or below their age level. There are also several terms used to describe the overall score for the assessment and a child's risk level. The test result is considered 'normal' if there are no delays on any items and only one caution, while if the test yields two or more cautions and/or one or more delays, then the test result is considered 'suspect', and finally, if a child refuses to complete one or more items that are at or below their age level or more than one item that 75-90% of children of the same age can do, then the result is 'non-testable'.

In Sudan, the Denver scale has been translated into Arabic and some modifications have been made to the Denver scale, using 'mild', 'moderate' and 'severe deficiency', instead of 'suspect' etc. (see Appendix C). The test result is considered 'normal' if there are no delays on any items and only one caution, whereas if the test yields two cautions and/or one delay, then the result is 'mild'. If the assessment assigns more than two cautions and more than one delay, then the test result is considered 'moderate' and if a child refuses to complete one or more items that are at or below age level or more than one item that 75-90% percent of children of the same age can do, then the test result is 'severe deficiency'.

6.2.10.3.1 Conducting the Test

- Language: to determine the extent to which a child could produce sounds, listen, recognise, understand and use language and follow instructions, e.g. their ability to combine words and then use language to communicate with others.
- Social/personal aspects: to assess the extent to which a child could interact with others effectively, and aspects of socialisation inside and outside the home, e.g. smiling.
- Gross motor functions: to assess motor control, taking a sitting position, crawling, walking, and jumping while maintaining balance and other movements.
- Fine motor functions: to assess vision, reactions to different sensory perceptions of movement, hand coordination and the manipulation of small objects, e.g. grasping.

6.2.10.3.2 The Practice of Testing

The first step was to record the exact age (years, months) of a child. The measurements were then explained to the parents, because they could think that these only measured a child's IQ, whereas in fact they measured the four areas listed above, with a view to comparing the observations with those from other children of the same age.

6.2.10.3.3 **Tools**

The test consisted of nine items which were used to assess children aged 1-3 years old:

20 pieces of wool threads, red-coloured,

8 cubes 12-15 cm long, green-coloured, 3 cm side

Bell

Jingle

Small tennis ball

Glass, non-coloured, 2cm diameter

Pencil

Plain white paper (17 x 28 cm)

Box containing dry fruit (raisins, beans)

Instructions for the Assessing Person

Each person who conducted an investigation was well trained and familiar with the different tools. The investigator tried not be distracted throughout the period of the assessment and endeavoured to enter into a good relationship with a child, and ensured that the child was comfortable. As the parents were present throughout the investigation, they were encouraged to express their support and appreciation of their child's responses to the investigator's prompts. The investigator asked the questions strictly in the order they were laid out, commencing with social and personal aspects, in order to enable a child to open up and to remove any sense of pressure on the child. Next, fine motor functions were tested, as these did not rely on language but only on behaviour, then language skills were then tested, and finally, gross motor functions.

The role of the investigator was to provide support and encouragement to the child, and not to change the questions, explain or simplify them in any way. Whenever necessary, a child had three chances to answer each question properly, and if a child was not well physically or emotionally at the time of the assessment, the test would be repeated, preferably two weeks later.

Reporting the Results

Observations or reports from the parents included details of how well the parents felt that the child was able to behave normally in everyday life.

Observations from the investigator were recorded in boxes next to each question, using the following key:

Y = the child answered the question

N = the child was not able to answer the question

R = the child refused to answer the question

C = the child did not have the chance to answer the question

Formalising Results

For each question asked the child's response was carefully recorded against the expected reaction of a 'normal' child of the same age. If the response was perfectly in the line with a child's age, then they scored 70-100% and were qualified as 'normal'. If the response was not in line with a child's age, the mental age associated with their response was estimated and expressed as a percentage of the child's actual age. If the response scored 55-70%, it was qualified as a 'mild deficiency', 40-55%, as a 'moderate deficiency', and 25-40% or less, as a 'severe deficency'.

Denver scale is a standardized measure that has been normed on a diverse sample. It can be quickly administered by trained professional and paraprofessional staff (Frankenburg & Dodds, 1967). The scale has been criticized for lacking sensitivity in screening children who may have problems in later developmental status or school readiness (Frankenburg, & Dodds. 1967).

6.2.11 Data Analysis

The data was initially entered into Microsoft Excel spreadsheets and then exported into SPSS version 19.0 where it was analysed statistically. Missing data, outliers and logical checks were performed, and the accuracy of the data was checked by proofreading the questionnaires against the SPSS data window. Using the descriptive statistics mode of SPSS frequencies, random cases were checked for accuracy. During the data analysis stage, missing data is a pervasive problem (Yulei, 2010); therefore, data which had less than 10% of the missing variables were handled by substituting column means. ANCOVA was then employed to statistically assess the data.

6.2.11.1 Z-score Calculation

The age and sex specific, mean height and weight of the children were compared with the WHO standards. Children were considered to be underweight, stunted and wasted if their weight-for-age and height-for-age Z-scores fell below -2.0 SD of the National Center for

Health Statistics reference standards. Severe and moderate malnutrition were defined as Z-scores below -3.0 SD and -3.0 to -2.0 SD, respectively.

6.2.11.2 Chi-Squared Analysis

Cross tabulation is a combined frequency allocation of the facts based on more than one classified variable. Exhibiting an allocation of facts based on their worth for more than one variable is called a contingency table examination and is a frequently employed investigative methodology in the social sciences.

$$x^2 = \frac{\sum(0 - E)^2}{E}$$

Based on the information, O is the observed frequency

Based on the theorised means, E is the expected frequency

The clinical, psychological, nutritional and EEG related features were compared across the cases and controls, as well as for the pre and post-tests.

6.2.11.3 ANCOVA

The analysis of covariance is a linear relationship model which examines the degree of the relationship between dependent variables and different levels of categorical independent variables by testing the impact of equality and impact of the inter-association between the independent variables. ANCOVA was used in this study to identify whether PCM impacted upon the EEG, nutritional, psychological and clinical variables. This statistical test also controls for a covariate which may have an impact but is not of primary interest (e.g. tribe).

To investigate the rehabilitation response, after a specified period of nutritional treatment, the relationship between marasmus, kwashiorkor and under nutrition and dependent variables (neuropsychological, EEG and Clinical signs) was tested. The preceding bivariate and ANCOVA analysis were repeated, and tests for trends to assess for a linear fit between the three types of malnutrition and the dependent variables were conducted.

The linear relationship was used for the outcome, ‘recover from PCM during the 12-week period’, as the outcome for the treatment was based on whether or not the health of a study participant improved within the pre-determined 12-week feeding period following their discharge. Study participants were followed for 4 weeks and 12 weeks in order to assess clinical, EEG and neuropsychological changes. An ANCOVA was conducted to assess the characteristics of the children, with their overall percentage of change for the total period of time followed being the health outcome. All the available variables were utilised in the model to identify characteristics of the study participants who improved over the time period followed. Finally, the overall relationship between the clinical indications, as well as neuropsychological and EEG results, was tested.

6.3 Results

6.3.1 Study Flow Chart

From 9 July 2011 to 21 July 2012, 673 children were admitted to the ward and their progress is summarised in the study flowchart presented in Figure 6.2.

All children admitted to the hospital 647

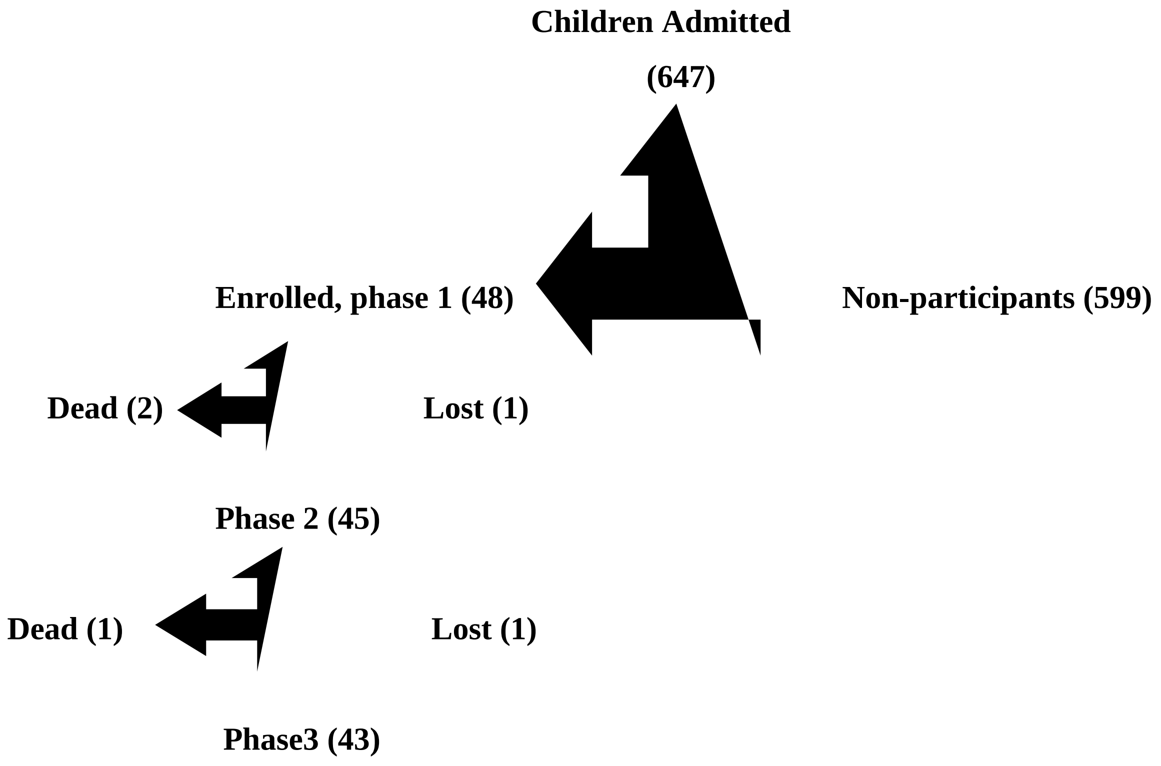


Figure 6.2: Study flow chart

6.3.2 Family and Socioeconomic Status

6.3.2.1 Family profile

Table 6.1 shows a summary of the family profiles (a more detailed supplementary table is provided in Appendix D7). The majority of mothers of the patients were aged between 21-35 years old. All the children in both the case and the control groups had fathers who were alive, and most of the mothers were too. Most fathers for both the case and control groups were of good health; however, the father of one child in the control group reported signs of sickness. All the mothers were found to be well in both the case and control groups.

Table 6.1: Family profiles

Variables	**Case Group (N=48)**	**Control Group (N=12)**	**Total (N=60)**
Maternal Age			
15-20	6(12.5%)	2(16.7%)	8(13.3%)
21-35	27(56.3%)	8(66.6%)	35(58.3%)
36-45	15(31.3%)	2(16.7%)	17(28.3%)
Father Alive			
Yes	48(100%)	12(100%)	60(100.0%)
Paternal Health			
Well	48(100%)	11(91.7%)	59(98.7%)
Unwell	0(0.0%)	1(8.3%)	1(1.3%)
Mother Alive			
Yes	48(100%)	12(100%)	60(100.0%)
Maternal Health			
Well	48(100%)	12(100%)	60(100.0%)

6.3.2.2 Socioeconomic Status

Table 6.2 shows a summary of the socioeconomic status of the families (a more detailed supplementary table is provided in Appendix D8). More than 40% of all the mothers had no formal education, although in the control group, half of the mothers reported having had a primary school education, yet almost a third also described themselves as illiterate. Fathers were overall better educated than the mothers, with fewer reports of illiteracy.

It can be advocated that most of the mothers of the case group were found to have either a poor salary or no salary. This indicates that the income of the mother rarely contributed to the running of the household. While a number of respondents in the case group had access to a safe water supply, a considerable number of them did not. In contrast, most of the children in the control group had access to piped or borehole water which is generally good drinking quality.

Table 6.2: Socioeconomic status

Variables	Case Group (N=48)	Control Group (N=12)	Total (N=60)
Maternal Education			
Uneducated	20(41.2%)	3(25%)	23(38.3%)
Informal	5(10.1%)	1(8.3%)	6(10.0%)
Primary	20(25%)	6(50%)	26(43.3%)
Secondary	3(6.3%)	2(16.7%)	5(8.3%)
Education			
Uneducated	12(25.0%)	1(8.3%)	13(21.7%)
Khalwa	13(27.1)	1(8.3%)	14(23.3%)
Primary	15(31.3)	5(41.7%)	20(33.3%)
Secondary	6(12.5)	3(25%)	9(15.0%)
University	2(4.2)	1(8.3%)	3(5.0%)
Mother Income			
Good	3(6.3%)	1(8.3%)	4(6.7%)
Satisfactory	4(8.3%)	1(8.3%)	5(8.3%)
Poor	9(18.8%)	10(83.3%)	19(31.7%)
Nil	32(66.6%)	0(0.0%)	32(53.3%)
Safe Water Supply			
Yes	26(54.2%)	8(66.7%)	34(56.7%)
No	22(45.8%)	4(33.3%)	26(43.3%)

6.3.2.3 Maternal Characteristics

Table 6.3 shows a summary of the maternal characteristics (a more detailed supplementary table is provided in Appendix D9).

It is evident that most of the respondents from both groups showed signs of proper and full term delivery, and only one child in the case group reported an abnormal pregnancy. For both groups the delivery of the children was primarily at home and the delivery has been normal. However, three children from the case group had been born by caesarean due to being breech. It should be noted that since the birth place was in the home, caesarean births are not possible and most of the mothers who face complications during such births may die in this situation. Two respondents in the case group were unwell at birth; however, overall, at birth similar health conditions were observed among both groups of respondents. During the neonatal period, the majority of the respondents in the control group were normal, but in contrast, for the children in the case group fever and jaundice were reported.

Table 6.3: Maternal characteristics

Variables	Case Group (N=48)	Control Group (N=12)	Total (N=60)
Pregnancy related Information			
Full	47(97.9%)	12(100.0%)	59(98.3%)
Abnormal	1(2.1%)	0(0.0%)	1(1.7%)
Place of Delivery			
Hospital	13(27.1%)	3(25.0%)	16(26.7%)
Home	35(72.9%)	9(75.0%)	44(73.3%)
Mode of Delivery			
Normal	45(93.7%)	12(100.0%)	57(95.0%)
Caesarean	3(6.3%)	0(0.0%)	3(5.0%)
Presentation of Delivery			
Normal	45(93.7%)	12(100.0%)	57(95.5%)
Breech	3(6.3%)	0(0.0%)	3(5.0%)
Condition at Birth			
Well	46(95.8%)	12(100.0%)	58(96.7%)
Not Well	2(4.2%)	0(0.0%)	2(3.3%)
Neonatal Period			
Infection	8(16.6%)	3(25.0%)	11(18.3%)
Fever	1(2.0%)	0(0.0%)	1(1.6%)
Jaundice	2(4.2%)	0(0.0%)	2(3.3%)
Normal	31(64.5%)	8(66.6%)	39(65.0%)
Other	2(4.2%)	1(8.3%)	3(5.0%)

6.3.3 Child Characteristics

6.3.3.1 Supplementary Feeding and Immunisations

Table 6.4 presents the data on supplementary feeding and immunisation for the case and control groups. Children from both groups were found to show satisfactory signs of supplementary feeding and immunisation. However, among the case group nine children showed signs of poor supplementary feeding, although almost all had been fully immunised, with only four children receiving partial immunisation and two children no immunisations. In the control group, the majority of respondents were all found to be up to date with their immunisations. The majority of children in both groups exhibited a vitamin A deficiency.

Table 6.4: Supplementary feeding and immunisation

Variables	Case Group (N=48)	Control Group (N=12)	Total (N=60
Supplementary feeding			
Satisfactory	39(81.3%)	11(91.7%)	50(83.3%)
Poor	9(9.7%)	1(8.3%)	10(16.7%)
Immunisation			
All up to date	42(87.5%)	11(91.7%)	53(88.3)
Partial	4(8.3%)	1(8.3%)	5(8.3%)
Nil	2(3.4%)	0(0.0%)	2(3.3%)
Vitamin A supplementation			
Yes	39(81.3%)	11(91.7%)	50(83.3%)
No	9(9.7%)	1(8.3%)	10(16.7%)
Vitamin deficiency			
Yes	21(43.8%)	8(66.7%)	29(48.3)
No	27(56.3%)	4(33.3%)	31(51.7)

6.3.3.2 Anthropometric Indicators

6.3.3.2.1 Characteristics of the Study Population

Table 6.5 examines the characteristics of the study population and presents the average age, weight and height of the children based on gender. The observed p-value indicates the presence of a significant difference in respondent's characteristics across the genders.

Table 6.5: Characteristics of study population (n=60)

Gender	Boys	Girls	P-value
Age/month	19.91±7.256	18.85±5.34	0.004
Child Weight at Admission	7.912±1.9898	8.204±2.2439	0.001
Length/Height	72.26±8.351	74.61±5.589	0.014

From Table 6.5 it can be seen that the mean height among the boys was 72.26 cm and weight was 7.92 kg. In contrast, girls were taller at 74.61 cm and heavier than 8.204 kg. There is a significant difference between the weight and height among both boys and girls. Across all ages the girls show a higher mean weight-for-age when compared to boys and also a higher mean height-for-age compared to the boys (Tables 6.6 and 6.7).

Table 6.6: Anthropometric indicators

Variables	Gender	n	Mean	Std. Deviation	t value	P value
Weight/age	Boys	33	7.912	1.9898	2.87	0.033
	Girls	27	8.204	2.2439		
Height/age	Boys	33	72.26	8.351	2.94	0.012
	Girls	27	74.61	5.589		

Table 6.7: Distribution of anthropometric indicators by age and gender

Variables	Gender	n	Mean	Std. Deviation	Minimum	Maximum
Weight-for-Age/gender						
1 year old	Boys	6	6.05	0.7688	5.2	7
	Girls	5	6.32	1.4721	4.0	8.1
2 year old	Boys	20	7.75	1.5823	4.8	11.2
	Girls	19	8.174	1.8427	4.7	12
3 year old	Boys	3	9.971	2.0475	6.3	12.6
	Girls	7	11.533	2.248	9.6	14
Height-for-Age/gender						
1 year old	Boys	6	67.17	3.764	62	72
	Girls	5	71.0	3.742	66	76
2 year old	Boys	20	72.69	8.566	45	86
	Girls	19	75.03	4.735	66	84
3 year old	Boys	7	75.39	9.476	65	88
	Girls	3	77.97	11.189	66	88

6.3.3.2.2 Linear Regression of Weight-for-Height

Table 6.8 provides the results of the linear regression of weight-for-height for the different ages of girls and boys. It is evident from Table 6.8 that girls seem to be gaining weight in proportion to their height and this shows a gradual increase as the girls get older. However, Table 6.8 also shows that there is no significance for the different ages of the girls and their corresponding height and weight ratios.

Table 6.8: Linear regression of weight for height among children

Gender	Age (Years)	Mean Weight (Kg)	Mean Height (cm)	Mean square residual	F-ratio	Significance
Boys	1 year old	6.1	67.17	0.5	1.9	0.230
	2 year old	7.8	72.69	2.5	1.3	0.264
	3 year old	9.9	75.39	2.02	7.4	0.042
Girls	1 year old	6.3	71	1.3	3.6	0.153
	2 year old	8.2	75.1	2.8	4.7	0.044
	3 year old	11.5	77.9	1.2	6.8	0.232

6.3.3.2.3 Distribution of Wasting (Weight for Height)

This is measured via the weight-for height ratio, and from Table 6.9 it can be seen that more infant girls were normal compared to boys. Severe wasting is observed among more boys than girls. Boys aged 1-2 years old showed the most wasting

Table 6.9: Distribution of wasting (weight for height) for children

Variables	Normal		Mild		Moderate		Severe		Total	
	N	%	N	%	N	%	N	%	N	%
Gender										
Girl	2	9.1	4	18.2	6	27.3	10	45.4	22	100
Boy	2	7.4	5	18.5	8	29.6	12	44.4	27	100
Total	4	8.1	9	18.4	14	28.6	22	44.9	49	100
Weight for height (Girls)										
0-1	0	0.0	1	20.0	1	20.0	3	60.0	5	100
1-2	1	6.3	3	18.7	4	25.0	8	50.0	16	100
2-3	0	0.0	0	0.0	0	0.0	1	100.0	1	100
Total	1	4.5	4	18.2	5	22.7	12	54.5	22	100
Weight for height (Boys)										
0-1	0	0.0	1	16.7	2	33.3	3	50.0	6	100
1-2	1	5.8	3	17.6	6	35.3	7	41.2	17	100
2-3	0	0.0	1	25.0	2	50.0	1	25.0	4	100
Total	1	3.7	5	18.5	10	37.0	11	40.7	27	100

6.3.3.3 Child Characteristics and Diagnosis on Admission

Table 6.10 presents the diagnoses of PCM, and three different categories of protein energy malnutrition were observed. A total of 60 children were chosen for the study, 16 of which were diagnosed with marasmus, 16 with kwashiorkor, and 16 as underweight. The control population was represented by 12 healthy children.

Table 6.10: Child characteristics and diagnosis on admission

Variables	Case (N=48)		Control (N=12)		Total (N=60	
	Frequency	%	Frequency	%	Frequency	%
Diagnosis						
Marasmus	16	100	0	0.0	16	100
Kwashiorkor	16	100	0	0.0	16	100
Underweight	16	100	0	0.0	16	100
Control	0	0.0	12	100	12	100
Age						
0-1 year	11	100	0	0.0	11	100
1-2 year	32	82.0	7	17.0	39	100

2-3 year	5	50.0	5	50.0	10	100
Gender						
Male	27	81.8	6	18.2	33	100
Female	21	77.8	6	22.2	27	100
Initial contact with child						
Outpatients	21	100	0	0.0	21	100
Referred	27	100	0	0.0	27	100
Control	0	0.0	12	100	12	100
Informer						
Mother	46	80.7	11	19.3	57	100
Relative	2	66.7	1	33.3	3	100

Oedematous forms of malnutrition are considered as severe malnutrition in any patient independently of the degree of oedema. In children, such a severe condition is defined as kwashiorkor (≥60% weight-for-age). Children without oedema but who are severely wasted (marasmus) and/or stunted (< -3 SD of the median NCHS/WHO reference values for weight-for-age or height for-age respectively) are also classified as severely-malnourished (WHO, 1992).

The majority of the children in the control group (100%) are aged between 1 and 2 years, and the remainder are 2-3 years old. There were slightly more boys in the case group than girls, but in the control group there was an equal distribution of the genders. Among the case children, the majority had been referred whilst some were outpatients. All the children in the control group were selected on the basis of their good health. The children in the case and control groups were mostly brought in by their mothers, which is to be expected the oldest infant was only 3 years old.

6.3.3.4 Medical History of the Children

Table 6.11 shows the past medical history of the children in the study. In the case group, more than one quarter had previously been admitted as an inpatient for PCM, and almost three quarters reported different complications. In contrast, in the control group almost all of the respondents had never been admitted before; only a single child had a past history of measles and no signs of diarrhoea were observed.

Table 6.11: Medical history of the children

Variables	Case group (N= 48)		Control group (N= 12)		Total (N=60)	
	Frequency	%	Frequency	%	Frequency	%
Previous admission						
None	31	64.5	11	91.7	42	70
Three times	3	6.3	0	0	3	5
Two times	1	2.1	0	0	1	1.7
Once	13	27.1	1	8.3	14	21.7
Pre-study complications						
Gastroenteritis	2	4.2	0	0	2	3.3
Vomiting	1	2.1	0	0	1	1.7
Malnutrition	2	4.2	0	0	2	3.3
Measles	1	2.1	1	50	2	3.3
Fever	4	8.4	0	0	4	6.6
Fast breathing	1	2.1	0	0	1	1.7
Present medical history						
Diarrhoea						
Yes	34	70.8	0	0	32	53.3
No	14	29.2	0	0	14	46.7
Fever						
Yes	31	64.5	0	0	31	51.7
No	17	35.4	0	0	17	48.3
Vomiting						
Yes	20	41.7	0	0	20	33.3
No	28	58.3	0	0	28	66.7
Coughing						
Yes	13	21.1	0	0	13	21.7
No	35	78.9	0	0	35	78.3

6.3.3.5 Biochemistry Investigations for children with PCM

Table 6.12 shows that most of the case children had the lower limits of protein in their blood and some showed normal levels. Similarly, the low albumin levels are observed in most of the children, and most were anaemic with a haemoglobin level of 8.5-10.

Table 6.12: Biochemistry investigations for children with PCM

Variables	Frequency	Percent
Protein Level		
Lower Limit	29	56.9
Normal	22	43.1
Total	51	100.0

Albumin Level		
Lower Limit	45	88.2
Normal	6	11.8
Total	51	100.0
Haemoglobin Level		
>5	2	4.3
5-8	21	44.7
8.5-10	18	38.3
>10	6	12.8
Total	47	100.0

6.3.4 Bivariate Analysis

6.3.4.1 Association between Child Breast Feeding, Age at Weaning and PCM

Table 6.13 shows that the majority of the children in case and control groups were exclusively breastfed. However, among the children with PCM, 6 kwashiorkor children, 8 underweight children and 10 marasmus children, were found to have partial breastfeeding tendencies. The majority of the children across both groups were still receiving breast milk, which is good as most of the children are still considered to be infants. A quarter of the children who were underweight had been weaned off breast milk at the age of 19-24 months, and for those with kwashiorkor, some had been weaned between 12-18 months of age. Weaning at less than 12 months of age among kwashiorkor and underweight children was very rare.

6.13: Association between child breast feeding, age at weaning and PCM

Variable	SPCM and Control Group				
	Marasmus	**Kwashiorkor**	**Underweight**	**Control**	**Total**
Breastfeeding mode					
Exclusive	6 (37.5%)	10 (62.5%)	8 (50.0%)	8 (66.7%)	32 (53.3%)
partial	10(62.5%)	6 (37.5%)	8 (50.0%)	4(33.3%)	28 (46.7%)
Total	16(100.0)	16(100.0)	16(100.0)	12(100.0)	60(100.0)
P =0.618					
Age at weaning					
On breast milk	9 (56.2%)	6 (37.5%)	2 (12.5%)	5 (41.7%)	22 (36.7%)
<12	3 (18.8%)	2 (12.5%)	2 (12.5%)	2(16.7%)	9 (15.0%)
12-18	3 (18.8%)	5 (31.2%)	8 (50.0%)	1 (8.3%)	17 (28.3%)
19-24	1 (6.2%)	3 (18.8%)	4 (25.0%)	4 (33.3%)	12 (20.0%)
Total	16(100%)	16(100.0%)	16(100.0%)	16(100)	(100.0%
P =0.061					

6.3.4.2 Nutritional Assessment

Table 6.14 presents a comparison of the nutritional intake between the different protein disorders and the control group (a more detailed supplementary table is provided in Appendix D10).

Four results are noteworthy:

- Children who were healthy and normal consumed more legumes than severely malnourished children (p=0.05).
- There was a significant difference in the intake of milk (p=0.008); about 15% of malnourished children had never consumed milk, whereas almost all the healthy children consumed milk.
- Meat had never been consumed by 8.3% of the patients never whilst almost half of the healthy children consumed meat every day (p=0.05).
- The consumption of fresh vegetables was higher among the control group children (p=0.006).

Table 6.14: Nutritional analysis of case and control

Variables	**Never**	**Once/ Day**	**Twice/ Day**	**>Twice /Day**	**Once/ Week**	**Twice/ Week**	**>Twice /Week**	**Once/ Month**	**Total**
Legumes p=0.05									
Marasmus	0 (0.0%)	10 (62.5)	2 (12.5%)	2 (12.5%)	1 (6.2%)	0 (0.0%	0 (0.0%)	0 (0.0%)	16 (100%)
Kwashiorkor	0 (0.0%)	5 (31.2%)	5 (31.2%)	6 (37.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	16 (100%)
Underweight	0 (0.0%)	2 (12.5%)	7 (43.8%)	6 (37.5%)	0 (0.0%)	1 (6.2%)	0 (0.0%)	0 (0.0%)	16 (100%)
Control	0 (0.0%)	2 (16.7%)	6 (50.0%)	2 (16.7%)	2 (16.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	12 (100%)
Total	0 (0.0%)	19 (31.7%)	20 (33.3%)	16 (26.7%)	3 (5.0%	1 (1.7%)	0 (0.0%)	0 (0.0%)	60 (100%)
Milk p=0.008									
Marasmus	2 (12.5%)	2 (12.5%)	1 (6.2%)	2 (12.5%)	4 (25.0%)	3 (18.8%)	2 (12.5%)	0 (0.0%)	16 (100%)
Kwashiorkor	2 (12.5%)	2 (12.5%)	1 (6.2%)	2 (12.5%)	4 (25.0%)	1 (6.2%)	0 (0.0%)	0 (0.0%)	12 (100%)
Underweight	3 (18.8%)	4 (25.0%)	0 (0.0%)	1 (6.2%)	5 (31.2%)	2 (12.5%)	1 (6.2%)	0 (0.0%)	16 (100%)
Control	0 (0.0%)	3 (25.0%)	3 (25.0%)	0 (0.0%)	4 (33.3%)	2 (16.7%)	0 (0.0%)	0 (0.0%)	12 (100%)
Total	7 (12.5%)	11 (19.6%)	5 (8.9%)	5 (8.9%)	17 (30.4%)	8 (14.3%)	3 (5.4%)	0 (0.0%)	56 (100%)
Fresh vegetables p=0.06									
Marasmus	1 (6.3%)	4 (25.0%)	1 (6.3%)	1 (6.3%)	5 (31.2%)	4 (25.0%)	0 (0.0%)	0 (0.0%)	16 (100%)
Kwashiorkor	0 (0.0%)	5 (31.2%)	1 (6.3%)	1 (6.3%)	6 (37.5%)	2 (12.5%)	1 (6.3%)	0 (0.0%)	16 (100%)

Variables	Never	Once/ Day	Twice/ Day	>Twice /Day	Once/ Week	Twice/ Week	>Twice /Week	Once/ Month	Total
Underweight	0 (0.0%)	7 (43.7%)	0 (0.0%)	0 (0.0%)	7 (43.7%)	2 (12.5%)	0 (0.0%)	0 (0.0%)	16 (100%)
Control	0 (0.0%)	4 (33.3%)	2 (16.7%)	2 (16.7%)	2 (16.7%)	1 (8.3%)	1 (8.3%)	0 (0.0%)	12 (100%)
Total	1 (1.7%)	20 (33.3%)	4 (6.7%)	4 (6.7%)	20 (33.3%)	9 (15.0%)	2 (3.3%)	0 (0.0%)	60 (100%)
Meat p=0.06									
Marasmus	3 (18.7%)	1 (6.3%)	0 (0.0%)	5 (31.2%)	5 (31.2%)	1 (6.3%)	1 (6.3%)	0 (0.0%)	16 (100%)
Kwashiorkor	1 (6.3%)	2 (12.5%)	0 (0.0%)	6 (37.5%)	3 (18.7%)	3 (18.7%)	0 (0.0%)	1 (6.3%)	16 (100%)
Underweight	0 (0.0%)	3 (20.0%)	0 (0.0%)	10 (66.7%)	0 (0.0%)	2 (13.3%)	0 (0.0%)	0 (0.0%)	15 (100%)
Control	0 (0.0%)	6 (46.1%)	2 (15.4%)	2 (15.4%)	2 (15.4%)	1 (7.7%)	0 (0.0%)	0 (0.0%)	13 (100%)
Total	4 (6.7%)	12 (20.0%)	2 (3.3%)	23 (38.3%)	10 (16.7%)	7 (11.7%)	1 (1.7%)	1 (1.7%)	60 (100%)

6.3.4.3 Clinical Assessment and Behaviour of Children

6.3.4.3.1 Clinical indicators of Case and Control

Table 6.15 shows that the clinical symptoms were different in the groups at baseline (a more detailed supplementary table is provided in Appendix D11). None of the clinical symptoms seen in the SPCM children (marasmus, kwashiorkor and underweight) were seen in any child in the control group except for muscle wasting.

Changes in skin colour were only seen in children affected by PCM, where the majority were pale, while none of the control group had any sign of skin changes (p=0.001). A large majority of children with PCM showed signs of hair changes compared with the control group (p=0.0001) and likewise skin depigmentation was only seen in children with PCM (p =0.0001). A moon face was seen in nearly half of the malnourished children compared to the control group (p= 0.0001), and whilst flaky paint skin symptoms was observed in children with SPCM only, this was not statistically significant (p=0.615). Other skin lesions were seen in nearly half of the PCM children compared to the control group which was statistically significant (p=0.001). Signs of growth retardation were only seen in children with PCM but this was not statistically significant (p =0.016); however, the difference between the two groups in terms of muscle wasting was significant (p=0.016). Muscle wasting was observed in all the marasmic children and three quarters of the underweight children, whilst only a minority of the control group exhibited muscle wasting

Table 6.15: Distribution of clinical profiles for the case and control groups

Variables	Yes	No	p-value	Variables	Yes	No	p-value
Pallor				**Skin lesions**			
Marasmus	11(68.8%)	5(31.2%)	0.001	Marasmus	1(6.2%)	15(93.8%)	0.001
Kwashiorkor	9(56.2%)	7(43.8%)		Kwashiorkor	9(56.2%)	7(43.8%)	
Underweight	10(62.5%)	6(37.5%)		Underweight	3(18.8%)	13(81.2%)	
Control	0(0.0%)	12(100%)		Control	0(0.0%)	12(100%)	
Total	30(50.0%)	30(50.0%)		Total	13(21.7%)	47(78.3%)	
Hair change				**Associated infection**			
Marasmus	13(81.2%)	3(18.8%)	0.0001	Marasmus	2(12.5%)	14(87.5%)	0.305
Kwashiorkor	12(75.0%)	4(25.0%)		Kwashiorkor	3(18.8%)	13(81.2%)	
Underweight	10(62.5%)	6(37.5%)		Underweight	4(25.0%)	12(75.0%)	
Control	1(8.3%)	11(91.7%)		Control	0(0.0%)	12(100%)	
Total	36(60.0%)	24(40%)		Total	9(18.8%)	51(81.2%)	
Skin depigmentation				**Associated vitamin deficiency**			
Marasmus	3(18.8%)	13(81.2%)	0.0001	Marasmus	2(12.5%)	14(87.5%)	0.290
Kwashiorkor	11(68.8%)	5(31.2%)		Kwashiorkor	2(12.5%)	14(87.5%)	
Underweight	4(25.0%)	12(75.0%)		Underweight	4(25.0%)	12(75.0%)	
Control	0(0.0%)	12(100%)		Control	0(0.0%)	12(100%)	
Total	18(30.0%)	42(70.0%)		Total	8(13.3%)	52(86.3%)	
Moon Face				**Growth retardation**			
Marasmus	4(25.0%)	12(75.0%)	0.0001	Marasmus	6(37.5%)	10(62.5%)	0.016
Kwashiorkor	14(87.5%)	2(12.5%)		Kwashiorkor	1(6.2%)	15(93.8%)	
Underweight	4(25.0%)	12(75.0%)		Underweight	6(37.5%)	10(62.5%)	
Control	0(0.0%)	12(100%)		Control	0(0.0%)	12(100%)	
Total	22(36.7%)	38(63.3%)		Total	13(21.7%)	47(78.3%)	
Flaky Paint				**Wasting of muscle**			
Marasmus	2(12.5%)	14(87.5%)	0.615	Marasmus	15(93.8%)	1(6.2%)	0.001
Kwashiorkor	5(31.2%)	11(68.8%)		Kwashiorkor	5(31.2%)	11(68.8%)	
Underweight	3(18.8%)	13(81.2%)		Underweight	12(75.0%)	4(25.0%)	
Control	0(0.0%)	12(100%)		Control	2(16.7%)	10(83.3%)	
Total	10(16.7%)	50(83.3%)		Total	13(21.7%)	47(78.3%)	

6.3.4.4 Behaviour Disorders

Table 6.16 presents a comparison of the behaviour of children in the case and control groups. There is a definitive difference between the groups with respect to the clinical behaviour of the respondents (p=0.001). All children in the control group showed signs of normal behaviour and no abnormal behaviour; however, among the children with PCM, it can be seen that signs of apathetic, irritable and anorexic behaviour is prevalent. For example, among children with marasmus both apathetic and irritable behaviour is seen, while children with kwashiorkor exhibit apathetic, irritable and anorexic behaviour, and most underweight children demonstrate irritable behaviour.

Table 6.16: Association between disease and behaviour disorders

Behaviour	Apathetic	Irritable	Anorexia	No	Total
Marasmus	8(50.0%)	8 (50.0%)	0 (0.0%)	0 (0.0%)	16 (100.0%)
Kwashiorkor	6 (37.5%)	8 (50.0%)	2 (12.5%)	0 (0.0%)	16 (100.0%)
Underweight	4 (25.0%)	11 (68.8%)	1 (6.2%)	0 (0.0%)	16 (100.0%)
Control	0 (0.0%)	0 (0.0%)	0 (0.0%)	12(100.0%)	12 (100.0%)
Total	18 (30.0%)	27 (45.0%)	3 (5.0%)	12 (20.0%)	60 (100.0%)
					p-value 0.001

6.3.4.5 Psychological Assessments

Table 6.17 compares the psychological assessment results for children with PCM and the control group (a more detailed supplementary table is provided in Appendix D12). Severe forms of psychological disorders were more prevalent in the children with PCM followed by moderate and then mild disorders. More than half of the respondents rated severe on the personal-social attributes scale had a personal social disorder. In contrast, more than half of the control group had a normal rating on the personal-social scale, thus there is a significant difference between the two groups. The prevalence of a fine motor disorder was statistically different between the children with children and the control group (p=0.001), with the majority of malnourished children having a severe fine motor delay, in contrast to the control group where the majority were rated normal on the fine motor adaptive scale. Half of the patients had a severe language skills delay, while more than half of the control group had normal language skills, a statistically significant finding. Finally, two-thirds of the patients had a severe gross motor attribute scale rating whereas the majority of the control group were normal, and again this was statistically significant.

Table 6.17: Neuropsychological indicators for the case and control groups

Variables	Normal	Mild	Moderate	Severe	p-value
Personal-Social					
PCM	0(0.0%)	7(14.6%)	13(27.1%)	28(58.3%)	0.001
Control	7(58.3%)	3(25.0%)	1(8.3%)	1(8.3%)	
Fine Motor					
PCM	0(0.0%)	1(2.1%)	18(37.5%)	28(58.3%)	0.001
Control	8(66.7%)	2(16.7%)	1(8.3%)	1(8.3%)	
Language					
PCM	0(0.0%)	6(12.5%)	19(39.6%)	23(47.9%)	0.001
control	7(58.3%)	4(33.3%)	0(.0%)	1(8.3%)	
Gross motor					
PCM	1(2.1%)	5(10.4%)	10(20.8%)	32(66.7)	0.001
Control	7(58.3%)	3(25.0%)	0(.0%)	2(16.7%)	

6.3.4.6 EEG Assessments

Table 6.18 shows the EEG patterns and abnormalities observed for the children with PCM at the time of their admission and the control group. The majority of children with marasmus, kwashiorkor and who were underweight showed several EEG abnormalities, while nearly all the children in the control group were found to have a normal EEG (p=0.002).

The EEG background and abnormalities seen in children with PCM and the control children were analysed. Slow wave activity was seen in 25% of children with marasmus, 37.5% of children with kwashiorkor and 12.5% of underweight children Very slow waves (delta range) were seen only among children with kwashiorkor (43.8%). In contrast, the EEGs of children in the control group were dominated by a normal background rhythm appropriate for the child's age and state. No statistical difference in the background rhythm was observed between the case and control group (p=0.792). In two children with kwashiorkor and one child with marasmus, the background of their EEGs was dominated by very low and slow wave activity than would normally be expected for their age and state.

Generalised EEG changes were seen in over a third of children with kwashiorkor, and a quarter of children who were underweight and had marasmus, unlike the control which exhibited no abnormalities. Focal abnormalities were observed in over a third of children with marasmus, and an appreciable difference with respect to the EEG pattern was observed between the case and control group, indicating that there was a difference (p=0.003). There was a good association between the EEG focal abnormalities and PCM. In half of the children with PCM, their EEGs showed focal slow activity, while over a third exhibited focal sharp activity. However, there was no statistical difference with respect to focal activity observed between the two groups (p=0.334)

An association was observed between the multifocal abnormalities seen in the EEG of children with PCM, and multifocal sharp EEG abnormalities were seen in the majority of children with all types of PCM. In a very few children with PCM, their EEG shows focal slow waves and multifocal sharp activity; however, there was no statistical difference with respect to multifocal activities between the different groups (p=0.543).

Table 6.18: Distribution of EEG Abnormalities among of Case and Control at Admission

Variables	Marasmus	Kwashiorkor	Underweight	Control	Total	P-value
EEG						0.002
Normal	5(31.3%)	0(.0%)	9(56.3%)	11(91.7%)	25(31.7%)	
Abnormal	11(68.8%)	16(100.0%)	7 (43.7%)	1(8.3%)	35(68.3%)	
Total	16(100%)	16(100%)	16(100%)	12(100%)	60(100%)	
Background						0.792
SlB	4(25.0%)	6(37.5%)	2(12.5%)	1(8.3%)	13(21.7%)	
VSlB	0(0.0%)	3(18.8%)	0(0.0%)	0(.0%)	3(5.0%)	
EEG patterns						0.030
Generalised	2(12.5%)	5(31.3%)	2(12.5%)	0(0.0%)	9(15.0%)	
Focal	3(18.8%)	5(31.3%)	3(18.8%)	1(8.3%)	12(20%)	
Multifocal	3(18.8%)	2(12.5%)	2(12.5%)	0(.0%)	7(11.7%)	
Focal & Multifocal	3(18.8%)	5(31.3%)	0(.0%)	0(.0%)	8(13.3%)	
Generalised Activities						0.040
GShA	1(6.3%)	2(12.5%)	2(12.5%)	0(0.0%)	5(55.5%)	
GSIA	1(6.3%)	3(18.8%)	0(0.0%)	0(0.0%)	4(33.3%)	
GLSISHA	0(0.0%)	1(6.3%)	0(0.0%)	0(0.0%)	1(11.1%)	
Focal Activities						0.334
FSlA	3(18.8%)	2(12.5%)	3(18.8%)	1(8.3%)	9(47.4%)	
FShA	2(12.5%)	4(25.0%)	0(0.0%)	0(0.0%)	6(31.6%)	
LFShA	0(0.0%)	2(12.5%)	0(0.0%)	0(0.0%)	2(10.5%)	
RFShA	1(6.3%)	1(6.3%)	0(0.0%)	0(0.0%)	2(10.5%)	
Multifocal Activities						0.541
MFoShA	5(43.8%)	5(43.8%)	2(12.5%)	0(0.0%)	12(20.0%)	
MFoShSlA	1(6.3%)	2(12.5%)	0(0.0%)	0(0.0%)	3(5.0%)	

6.3.4.7 Location of EEG Abnormalities in Children with Severe Protein Calorie Malnutrition

Table 6.19 shows the EEG activities in children with PCM, clearly indicating that the control group had a normal EEG background and only one child exhibited abnormalities, while children with any type of PCM showed different types of focal abnormalities in their EEGs. Frontal lobe abnormalities were commonly observed, followed by temporal and parietal temporal abnormalities. These focal abnormalities were seen in the frontal and fronto-central region and in the temporal region. Multifocal sharp activity was seen in frontal temporal and frontal central temporal region, in the parietal temporal region and the centro parietal region.

Table 6.19: Abnormal EEG locations in children with PCM

Diagnosis	Marasmus	Kwashiorkor	Under weight	Control
Bi frontal sharp activity	1(50.0%)	0(0.0%)	0(0.0%)	1(50.0%)
Bilateral centro-focal sharp act	1(100.0%)	0(0.0%)	0(0.0%)	0(0.0%)
Frontal slow activity	1(20.0%)	1(20.0%)	3(60.0%)	0(0.0%)
Fronto- central- slow activity	0(0.0%)	1(100.0%)	0(0.0%)	0(0.0%)
Left sided sharp activity	0(0.0%)	2(100.0%)	0(0.0%)	0(0.0%)
Right centro-temporal slow activity	1(50.0%)	1(50.0%)	0(0.0%)	0(0.0%)
Left frontal Temporal sharp activity	2(66.7)	1(33.3%)	0(0.0%)	0(0.0%)
Right frontal central temporal sharp activity	1(50.0%)	1(50.0%)	0(0.0%)	0(0.0%)
Left temporal multifocal sharp activity	1(100%)	0(0.0%)	0(0.0%)	0(0.0%)
Left parietal temporal sharp activity	0(0.0%)	2(100 %)	0(0.0%)	0(0.0%)
Left sided multifocal sharp activity	0(0.0%)	1(100%)	0(0.0%)	0(0.0%)
Frontal parietal central sharp activity	0(0.0%)	1(100%)	0(0.0%)	0(0.0%)
Left centro- parietal- temporal sharp activity	0(0.0%)	2(66.6.)	1(33.3%)	0(0.0%)
Right centro- parietal-temporal sharp activity	1(50.0%)	1(50%)	0(0.0%)	0(0.0%)

6.3.4.8 Association between EEG abnormalities and Clinical Indicators

Table 6.20 shows the relationship between the clinical indications and the EEG abnormalities (a more detailed supplementary table is provided in Appendix D13). Behaviour disorders were significantly (p=0.023) associated with focal abnormalities, whilst focal and multifocal abnormalities were associated with a moon face (p=0.013) and multifocal abnormalities with skin depigmentation (p=0.041).

Table 6.20: Relationship between the clinical indications and EEG results

Variables	Generalised	Focal	Multifocl	Focal and multifocal	Normal	Total	P-value
Behaviour disorder							0. 023
Yes	4(8.3%)	11(22.9)	7(14.5%)	8(16.6%)	18(37.5%)	48(100%)	
No	0(0.0)	1(8.3%)	0(0.0%)	0(.0%)	11(91.6%)	12(100%)	
Other Skin Lesion							0.083
Yes	2(15.3%)	2(15.3%)	2(15.3%)	4(30.7%)	3(23%)	13(100%)	
No	2(4.2%)	10(21.2%)	5(10.6%)	4(8.5%)	26(55.3%)	47(100%)	
Moon face							0.013
Yes	4(18.0%)	5(22.7%)	2(9.0%)	5(22.7%)	6(27.2%)	22(100%)	
No	0(.0%)	7(18.4%)	5(13.1%)	3(7.8%)	23(60.0%)	28(100%)	
Skin depigmentation							0.041
Yes	2(10.0%)	4(20%)	1(5%)	6(30%)	7(35%)	20(100%)	
No	2(5.0%)	8(20.0%)	6(15.0%)	2(5.0%)	22(55.0%)	40(100%)	

6.3.4.9 Association between EEG Abnormalities and Neuropsychological Indications

Table 6.21 illustrates the relationship between the neuropsychological indications and EEG abnormalities. Fine motor delay skills and personal social delay skills were significantly associated with EEG abnormalities. Fine motor delay was associated with abnormalities in the focal region, while personal social delay skills were associated with a abnormalities in the multifocal region. Language delay and gross motor delay were associated with multifocal abnormalities, although this association was not statistically significant.

Table 6.21: Relationship between neuropsychological indications and EEG results

Variables	Generalisd	Focal	Multi focal	Focal and multifocal	Normal	p-value
Fine Motor						0.018
Yes	4(7.6%)	11(21.1%)	7(13.4%)	8(15.3%)	22(42.3%)	
No	0(0.0%)	1(12.5%)	0(.0%)	0(0.0%)	7(87.5%)	
Language						0.064
Yes	4(6.6%)	11(18.3)	14(23.2%)	8(13.3%)	23(38.3)	
No	0(0.0%)	1(14.2%)	0(0.0%)	0(.0%)	6(85.7%)	
Gross Motor						0.399
Yes	4(6.1%)	10(16.9%)	14(23.7%)	8(13.5%)	23(38.9%)	
No	0(.0%)	2(16.7%)	0(0.0%)	0(0.0%)	6(75.0%)	
Personal social						0.011
Yes	1(1.8%)	10(18.8%)	12(22.6%)	7(13.2%)	23(43.3)	
No	0(0.0%)	0(0.0%)	4(0.0%)	3(0.0%)	7(100%)	

6.3.4.10 Profiles of children at 4 Weeks Follow-Up

6.3.4.10.1 Clinical Indicators 4 Weeks after Discharge

Table 6.22 summarises the clinical progress following discharge from hospital treatment after 4 weeks. The incidence of all the symptoms was significantly (except pallor and hair changes) decreased 4 weeks after discharge, with distinctive patterns of change. The majority of the children who did not show signs of symptoms at admission were found to have maintained the same condition, and pallor had improved during and after treatment. However, unlike the other symptoms, hair changes in some children were persistent and showed no response to treatment 4 weeks after discharge, although in others there had been some improvement. The majority of children with skin depigmentation had not improved but a small number did show some signs of improvement. The majority of moon faced children had responded to treatment, whereas the majority of children with flaky paint signs at admission did not. Vitamin deficiency and growth retardation showed minimal improvements 4 weeks after discharge.

Table 6.22: Comparison of clinical indicators at admission and 4 weeks after discharge

Clinical sign on admission	After 4 weeks		Total	p-value
	Yes	No		
Pallor				0.113
Yes	14(51.9%)	13(48.1%)	27(100.0%)	
No	5(27.8%)	13(72.2%)	18(100.0%)	
Total	19(42.2%)	26(57.8%)	45(100.0%)	
Hair change				0.151
Yes	12(37.5%)	20(62.5%)	32(100.0%)	
No	2(15.4%)	11(84.6%)	13(100.0%)	
Total	14(31.1%)	31(68.9%)	45(100.0%)	
Skin Depigmentation				0.001
Yes	12(70.6%)	5(29.4%)	17(100.0%)	
No	0(0.0%)	28(100.0%)	28(100.0%)	
Total	12(26.7%)	33(73.3%)	45(100.0%)	
Moon Face				0.018
Yes	6(30.0%)	14(70.0%)	20(100.0%)	
No	1(4.0%)	24(96.0%)	25(100.0%)	
Total	7(15.5%)	38(84.5%)	45(100.0%)	
Flaky Paint				0.002
Yes	3(37.5%)	5(62.5%)	8(100.0%)	
No	1(2.7%)	36(97.3%)	37(100.0%)	
Total	4(8.9%)	41(91.1%)	45(100.0%)	
Growth Retardation				0.001
Yes	8(72.7%)	3(27.3%)	11(100.0%)	
No	3(8.8%)	31(91.2%)	34(100.0%)	
Total	11(24.4%)	34(75.6%)	45(100.0%)	
Associated Infection				0.003
Yes	3(37.5(%)	5(62.5%)	08(100.0%)	
No	1(2.9%)	33(97.1%)	34(100.0%)	
Total	4(9.5%)	38(90.5%)	42(100.0%)	
Associated Vitamin Deficiency				0.001
Yes	5(71.4%)	2(28.6%)	7(100.0%)	
No	2(5.3%)	36(94.7%)	38(100.0%)	
Total	7(15.6%)	38(84.4%)	45(100.0%)	

6.3.4.10.1 Behaviour Disorders 4 Weeks after Discharge

Table 6.23 shows the changes in behaviour four weeks after discharge. It can be seen that children with PCM showed definite improvements in their behaviour after correction of their malnutrition and they demonstrated normal behaviour on recovery.

Table 6.23: Comparison of behavioural disorders at admission and 4 weeks after discharge

Clinical indication on admission	Clinical indication after 4 weeks				Total
	Apathetic	Irritable	Anorexia	Normal	
Apathetic	1(5.6%)	1(5.6%)	1(5.6%)	15(83.3%)	18(100.0%)
Irritable	0(0.0%)	2(8.0%)	0(0.0%)	23(92.0%)	25(100.0%)
Anorexia	0(0.0%)	0(0.0%)	0(0.0%)	3(100.0%)	3(100.0%)
Total	1(2.2%)	3(6.5%)	12(.2%)	41(89.1%)	46(100.0%)
					P-value = 0.285

6.3.4.10.3 Neuropsychological Assessment 4 Weeks after Discharge

Table 6.24 indicates that the neuropsychological disorders in the PCM children were improved after 4 weeks (a more detailed supplementary table is provided in Appendix D14), and several issues are important to note from this table. The severity of the psychological disorder at admission to a therapeutic feeding programme is known to strongly predict improvement. Table 6.24 shows that it also predicts an increase in behaviour (normal, mid and moderate term) 4 weeks after discharge. Large numbers of children had mild and moderate symptoms of neuropsychological disorders, which is due to severe disorders improving and becoming mild or moderate or the child even becoming free of the disorder. Table 6.24 shows that there was a significant decrease in severe fine motor delay, which is associated with a significant increase in a moderate and mild fine motor delay. Gross motor skills among children who showed severe symptoms on admission were normal after 4 weeks.

Table 6.24: Comparison of neuropsychological indicators at admission and 4 weeks after discharge

Neuropsychological Indicator	Normal	Mild	Moderate	Severe	Normal	p-value
Personal social						0.224
At admission	0(0.0%)	7(14.6%)	13(27.1%)	28(58.3%)	48(100.0)	
At 4 weeks	0(0.0%)	19(42.2%)	20(44.4%)	6(13.3%)	45(100.0%)	
Fine motor						0.013
At admission	0(0.0%)	2(4.2%)	18(37.5%)	28(58.3%)	48(0.0%)	
At 4 weeks	1(2.2%)	15(33.3%)	23(51.1%)	6(13.3%)	45(100.0%)	
Language						0.883
At admission	0(0.0%)	6(12.5%)	19(39.6%)	23(49.9%)	48(0.0.0%)	
At 4 weeks	24(53.3%)	24(53.3%)	18(40.0%)	2(4.4%)	45(100.0%)	
Gross motor						0.024
At admission	1(2.1	5(10.4	10(20.8	32(66.7%)	48(100.0%)	
At 4 weeks	2(4.4%)	18(40.0%)	19(42.2%)	6(13.3%)	45(100.0%)	

6.3.4.10.4 EEG 4 Weeks after Discharge

Table 6.25 compares the background EEG details at admission and after 4 weeks. It can be observed that 30 children exhibited a normal background at admission which increased to 44 children after 4 week indicating a reduction in the number of children showing signs of a slow background and very slow background.

Table 6.25: Comparison of EEG background abnormalities at admission and 4 weeks after discharge

Background at admission	Background at 4 weeks			Total
	SlB	VSlB	Normal	
SlB	0(0.0%)	0(0.0%)	13(100.0%)	13(100.0%)
VSlB	1(33.3%)	0(0.0%)	2(66.7%)	3(100.0%)
Normal	1(3.0%)	0(0.0%)	29(97.0%)	30(100.0%)
Total	2(4.2%)	0(0.0%)	44(95.8%)	46(100.0%)
				p-value = 0.918

A comparison of focal and multifocal patterns at admission and at four weeks is shown in Table 6.26, where it can be seen that the total number of focal pattern abnormalities has been reduced to a single child 4 weeks after discharge compared to in 12 at admission. Similarly, the total number of multifocal pattern abnormalities at admission was 7, whereas at 4 weeks after discharge it was 1, and the number of children with focal and multifocal pattern abnormalities at admission has been reduced from 8 to only 1. Overall, there was an increase in the number of children who showed normal attributes at the 4 week follow up (from 19 to 43).

Table 6.26: Comparison of focal and multifocal abnormalities at admission and 4 weeks after discharge

Focal and multifocal at admission	Focal and multifocal at 4 weeks				Total
	Focal	Multifocal	Focal and Multifocal	Normal	
Focal	0(0.0%)	0(0.0)	0(0.0%)	12(100.0)	12(100.0%)
Multifocal	1(14.3%)	0(0.0%)	0(0.0%)	6(85.7%)	7(100.0%)
Focal and multifocal	0(0.0%)	0(0.0%)	0(0.0%)	8(100.0%)	8(100.0%)
Normal	0(0.0%)	1(4.5%)	1(4.5%)	17(90.9%)	19(100.0%)
Total	1(2.1%)	1(2.1%)	1(2.1%)	43(93.8%)	46(100.0%)
					p-value = 0.846

A comparison of focal activities at admission and after four weeks is presented in Table 6.27. At admission only 26 normal focal patterns were observed; however, 4 weeks after discharge there were 43 normal focal patterns. There was also a strong reduction in the number of focal slow activity, left focal slow activity, frontal slow activity and focal sharp activity since admission.

Table 6.27: Comparison of focal activities at admission and 4 weeks after discharge

Focal Patterns at admission	Focal Activities at 4 weeks			Total
	RFoShA	FoShA	Normal	
FoSlA	0(0.0%)	0(0.0%)	3(100 %)	3(100.0%)
LFoShA	0(0.0%)	0(0.0%)	3(100.0%)	3(100.0%)
FrSlA	0(0.0%)	0(0.0%)	2(100.0%)	2(100.0%)
RFoShA	0(0.0%)	0(0.0%)	4(100.0%)	4(100.0%)
RCTSlA	0(0.0%)	0(0.0%)	1(100.0%)	1(100.0%)
FoShA	0(0.0%)	0(0.0%)	2(100.0%)	2(100.0%)
FrShSlA	0(0.0%)	0(0.0%)	1(100.0%)	1(100.0%)
LSiShA	0(0.0%)	0(0.0%)	3(100.0%)	3(100.0%)
Normal	1(3.4%)	1(3.4%)	24(93.1%)	26(100.0%)
Total	1(2.1%)	1(2.1)	43(95.8%)	45(100.0%)
				p-value = 0.408

In Table 6.28 it is clear that at admission there were only 30 normal multifocal patterns observed; however at 4 weeks after discharge there were 43 children had normal multifocal patterns.

Table 6.28: Comparison of multifocal activities at admission and 4 weeks after discharge

Multifocal Patterns	Multifocal Activities			Total
	LFtCTShA	MFoShA	Normal	
BiFrCShA	0(0.0%)	0(0.0%)	1(100.0%)	1(100.0%)
RCPTShA	0(0.0%)	0(0.0%)	1(100.0%)	1(100.0%)
LTMFoShA	0(0.0%)	0(0.0%)	1(100.0%)	1(100.0%)
MFoShA	0(0.0%)	0(0.0%)	4(100.0%)	4(100.0%)
LPTShA	0(0.0%)	0(0.0%)	1(100.0%)	1(100.0%)
RFrCTShA	0(0.0%)	0(0.0%)	1(100.0%)	1(100.0%)
LSiMFoShA	0(0.0%)	0(0.0%)	2(100.0%)	2(100.0%)
FrPCShSlA	0(0.0%)	0(0.0%)	1(100.0%)	1(100.0%)
LCPTShA	0(0.0%)	0(0.0%)	1(100.0%)	1(100.0%)
BiFrShSlA	0(0.0%)	0(0.0%)	1 (100.0%)	1(100.0%)
MFoShSlA	0(0.0%)	0(0.0%)	1(100.0%)	1(100.0%)
Normal	1(3.0%)	1(3.0%)	28(93.9%)	30(100.0%)
Total	1(2.1%)	1(2.1%)	43(95.8%)	45(100.0%)
				p-value = 0.414

6.3.4.11 Profiles of Children at 12 Weeks Follow-Up

6.3.4.11.1 Clinical Indicators 12 Weeks after Discharge

Table 6.29 compares the pallor of underweight children and those affected by kwashiorkor, marasmus. The results indicate that the children who had symptoms of pallor at admission were significantly (p-value=0.029) found to show improvements 12 weeks after discharge and the children who had symptoms of hair change at admission were also found to show signs of improvement, together with the children who had symptoms of skin depigmentation at admission. The children with moon faces at admission had improved 12 weeks after discharge and so too had the children with flaky paint signs at admission.

Children who had symptoms of an associated infection at admission had improved as had children with an associated vitamin deficiency at admission. Children who had symptoms of growth retardation at admission were found to show improvements 12 weeks after discharge. Finally, children who had symptoms of wasting muscle at admission were also improved 12 weeks after discharge.

Table 6.29: Comparison of clinical indicators at admission and 12 weeks after discharge

At admission	**After 12 weeks**			**At admission**	**After 12 weeks**		
	Yes	**No**	**Total**		**Yes**	**No**	**Total**
Pallor			p=0.029	**Growth Retardation**			p=0.877
Yes	11(45.8%)	13(54.2%)	24(100%)	Yes	2(18.2%)	9(81.8%)	11(100%)
No	2(12.5%)	14(87.5%)	16(100%)	No	5(16.1%)	26(83.9%)	31(100%)
Total	13(32.5%)	27(67.5%)	40(100%)	Total	11(24.4%)	34(75.6%)	45(100%)
Hair change			p=0.319	**Associated Infection**			p=0.003
Yes	8(25.0%)	24(75.0%)	32(100%)	Yes	3(37.5(%)	5(62.5%)	08(100%)
No	1(10.0%)	9(90.0%)	10(100%)	No	1(2.9%)	33(97.1%)	34(100%)
Total	9(21.4%)	33(78.6%)	42(100%)	Total	4(9.5%)	38(90.5%)	42(100%)
Skin Depigmentation			p=0.001	**Associated Vitamin**			p=0.006
Yes	9(52.9%)	7(47.1%)	17(100%)	Yes	3(42.8%)	4(57.2%)	7(100%)
No	0(0.0%)	26(100%)	28(100%)	No	2(5.7%)	33(94.3%)	35(100%)
Total	9(20.0%)	33(80.0%)	45(100%)	Total	5(11.9%)	37(88.1%)	45(100%)
Moon Face			p=0.018	**Wasting of muscle**			p=0.001
Yes	4(30.0%)	15(70.0%)	19(100%)	Yes	12(44.5%)	17(55.5%)	27(100%)
No	0(0.0%)	23(100%)	23(100%)	No	3(23.1%)	10(76.9%)	13(100%)
Total	4(15.5%)	38(84.5%)	42(100%)	Total	15(35.7)	27(64.3%)	42(100%)
Flaky Plant			p=0.007				
Yes	3(33.3%)	6(66.7%)	9(100%)				
No	1(3.0%)	32(97.0%)	33(100%)				
Total	4(15.5%)	38(84.5%)	42(100%)				

6.3.4.11.2 Behaviour Disorders 12 Weeks after Discharge

Table 6.30 identifies the differences between behaviour at admission and 12 weeks after discharge, where following treatment there is a definitive improvement. Most children afflicted with protein energy malnutrition disorders were found to show normal behaviour on recovery.

Table 6.30: Comparison of behaviour disorders at admission and 12 weeks after discharge

Behaviour Disorder at admission	Behaviour Disorder after 12 weeks				Total
	Apathetic	Irritable	Anorexia	Normal	
Apathetic	1(7.1%)	0(0.0%)	0(0.0%)	13(92.9%)	14(100.0%)
Irritable	0(0.0%)	4(16.0%)	1(4.0%)	20(80.0%)	25(100.0%)
Anorexia	0(0.0%)	0(0.0%)	0(0.0%)	3(100.0%)	3(100.0%)
Total	1(2.4%)	4(9.5%)	1(2.4%)	36(85.7%)	42(100.0%)
					p-value = 0.811

6.3.4.11.3 Neuropsychological Indicators 12 Weeks after Discharge

The overall results for the neuropsychological indicators 12 months after discharge are shown in Table 6.31 (a more detailed supplementary table is provided in Appendix D15). The percentage of children who had neuropsychological disorders at admission had significantly reduced 12 weeks after discharge, with only one child demonstrating a severe personal social disorder and one child a severe gross motor delay.

Table 6.31: Comparison of neuropsychological indicators at admission and 12 weeks after discharge

Neuropsychological Indicator	Normal	Mild	Moderate	Severe	Normal	p-value
Personal social						0.001
At admission	0(0.0%)	7(14.6%)	13(27.1%)	28(58.3%)	48(100.0)	
At 12 weeks	8(18.6%)	24(65.1%)	6(14.0%)	1(2.3%)	43(100.0%)	
Fine motor						0.001
At admission	0(0.0%)	2(4.2%)	18(37.5%)	28(58.3%)	48(0.0%)	
At 12 weeks	6(14.0%)	29(67.4%)	8(18.6%)	0(0.0%)	43(100.0%)	
Language						0.001
At admission	0(0.0%)	6(12.5%)	19(39.6%)	23(49.9%)	48(0.0.0%)	
At 12 weeks	9(20.9%)	25(58.1%)	9(42.9%)	0(0.0%)	43(100.0%)	
Gross motor						0.001
At admission	1(2.1%)	5(10.4%)	10(20.8%)	32(66.7%)	48(100.0%)	
At 12 weeks	9(31.0%)	17(58.6%)	2(6.9%)	1(3.4%)	44(100.0%)	

6.3.4.11.4 EEG 12 Weeks after Discharge

Table 6.32 compares the EEG backgrounds at admission and 12 weeks after discharge. A normal background was observed in 27 children at admission and 40 children 12 weeks after discharge, indicating a reduction in the number of children showing signs of a slow background and very slow back ground.

Table 6.32: Comparison of EEG background at admission and 12 weeks after discharge

Background after admission	Background after 12 weeks			Total
	SlB	VSlB	Normal	
SlB	0(0.0%)	(0.0%)	13(100.0%)	13(100.0%)
VSlB	0(0.0%)	0(0.0%)	3(100.0%)	3(100.0%)
Normal	2(6.4%)	0(0.0%)	25(93.6%)	27(100.0%)
Total	2(4.4%)	0(0.0%)	40(95.5%)	42(100.0%)
	p-value =0.352			

Table 6.33 shows that there was also an increase in the number of children who showed normal focal, multifocal and focal and multifocal patterns 12 week after discharge (a more detailed supplementary table is provided in Appendix D16 and D17). There was also an increase in the number of children who showed normal focal activity and normal multifocal activity 12 weeks after discharge.

Table 6.33: Comparison of focal and multifocal abnormalities at admission and 12 weeks after discharge

Focal and multifocal at admission	Focal and multifocal after 12 weeks				Total
	Focal	Multifocal	Focal and multifocal	Normal	
Focal	0(0.0%)	0(0.0%)	0(0.0%)	11(100.0%)	11(100.0%)
Multifocal	0(0.0%)	0(0.0%)	0(0.0%)	7(100.0%)	7(100.0%)
Focal and Multifocal	0(0.0%)	0(0.0%)	0(0.0%)	8(100.0%)	8(100.0%)
Normal	0(0.0%)	1(4.5%)	0(0.0%)	15(95.5%)	16(100.0%)
Total	0(0.0%)	1(2.1%)	0(0.0%)	41(97.9%)	42(100.0%)

6.3.5 ANCOVA Results

In this analysis the study used the one-way analysis of covariance (ANCOVA) to assess the role of tribes as a possible confounder or effect modifier, therefore tribe status was included as a stratification level in all the subsequent analyses.

6.3.5.1 Association of PCM and Tribe with Clinical Indicators

In table 6.34, the impact of PCM on clinical indicators is identified at the time of a child's admission (a more detailed supplementary table is provided in Appendix D18). If the Levene's test is significant with a p-value (p=0.002) < α (0.05), then equal variances of the clinical indicator are not assumed. The linear relationship between the tribes and the clinical indicator, controlling for the case and control was found not to be significant. The test assesses the differences among the adjusted means for the four groups which are reported in the estimated marginal means box as 2.155 for marasmus, 2.554 for kwashiorkor), 1.973 for underweight, and 1.007 for control group. The measure of association found that the three levels of PCM and the control group account for approximate 6% of the total variance in the clinical indicators, controlling for the effect of tribe. At this point in the analysis, Table 6.34 shows that the main effect for PCM is significant when controlling for the effect of tribe.

Table 6.34: ANCOVA result for the association of PCM with clinical indicators

Levene's Test of Equality of Error Variances[a]					
Dependent Variable: Clinical indicator					
F	**df1**		**df2**	**Sig.**	
5.412	3		56	0.002	
Source	**Type I Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	18.385[a]	4	4.596	23.852	0.000
Intercept	55.180	1	55.180	286.355	0.000
Tribes	0.714	1	0.714	3.706	0.059
SPCM	17.060	3	5.687	29.511	0.000
Error	10.598	55	0.193		
Total	265.000	60			
Corrected Total	28.983	59			

[a.] R Squared = 0.082 (Adjusted R Squared = -0.063)

Measure of association

$$\boldsymbol{\omega^2 = \frac{SS_\beta - (K-1)MS_W}{SS_T + MS_W}}$$

$$\omega^2 = \frac{17.060 - (4-1) \times 0.193}{28.983 + 0.193}$$

$$\omega^2 = \frac{17.060 - 0.579}{29.176}$$

$$\omega^2 = \frac{16.381}{229.176}$$

$$\omega^2 = 0.56\ (6\%)$$

6.3.5.1.1 Pairwise Comparisons and Effect Sizes of Clinical Indicators by PCM

Follow-up tests were conducted to evaluate the pairwise differences among the adjusted means for PCM (Table 6.35). The Bonferroni procedure was used to control for Type I error across the six pairwise comparisons (p=<0.0017). The results showed that children who had kwashiorkor significantly had (M=2.55) more symptoms of PCM after controlling for the effect of tribe, than children who were underweight (M=1.973) or control children (M=1.007) The effect sizes for these significant adjusted mean differences were 0.91, 1.7, and 1.2 respectively.

Table 6.35: Pairwise **c**omparisons and **e**ffect **s**izes of **c**linical **i**ndicator**s by PCM**

Group	**Mean**	**Adjusted Mean**	**Adjusted Mean Differences (Effect Sizes are indicated in parentheses)**			
			1	**2**	**3**	**4**
Marasmus	2.19	2.155	-----------			
Kwashiorkor	2.56	2.554	0.400*	--------		
Underweight	1.94	1.973	0.182	0.218	-----------	
Control	1.00	1.007	1.148	0.748*	0.53*	--------
			0.911	1.7	1.2	

(p=<0.0017)

6.3.5.2 Association of PCM and Tribe with Behaviour Disorders

Table 6.36 shows that the overall effect across behaviour disorders was significant (p=0.000), and PCM has a significant influence on behaviour, which is indicated by the difference among the adjusted means for the four groups as presented in the estimated marginal means box, as 1.481 for marasmus, 1.745 for kwashiorkor, 1.833 for underweight children and 6.004 for the control group (a more detailed supplementary table is provided in Appendix D19) However, the relationship between tribe and behaviour disorders was not significant, but after adjusting for tribes the association between PCM and behaviour disorders becomes significant. PCM accounts for 100% of the total variance in the behaviour disorders.

Table 6.36: ANCOVA result for the association of PCM and tribe with behaviour disorders

Levene's Test of Equality of Error Variances[a]					
Dependent Variable: behaviour disorder					
F	**df1**		**df2**	**Sig.**	
8.779	3		56	0.000	
Source	**Type I Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	179.655[a]	4	44.914	162.567	0.000
Intercept	127.551	1	127.551	461.675	0.000
Tribes	.242	1	0.242	0.877	0.353
SPCM	179.645	3	59.882	216.744	0.000
Error	15.195	55	0.276		
Total	585.000	60			
Corrected Total	194.850	59			

[a] R Squared = 0.922 (Adjusted R Squared = 0.916)

Measure of Association

$$\boldsymbol{\omega^2 = \frac{SS_\beta - (K-1)MS_W}{SS_T + MS_W}}$$

$$\omega^2 = \frac{179.645 - (4-1) \times 0.276}{194.850 + 0.276}$$

$$\omega^2 = \frac{179.645 - 0.828}{195.126}$$

$$\omega^2 = \frac{196.812}{195.126}$$

$$\omega^2 = 1.01 \ (100\%)$$

6.3.5.2.1 Pairwise Comparisons and Effect Sizes of Behaviour Disorder by PCM

The results of the first pairwise comparison are shown in Table 6.37, where the overall effect across conditions was found to be significant, and the tests indicated that all four conditions were significantly different from each other. The participants who were underweight (M = 6.004) demonstrated a significantly higher level of behavioural disorders than the two other syndromes. The effect sizes for the adjusted means are 8.615, 8.112 and 7.945, respectively

Table 6.37: Pairwise comparisons and effect sizes of behaviour disorders by PCM

Group	Mean	Adjusted Mean	Adjusted Mean Differences (Effect Sizes are indicated in parentheses)			
			1	2	3	4
Marasmus	1.50	1.481	------			
Kwashiorkor	1.75	1.745	0.264	--------		
Underweight	6.00	6.004	4.523*	4.259*	-------	
Control	1.81	1.833	0.352	0.088	4.171*	----------
			8.615	8.112	7.945	

p=<0.0001

6.3.5.3 Association of PCM and Tribe with EEG Abnormalities

In Table 6.38 (a more detailed supplementary table is provided in Appendix D20), the overall effect of PCM across conditions is shown to be significant (p=0.0001). A linear relationship is present between the covariate (tribe) and the dependent variable (EEG abnormality) is not observed due to an insignificant p-value (p= 0.055 > α 0.05); however, after adjusting for tribe, the effect of PCM on EEG abnormality is significant (p=0.0001). The pattern of means for the main effect is presented in the estimated marginal means box as 1.713 for marasmus, 2.006 for kwashiorkor, 1.784 for underweight children and 1.078 for the control group. PCM accounts for 45% of the total variance in the EEG abnormalities, although At this point in the analysis tribe has no influence on EEG abnormalities.

Table 6.38: ANCOVA result for the association of PCM and tribe with EEG abnormalities

Levene's Test of Equality of Error Variances[a]					
Dependent Variable: EEG abnormality					
F	**df1**		**df2**	**Sig.**	
7.855	3		56	0.000	
Source	**Type I Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	6.635[a]	4	1.659	14.371	0.000
Intercept	56.571	1	56.571	490.121	0.000
Tribes	0.443	1	0.443	3.842	0.055
SPCM	6.239	3	2.080	18.017	0.000
Error	6.348	55	0.115		
Total	183.000	60			
Corrected Total	12.983	59			

[a.] R Squared = 0.511 (Adjusted R Squared = 0.475)

Measure of association

$$\boldsymbol{\omega^2 = \frac{SS_\beta - (K-1)MS_W}{SS_T + MS_W}}$$

$$\omega^2 = \frac{6.239 - (4-1) \times 0.115}{12.983 + 0.115}$$

$$\omega^2 = \frac{6.239 - 0.345}{13.098}$$

$$\omega^2 = \frac{5.894}{13.098}$$

$$\omega^2 = 0.449\ (45\%)$$

6.3.5.3.1 Pairwise Comparisons and Effect Sizes of EEG Abnormality by PCM

The results (Table 6.39) showed that children who had kwashiorkor (M = 2.006) had significantly higher EEG abnormalities, after controlling for the effect of their tribe, than children who were underweight (M=1.784), or marasmic (M=1.713), while children who were free of PCM had a lower level of brain abnormalities (M=1.078). The effects sizes for these significant adjusted mean differences were1.873, 1.008 and 0.354 respectively.

Table 6.39: Pairwise comparisons and effect sizes of EEG abnormalities by PCM

Group	Mean	Adjusted Mean	Adjusted Mean Differences (Effect Sizes are indicated in parentheses)			
			1	2	3	4
Marasmus	1.69	1.713				
Kwashiorkor	2.00	2.006	0.293*	-------		
Underweight	1.81	1.784	0.071	0.222*	------	
Control	1.08	1.078	0.635	0.342	0.120*	-------
			1.873	1.008	0.354	

p=<0.0001

6.3.5.4 Association of PCM and Tribe with Neuropsychological Disorders

In Table 6.40 (a more detailed supplementary table is provided in Appendix D21), Levene's Test shows that the error variance of neuropsychological disorders is equal across the groups (p=0.834). As noted in Table 6.40, the linear relationship between the case and control groups and neuropsychological disorders after controlling for tribe is not significant, although the relationship between PCM and neuropsychological disorders is nearly significant. At this stage of the analysis, the test assesses the differences among the adjusted means for the four groups which are reported in the estimated marginal means box in as 3.288 for marasmus, 3.669 for kwashiorkor, 3.506 for underweight children, and 1.717 for the control group. The measure of association found that that the three levels of PCM and the control group account for approximate 5% of the total variance in the neuropsychological disorder after controlling for the effect of tribe.

Table 6.40: ANCOVA result for the association of PCM and tribe with neuropsychological disorders

Levene's Test of Equality of Error Variances[a]					
Dependent Variable: Neuropsychological disorder					
F	**df1**	**df2**	**Sig.**		
0.182	2	40	0.834		
Source	**Type I Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	2.264[a]	3	0.755	1.871	0.151
Intercept	45.644	1	45.644	113.128	0.000
Tribes	0.055	1	0.055	0.136	0.714
SPCM	2.205	2	1.102	2.732	0.058
Error	15.736	39	0.403		
Total	190.000	43			
Corrected Total	18.000	42			

[a.] R Squared = 0.126 (Adjusted R Squared = 0.059)

Measure of Association

$$\boldsymbol{\omega^2 = \frac{SS_\beta - (K-1)MS_W}{SS_T + MS_W}}$$

$$\omega^2 = \frac{2.205 - (4-1) \times 0.403}{18.000 + 0.403}$$

$$\omega^2 = \frac{2.205 - 1.209}{18.403}$$

$$\omega^2 = \frac{0.996}{18.403}$$

$$\omega^2 = 0.05\ (5\%)$$

6.3.5.4.1 Pairwise Comparisons and Effect Sizes of Neuropsychological disorders by PCM

There is a significant pairwise difference between SPCM and the control group at the 0.002 alpha level (Table 6.41). The control group had a significantly lower level of neuropsychological disorders compared to the children with marasmus, kwashiorkor and who were underweight. The effect sizes for these significant adjusted mean differences were 0.247, 1.874 and 1.617, respectively.

Table 6.41: Pairwise comparisons and effect sizes of neuropsychological disorders by PCM

Group	Mean	Adjusted Mean	Adjusted Mean Differences (Effect Sizes are indicated in parentheses)			
			1	2	3	4
Marasmus	3.19	3.288				
Kwashiorkor	3.69	3.669	0.381	----------		
Underweight	3.44	3.506	0.218	0.163	----------	
Control	1.67	1.717	1.571*	1.190*	1.027*	
			0.247	1.874	1.617	---------

p=<0.002

6.3.5.5 Association of PCM and Tribe with Nutrition

In Table 6.42 the impact of PCM on nutrition is identified at the time of child admission (a more detailed supplementary table is provided in Appendix D22). The assumption of homogeneity of variance is met with but a linear relationship between tribe and nutrition, controlling for the case and control group is not significant (p=0.377). However, after adjusting for tribe, there is a significant impact of PCM (p=0.024). This is indicative of a significant positive relationship between the dependents (different nutrition features) and the independent (PCM) variables at admission. The test assesses the differences among the adjusted means for the four groups which are reported in the estimated marginal means box in as 1.662 for marasmus, 2.370 for kwashiorkor, 2.293 for underweight children, and 2.507 for the control group. The measure of association found that that the three levels of PCM and the control group account for approximately 11% of the total variance in nutrition, after controlling for the effect of tribe.

Table 6.42: ANCOVA result for the association of PCM and tribe with nutrition

Levene's Test of Equality of Error Variances[a]			
Dependent Variable: Nutrition			
F	**df1**	**df2**	**Sig.**
0.048	3	55	0.986

Source	**Type I Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	6.307[a]	4	1.577	2.608	0.046
Intercept	74.783	1	74.783	123.713	0.000
Tribes	0.479	1	0.479	0.792	0.377
SPCM	6.198	3	2.066	3.418	0.024
Error	32.642	54	0.604		
Total	321.000	59			
Corrected Total	38.949	58			

[a.] R Squared = 0.162 (Adjusted R Squared = 0.100)

Measure of association

$$\boldsymbol{\omega^2 = \frac{SS_\beta - (K-1)MS_W}{SS_T + MS_W}}$$

$$\omega^2 = \frac{6.198 - (4-1) \times 0.604}{38.949 + 0.604}$$

$$\omega^2 = \frac{6.198 - 1.812}{39.553}$$

$$\omega^2 = \frac{4.386}{39.553}$$

$$\omega^2 = 0.111\ (11\%)$$

Follow-up tests (Table 6.43) were conducted to evaluate the pairwise differences among the adjusted means for PCM and the control group. The Bonferroni procedure was used to control for Type I errors across the six pairwise comparisons (a¢ =0.0001). The results showed that underweight children (M = 2.507) had significantly higher nutritional deficiencies after controlling for the effect of tribe, than children who had kwashiorkor (M = 2.370), were marsmic (M = 2.293), and children who had no PCM. The effects of size for the significant adjusted mean difference were 1.088.

Table 6.43: Pairwise comparisons and effect sizes of nutritional deficiency by PCM

Group	**Mean**	**Adjusted Mean**	**Adjusted Mean Differences (Effect Sizes are indicated in parentheses)**			
			1	**2**	**3**	**4**
Marasmus	1.69	1.662				
Kwashiorkor	2.38	2.370	0.708			
underweight	2.50	2.507	0.845*	0.137		
Control	2.27	2.293	0.631	0.077	0.060	
			1.088	0.176	0.077	

p=<0.0001

6.3.5.6 Assessment of PCM and its Impact on Clinical, Psychological, EEG and Nutritional Attributes 12 Weeks after Discharge

This section presents the overall relationship between PCM and the dependent variables (clinical indicators, neuropsychological disorders, EEG abnormalities and nutritional deficiency). The ANCOVA results are shown in Table 6.44.

Table 6.44: ANCOVA results at admission

Levene's Test of Equality of Error Variances[a]			
F	**df1**	**df2**	**Sig.**
1.221	46	1	0.232.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	31.809[a]	44	0.723	11.366	0.034
Intercept	0.116	1	0.116	1.820	0.270
Tribes	1.530	1	1.530	24.056	0.016
Overall clinical	5.590	7	0.799	12.555	0.031
Overall nutritional_	3.936	5	0.787	12.376	0.032
Overall Neuropsychological	1.363	3	0.542	9.461	0.074
Personal social	0.900	2	0.450	7.078	0.073
Fine motor	4.208	2	2.104	33.081	0.009
Language	3.071	2	1.536	24.142	0.014
Gross motor	1.615	3	0.538	8.464	0.050
EEG pattern	0.398	1	0.398	6.262	0.044
EEG Background	0.118	2	0.059	0.924	0.487
Focal patterns	3.361	6	0.560	8.808	0.050
Multi focal patterns	4.040	8	0.505	7.940	0.050
Error	0.191	3	0.064		
Total	224.000	48			
Corrected Total	32.000	47			

[a.] R Squared = .994 (Adjusted R Squared = .907)

From the ANCOVA results it can be seen that the underlying assumption of homogeneity of variance for the one-way ANCOVA has been met, as evidenced by $F(46, 1) = 1.122$, p=0.232. The test evaluates the relationship between tribe and the dependent variables, controlling for PCM. In this study it can be concluded that tribe is an effective covariate, F (1, 3) = 24.056, p <0.01. After adjusting for tribe, the association between PCM and the dependent variables is statistically significant (p=<0.05), except for personal social skills (p= 0.073) and EEG background (p=0.487).

6.4 Discussion of the Findings

6.4.1 Sociodemographic Characteristics

The study revealed that the mean weight of girls was found to be higher than for boys in all age groups. This finding is supported by a study conducted by Fazili (2012) among children to determine the mean weights among girls. It is observed from the study by Osinki (2003) that among the urban poor, mothers' work outside the home and mothers' responsibility for the management of household finances (both likely to reflect a necessity, rather than a choice), short birth intervals (resulting in competition from a younger sibling), and high dependency ratios within a household severely compromised the nutritional status of weaning-age children. Relatively less impact was found to be associated with similar attributes of the father. Similarly, in a study by Owar et al. (2000) it was observed that the family income, type of housing and other socioeconomic attributes were found to have a direct impact on the protein malnutrition condition among respondents. Poverty often accompanies PEM due to low food availability and a lack of means to produce or buy food, while parents on higher incomes had well-nourished children. A family's food buying capability may be low due to their low income, but a nursing mother's cultural food practices also determine the types of foods growing infants eat. Knowledge of local cultural food practices is very important in the search for a permanent solution to the problems of PCM.

6.4.2 Clinical Indicators

In this study signs of skin related problems were observed among all three different types of PCM and were highly prevalent in children with kwashiorkor. Studies by Liu et al. (2001) and Latham (1991) have indicated that the presence of flaky paint like skin is descriptive of kwashiorkor disease; this type of skin shows the presence of 'pasted on' scales, like dermatitis. Mclaren (1987) identified that there the presence of flaky paint skin is most prevalent among Kwashiorkor children compared to Marasmus or underweight children. Apart from the presence of flaky paint like skin, another feature which has been identified to be a part of the clinical diagnosis is the presence of skin depigmentation. It is observed from a study by Kul et al. (2004) that children who are afflicted with marasmus and kwashiorkor symptoms often show signs of skin depigmentation and extensive skin desquamation may present an appearance similar to a second degree burn. Areas commonly involved are nappy areas, legs and forearms, face, behind the ears, and armpits (Poskitt, 1991). These observations are line with the results observed in this study. It has been observed that among children affected by marasmus there are signs of xerotic, wrinkled, and loose skin, which is attributed to the loss of subcutaneous fat but is not characterised by any specific dermatitis (Ashworth et al., 2004). In kwashiorkor affected children, skin related depigmentation or decolouration are found to be associated with cutaneous manifestations in the form of dry atrophic skin with confluent areas of hyperkeratosis and hyperpigmentation, which splits when stretched resulting in erosions and underlying paler, and also erythematous skin (Deen et al., 2003).

In a study by Antwi (2011) the importance of clinical symptoms, such as moon faces with dropping cheeks, apathy and irritable behaviour as a result of PEM was identified. Behavioural changes are often associated with mental and neurological dysfunctions (Poskitt, 1991; Rollins et al., 2007), and in this study signs of behavioural problems were observed among all three different types of protein malnutrition. Clinical symptoms also identified that there is a distinctive change in hair type, including straightness, and lightly coloured to shades of brown or red in the hair. It also results in a sparse distribution to alopecia type skin, where hair is thin and easily pluckable; Wittenberg, (2007) observed the same results.

Apathy and irritability are commonly seen in children with kwashiorkor and EEG abnormalities have been previously documented (Freiman, 1975). It has also been observed by Ebenebe et al. (2007) and Wittenberg (2007) that the presence of protein malnutrition increases the susceptibility of a child to infections like *Candida* or anaerobic bacteria, and sometimes the presence of such infections may cause parallel infections related to the oral mucosa and gums (Jenkinson and Douglas, 2002). This may also be associated with the increased presence of a vitamin deficiency (Rollins et al., 2007). The role of the lack of nutrition in infection is clearly present, and the association between the two factors is strongly linked with environmental conditions, intracellular metabolism, and social cultural interrelations. During times of famine or poverty, children's diets often tend to consist primarily of carbohydrate staples, and this study showed that the intake of nutritious food, like legumes and fish, is relatively less in children with PCM.

6.4.3 Nutritional Assessment

From the bivariate analysis of the case and control groups it is clear that the children affected by PCM had a low consumption of staple food and legumes. A study by Chen et al. (1979) identified that there are seasonal dimensions of protein malnutrition in rural Bangladesh, due to the lack of enough cereals as staples and legumes. This finding is supported by Iqbal et al. (2006) who indicated that in third world nations the lack of access to plant protein sources, like legumes, results in PCM. In a study by Chadha et al. (2003) the importance of indigenous vegetables and fruits in promoting the nutritional status of infants was reported, whilst Muniz-Junqueria et al. (2002) observed that the relationship between PCM and a diet containing fruit and vegetables is important, as it will also result in improvements in the level of vitamin A in children. The results of a malnutrition survey found that children frequently lacked more than one micronutrient (Labadarios et al., 2008) and Labadarios et al. (2005) identified that there is a need for improvements to nutritional supplements. Graham et al. (2001) reported that staple foods are important in order to address malnutrition among children, and the absence of good nutritional supplements in terms of staple foods results in a nutritional deficit among children leading to protein malnutrition, a view supported by Français (1997).

6.4.4 Neuropsychological Assessment

The results of this study indicated that marasmus, kwashiorkor and underweight children had lower scores for fine motor, gross motor, language and personal social skills than the control group. This observation shows that children who are underweight or who have a slight degree malnutrition can be affected in their ability to perform. The result is in agreement with a study conducted on Senegalese children which found that underweight children had lower motor skills than normal children (Benefice, 1990).

The social behaviour of a child is directly impacted upon by several environmental conditions, including a lack of nutrition accompanied by neurochemistry and functional aspects of the central nervous system, which has repercussions on social behaviour and are often found to impact upon gross motor functions and language development (Morgane et al., 1978). Social responsiveness has been found to increase following an improvement in fine motor adaptive skills in malnourished rats (Pollitt, 1995), whilst a decrease in social interaction and an increase in aggressive behaviour was found to be associated with reduced levels of nutritional intake (Francova, 1972). The adverse effects of PCM on behaviour problems could be related to a delay in certain structural and functional maturation processes, such as delayed myelination and the reduced overall development of dendritic arborisation of the developing brain (Udani, 1992).

From a study by Powel et al. (2004), it was identified that early psychosocial stimulation is directly related to the nutritional status of a child. Their research identifies that an under nourished child is found to show a decreased ability to adapt to social situations and show lower personal social skills. This is supported by the finding from this study where treatment resulted in improvements in personal social skills. Powel et al. (2004) examined the instances of psychological issues in a study of 139 children in Jamaica, and found that psychosocial stimulation ensured an improvement in fine adaptive skills, language skills and gross motor skills as also observed in this study.

6.4.5 Electroencephalogram

The results showed that the majority of children with PCM showed abnormal EEGs, which is in agreement with the findings of others where children in the acute phase of PCM have been found to exhibit abnormal EEGs (Taroi, 1974). Following treatment, there was a significant reduction in the number of children with abnormal EEG, again a finding supported by other studies, although recovery may take a few weeks to a few months (Taroi, 1974). Successful treatment and an improvement in a child's EEG was also reported Nelson (1959) where the EEGs of the recovered children resembled those of healthy children. Bartel (1979) stated that with treatment EEG abnormalities eventually disappeared, but could persist for several months after treatment in the most severely malnourished children or in those children exposed to PCM before they were six months of age, which might reflect the long-term effects of malnutrition on cerebral function. In contrast, Durmaz et al. (1999) found different results when comparing malnourished infants to controls at the time of their admission into a nutritional programme and when discharged which were opposite to the results obtained in this study.

EEG activities have been found to be abnormal in several studies which involve malnourished animals and humans. Alterations in cortical and hipocampal electrical activity have been observed in the EEGs of malnourished rats (Nagy et al., 1977), and EEG abnormalities are also quite high among human patients. Furthermore, EEG activity is vital in exerting control over a variety of child growth and development factors; therefore, it is important to study the influence of the nutritional status during development on electrical cerebral activity.

During recovery, the food intake of a child will influence their improvement and during this process the psychological and emotional needs of a child should be catered for immediately before they are discharged. Whilst hospitalised, a child's parents and any other caregivers should be given proper counselling regarding rehabilitation and preventive measures in order to avoid a repeated occurrence (Golden and Golden, 2000). The most common aspect used to protect and save a child from nutritional rehabilitation are a weight-for-length of –1SD (90%) of the median NCHS/WHO standard (Fuchs et al., 2004).

6.4.6 Association between PCM, EEG, Clinical and Neuropsychological Indicators

This study has identified a number of clinical and neuropsychological indicators that are significantly associated with an abnormal EEG; clinical indicators include behaviour disorders, moon face and skin depigmentation, whilst neuropsychological indicators include fine motor and personal social skills. An explanation for this finding is that the brain receives, stores, and integrates sensory information, before initiating and controlling motor responses. These functions correspond to mental activities and form the basis for behaviour (Penland, 1993); thus, theoretically, there is a direct connection between nutrition, brain function, and behaviour. Furthermore, behaviour may be unique as a criterion for establishing nutritional adequacy, in that it represents the functional integration of all the biological systems, including homeostatic and other compensatory mechanisms that determine the practical importance of a nutritional deficit or excess (Penland, 1993).

6.4.7 Impact of PCM and Tribe on Brain Development

The linear relationship between tribe and the clinical indicators, controlling for the case and control group was found to not be significant. However, children who had kwashiorkor had all the clinical symptoms, which was a significant finding. In terms of behaviour, the study found a significant relationship between PCM and behaviour disorders but when controlled for tribe there was no association between PCM and behaviour. The participants who were underweight demonstrated significantly higher levels of behaviour disorders than the two other syndromes.

The relationship between PCM and EEG abnormalities was significant ($p = 0.0001$), but the relationship between tribe and EEG insignificant. After adjusting for tribes, the effect of PCM on EEG abnormalities remained significant ($p=0.0001$), and children with kwashiorkor had a higher level of EEG abnormalities, while the control group had the lowest levels. The association between PCM and tribe with neuropsychological disorders did not indicate a significant association, even after adjustment. The control group had a significantly lower level of neuropsychological disorders compared to children with marasmus, while underweight children had a significantly higher nutritional deficiency, after controlling for the effect of tribe, indicating a significant positive relationship.

Thus, this study provide evidence obtained from investigational research pertaining to human beings and animals on the way nutrition influences brain growth which will help us to comprehend the ways in which our surroundings can change the neuronal procedures in the growing brain of a young child and teenager, and could additionally provide specific information on ways to enhance the development of a child’s brain.

Chapter 7 - Overall Discussion and Recommendations

7.1 Overall Discussion

The overall discussion of the findings of this study will be divided into three major sections: the prevalence and seasonal variation of PCM, demographic factors influencing PCM among infants and young children in Sudan, and the impact of PCM on brain function. In the first part of the study data was collected during the wet and dry seasons to investigate the prevalence and seasonal variation of PCM. The study was carried out in KTH and CEH, which are referral hospitals located in the eastern part of Khartoum and a total of 466 patients aged 0-59 months were enrolled in the study. Determinant factors for PCM in children in Sudan were investigated, particularly demographic factors that contribute to the high prevalence of PCM in Sudanese children. Khartoum was selected because it houses 19% of the total population of Sudan (CBS, 2008) and represents all areas of Sudan. In the second study sixty children aged 12-36 months were examined in order to estimate the effect of PCM on brain function.

7.1.1 Prevalence of PCM and Seasonal Variation

7.1.1.1 Prevalence of SPCM

The overall level of PCM (marasmus, kwashiorkor, marasmic kwashiorkor) was 1.5% among Sudanese children aged less than 5 years old. This finding is similar to that of other studies which have stated that severe malnutrition affects 1-2% of pre-school children in developing countries, although the prevalence in Sudan was lower than in Tanzania which was 5% (Sunguya et al., 2006). The prevalence of PCM was relatively high, with marasmus at 66.9% and kwashiorkor at 23.4%. Although these are single anthropometric measurements, they are valid measures of nutritional status, especially for children at one year of age and beyond. Scholl et al. (1983) found that single anthropometric measurements taken at 1 year of age could identify up to 78% of future cases of PEM in 2-3 year old. In Khartoum, the presence of marasmus and marasmic kwashiorkor has previously been reported as 49%, and 16% of children, respectively (Omar, 1975), and this was corroborated with findings for Wad Medani, where marasmus was reported to be 55%, kwashiorkor was 31% and marasmic kwashiorkor was 13% (Taha, 1979). The prevalence was not substantially different from the findings reported by Mabyou (1990), where marasmus was 62%, kwashiorkor was 20% and marasmic kwashiorkor was 17.8%, whilst the prevalence did differ from study in a Paediatric Hospital in Eastern Sudan which reported that 92.4% were marasmic, 5.2% had kwashiorkor and 2.3% had marasmic kwashiorkor (Elbushra and Eltom, 1989). It has been observed by many paediatricians working at KTH and CEH that the number of children with PCM has shown a considerable increase over recent years (Hussain, 1991), and the prevalence of marasmus, kwashiorkor and marasmic kwashiorkor observed in this study was lower than expected. Despite the expansion of paediatric hospitals in Sudan, the data did not indicate a reduction in the prevalence of PCM, and these hospitals admit some of the children with PCM.

Certain factors in Sudan may contribute to the prevalence of PCM, and are the same as in other developing countries with an increasing population and displaced people. Slum residences with no hygiene, inadequate breastfeeding and early weaning to a diet of low nutritive value, and the contamination of food by bacteria leading to infection and diarrhoeal disease are also significant factors (Monckeberg, 1970). The recent war in Sudan has resulted in the movement of many families from the western and southern regions of the country to Khartoum, and the majority of people have settled in the most deprived area of Khartoum. It is tempting to assume that PCM is mainly the result of dietary deficiency.

7.1.1.2 Impact of Seasonal Variation on the Risk of Occurrence of PCM

In order to better understand the seasonal patterns of prevalence of PCM among infants and pre-school children living in Khartoum, this study investigated the impact of seasonal variation on PCM when interacted with household characteristics, socioeconomic characteristics, child feeding practices, and household food consumption, in order to consider the effects of the wet and dry season on the prevalence of marasmus, kwashiorkor and marasmic kwashiorkor.

The Chi squared test showed that the distribution of PCM was significant associated with the season (p-0.023). One of the most striking results of this study was the substantial seasonal variation in terms of the prevalence of PCM among children. The differences in the prevalence of PCM between the rainy season and the dry season with a marked deterioration during the rainy season, can be attributed to a number of ecological, cultural and socioeconomic factors; the incidence of infectious disease which is high during the rainy season, the increased incidence of diarrhoea resulting from the contamination of water and cereal gruels which form a major component of children diets in Sudan, and the difference in access to food during the wet season, all imply that inadequate food consumption plays a considerable role in the prevalence of PCM, and evidence of a significant relationship between household food availability and PCM (Burchi, 2011) supports this assumption. The study speculates that the high incidence of PCM in the rainy season could be related to increased morbidity from diarrhoea and malaria, whereas the high incidence of PCM at the end of the dry season may reflect changes in food access depending on the cropping season.

The prevalence of PCM may rise just before the harvest when food is scarcest, and in Khartoum, the hungry season during July August and September was linked to a sharp rise in the prevalence of PCM (61.4%). The lowest levels of malnutrition (38.6%) are seen around harvest time in November through to January. Brown et al. (1982) in their studies indicated that PCM occurs at the onset of the rainy season. A good question has arisen in the light of these findings concerning the season that is responsible for the prevalence of PCM in Sudanese children during the rainy season. Firstly, most food in Khartoum is purchased from markets, and although there are occasional shortages of particular items during the rainy season, household income was found to be generally low. Therefore, it seems likely that the prevalence of PCM during the rainy season may be due to a shortage of food. Secondly, child care also remains relatively unsteady throughout the rainy season, as there were significant seasonal demands on women during the rainy season outside the house aimed at earning money for the family. This means that they were away from the home for much of the time, and children were looked after by siblings or older family members, which in some cases may result in lower standards of childcare. Thirdly, the increased incidence of infectious diseases during the rainy season is probably an important factor, as contaminated water and food may increase the incidence of diarrhoea during the rainy season. Fourthly, some families do not have a piped supply of clean water, and instead bought water from a water seller or collected water from a public supplier outside the house, and it is possible that the purchased water is contaminated during storage in the compounds with pathogens during the rains (Watkinson et al., 1980); this may contribute to diarrhoea1 disease and food becoming contaminated. Diarrhoeal disease can lead to anorexia, nutrient losses and possibly increased nutrient requirements (Martorell et al., 1980; Rahaman & Wahed, 1983). Finally, most Sudanese women, if not all, who brought their children to the hospitals were poor, thus providing strong evidence that PCM is linked to poverty, where some children receive poor quality food. The harsh environmental conditions during the rainy season may cause irritability, and probably a reduced appetite in a child; consequently, food intake may be reduced (Hassan, 1990; Akoua-Koffi et al., 2014) and hence higher levels of PCM in pre-school children during the rainy season. Moreover, a comparison of the children with PCM in the rainy season with those in the dry season yields some important results. This is presumably because additional factors, which exist in the rainy season, do not operate during the dry season. For instance, food shortages generally develop during the rainy season as stores from the previous harvest run out, and this may affect child growth.

7.1.2 Household Characteristics

7.1.2.1 Family size

In Sudan children affected by PCM often live in households that are larger or have more people (Nabag et al., 2013) and therefore the risk of PCM has been found to be highest in large households (Taha, 1979). In Sudan, about 40% of households contain five or people (Nabag et al., 2013), and in this study, 43.3% children with PCM were found to reside households with 6-8 children, 9.4% in households with 9-11 people, and 46.1% in households with 2-5 people.

The risk of children being malnourished in Zimbabwe and Ethiopia increased from 7% when there was only one child, to 38% when a household contained seven children younger than ten. In Ethiopian communities, 24% of households with more than four children were affected by malnourishment (James et al., 1999), and in South Africa the size of a household can also be used as a predictor of malnutrition (Kleynhans et al., 2006).

Approximately 60% of household incomes for children with PCM in this study was less than 300 Sudanese Pounds (£30), although families during the dry season had higher incomes (48.9%) than in the wet season (39.8%). Children with PCM from the informal urban sector had the higher percentage of households that had no income at all (Mohiddin et al., 2012). Therefore, the socioeconomic status of a family is linked to income and PCM (Pierecchi-Marti et al., 2006), and food insecurity is a major problem in Sudan, where one in three households is reported to be food insecure (FAO, 2010).

7.1.2.2 Length of Residence

Differences in the prevalence of marasmus, kwashiorkor, and marasmic kwashiorkor according to length of residence was consistent across the seasons (p-0.002), with Sudanese children showing the highest prevalence of marasmus (75.4%), kwashiorkor (58.5%) and marasmic kwashiorkor (56.5%) when their families had resided in Khartoum for less than ten years, while children whose families had migrated to Khartoum more than 10 years ago had the best nutritional status. showed similar degrees of seasonal fluctuations were seen for children with marasmus, although during wet season greater and more consistent seasonal fluctuations (p-0.002) were observed for those who resided for in Khartoum for 10-20 years. Furthermore, marasmic kwashiorkor appeared to decline steadily in the first half year of age, which was not evident for marasmus and kwashiorkor. These results highlight differences in the degree of malnutrition, as well as differences in trends in child nutritional status among children of families who had recently migrated in different seasons. Such differences in malnutrition between seasons require increased attention and a greater focus should be placed on new residents.

The length of residence of a family (20 years or more) reduced the incidence of PCM. It can be argued that this period is an important influence on the nutritional status of children because it is reinforced by the household production. This is a dynamic process that occurs within a household and integration with other members in the area of residence allows family members to combine their knowledge, resources and patterns of behaviour. Recently migrated families suffered a high prevalence of PCM in both the wet and dry seasons, and adapting to a new situation is difficult, given the aggressive environment in which they live and that they have limited access to information regarding how to care for their children (Reyes et al., 2004). It is possible that the economic and social burden on poor families leads to the mother or caregiver paying less attention to the younger children, whose nutritional status suffers as a consequence. This result highlights the importance of considering the reproductive health sphere when developing health programmes. Longer years of residency showed a protective effect, as it facilitated a community union, interaction and integration, thereby strengthening the relationship between social networks and children's nutritional status. Greater community support can be advantageous for the care of young children and may be more likely to result in health benefits and positively influence the nutritional status of children.

7.1.2.3 Tribes

The bivariate findings in this study suggest that tribal influences may be reflected in infant feeding practices that vary substantially between seasons (p-0.002)., and that this could have significant effects on children’s early growth performance. Some tribes are more likely to delay the introduction of non-breast milk foods, while other tribes encourage the early introduction of solid food as young children and infants need food to grow. For example, the potential exists that differences in infant feeding practices underlie the between-group differences in the prevalence of PCM. It is likely that during the wet season and dry season mothers face different time constraints, which impacts upon their ability to feed and care for their children. Complementary foods available to some tribe's children may have a greater micronutrient and energy density, whereas the primary food for some young children could be a thin maize-based gruel. There is also the possibility that some of the between tribes differences in health stem from different maternal attitudes towards feeding during child illness, as some tribes encourage their children to feed during an illness. However, the study found quite different results between the wet and dry seasons, and tribe was a cofactor during the dry season which influenced the prevalence of PCM. This finding could be interpreted as the ability of tribes to cope with a difficult environment. In conclusion, although the studied individuals from different environmental conditions have been characterised by similar traditional sociocultural behaviour, family influences have an important effect on PCM. The reason for this relationship lies in the association between rural-urban migration and stress and anxiety, as there is less social support, a lack of education, and occupational experience for those transitioning from rural to urban locations (Khan and Kraemer, 2009).This may again explain why the analysis showed a significant association between the length of residence and PCM in both the wet and dry seasons.

7.1.3 Socioeconomic Characteristics

The socioeconomic characteristics of a family in terms of maternal education, maternal occupation, income and hygiene are discussed in this section in relation to the occurrence of PCM and the impact of seasonal variation.

7.1.3.1 Maternal Education and Occupation

The results of the study revealed that the majority of the mothers of the children with PCM (47.9%) had not completed a primary level of education, and a small but important proportion were illiterate (6.5%). Mothers from the urban areas were significantly (p-0.002) more educated than mothers from rural areas. Education is a very important variable within community studies as it has been found to increase a person's level of perception and their maternal education improves the quality of childcare. Furthermore, it has been shown that mothers who do not complete a primary level of education do not differ significantly (p-0.682) from those who have never gone to school. In this study, the number of mothers who had enrolled in school was quite high (47.9%), but the proportion who completed their primary education and who went on to secondary level education and beyond, was very small. Moreover, girls are more likely than boys not to be sent to school due to a lack of funds, and girls have a higher rate of drop-out due to early marriages and teen pregnancies. In this study, maternal education had a positive influence on the health of a child, with the more educated mothers (completed primary level and beyond) having significantly (p-0.031) healthier children than those with little or no education.

These results are in agreement with the findings from Uganda of Jitta et al. (1992) and Vella et al. (1992), who had found that increasing levels of parental education were associated with less stunting in children. Similarly, children from households with unemployed mothers were found to be associated with a higher prevalence of PCM, and when controlled for season, maternal employment had a significant effect on the prevalence of PCM. In many developing countries, PCM tends to be a condition associated with a low socioeconomic status, and this certainly contributes to the relationship between PCM and seasonal variation. This study identified significant predictors of PCM to be the season, also reflecting the relationship between seasonality and occupation, as there was a higher prevalence (95.4%) of PCM among those children whose mothers spent more time outside the home.

Even though Sudan, like many other developing countries, is growing economically, there has been no decrease in the prevalence of PCM, which parallels the unequal economic growth. Explanations for this occurrence can be attributed to income inequality and rural to urban migration (Khan and Kraemer, 2009). Furthermore, the generalised linear model analysis supported the established positive association between maternal occupation and the nutritional status of children.

7.1.3.2 Family Income and Money Spent on Food

It was observed that the family income was higher (24.5%) during the dry season, with 46 respondents earning more than 300 Sudanese Pounds during this season. A study by Maxwell (1995) presented a household analysis of alternative food security in Kampala, and the results reiterate those observed in this study, identifying that family income (especially for those who depend on agriculture) is limited during the wet season. However, Reardon (1997) examined the patterns of household income in Africa and identified that during the dry season family members are often forced to find additional work due to a lack of income from agricultural fields. This hypothesis is supported by the views of Roncoli et al. (2001), who identified that non-farm generating activities are carried out during the dry season and often extend into the rainy season when there is a drought. In contrast, Saueborn et al. (1996) identified that family income is directly related to the type of family occupation. The results of this study showed that the amount of money spent on food is higher during the dry season compared to the wet season, similar to other studies in the literature. For example, Becker (2000) identified that the variations in food procurement patterns in a Malian village were seasonal, as during the dry season, a family might run out of stocked food supplies from the previous harvest, and as a result begin rationing their available food. In contrast, a study by Benefice et al. (1984) identified that food intake was insufficient during the wet season, resulting in nutritional depression, while food intake was increased during the dry season. Benefice et al. also identified that there is often a balance between the amounts of money spent on nutrition between the two seasons. However, a lack of association between family income, seasonal variation and the occurrence of PCM was found in this study. This is different to previous empirical evidence, such as that by Sibrian et al. (2007) which measured hunger at sub-national levels, and identified that the undernourishment of children was often associated with family income, which is dependent on seasonal variation, especially in rural households.

7.1.3.3 Household Size

Household size may affect both a child's nutrition and acute illness outcomes through several pathways. A larger number of household members increases competition for food, increases disease transmission, may decrease a mother's available time and care, and may increase the availability of substitute caregivers for young children. The overall effect of household size on a child's health outcomes is likely to be complex, and therefore it is difficult to determine *a priori* what the sign of the coefficient might be. Nonetheless, household size is a potentially important determinant of PCM.

7.1.3.4 Presence of a Latrine

In this study season had an impact on PCM when factoring in the presence of latrines (p-0.05), although season did not have an influence on marasmus or kwashiorkor when examined in the presence of latrines. This problem is related to water availability, and in Sudan, healthy/safe water availability continues to be elusive. The existing boreholes only provide clean drinking water to a fraction of the population at a ratio of roughly 5000 individuals per borehole, which is far below the recommendation of one hand pump per 500 people during emergencies (Reliefweb, 2006). In total, 63.2% of the population are not able to access potable/safe drinking water due to the inadequacy of the hand pumps, long distances, and waiting times at the boreholes, and this is further strained by an increase in number of returnees (Reliefweb, 2006). Although there are many efforts to expand health, nutrition and sanitation services, still less than half of the population has access to basic survival services, which are in turn are being provided in a fragmented manner. In Sudan there is an ongoing national effort to promote the integration of health care services; however, this has not been reflected at the service provision sites (Ali et al., 2013).

7.1.3.5 Household Food Consumption

Household food consumption is discussed in this study in relation to the occurrence of PCM and the impact of seasonal variation. The results identified that an increased consumption frequency of bread, cereal and sugar was observed during the dry season compared to the wet season. The seasonal variation in dietary intake among children was established by Persson and Calgren (1984), who identified that an increased food intake occurs during the dry season compared to the wet season. Brown et al. (1985) observed a similar trend; this is similar to the results of this study. However; this study identified that seasonal variation had no influence on PCM when examining the consumption of bread, cereals, legumes, oil, green leafy vegetables, other vegetables and fruits.

From the bivariate analysis it can be concluded that the occurrence of PCM among children is often found to occur due to an inadequate or unbalanced food intake, and the presence of seasonal variation in food consumption and its impact on nutrition was observed in a study by Ferguson et al. (1993). In a study among Turkana children, Shell-Duncan (1995) reported that a low dietary intake of protein was observed during times of drought, indicating the occurrence of under nutrition and wasting. The results of this study are somewhat different from those observed in the literature with respect to household food consumption. In this study it was observed that the wet season and dry season were 50% less likely to impact upon the prevalence of marasmus when examined by degree of sugar consumption, whereas Michaelson (2000) found that one of the major factors impacting upon the occurrence of marasmus among children was the frequency of carbohydrate and sugar consumption.

7.1.3.6 Child Feeding Practices

Unquestionably, breast milk is the best food for an infant in the first few months of life (Rao and Kanade, 1992), and the rate of breastfeeding was found to be very high in Sudan (99.1%). Breast feeding at birth was universal and by 12 months of age, more than one third of children were found to still being breastfed. The UDHS (1988/89) found that 82% of children were still being breastfed at 10 months of age, and this study found that a small proportion of children (3.9%) were breastfed for periods until over 18 months in age. This study contradicted the findings of Vella et al. (1992) in Northern Uganda.

It is generally agreed that by the sixth month of age, breast milk is not sufficient, both in terms of quantity and quality, in order to meet the growing nutritional needs of a child. A child of 6 months requires almost 800mls of breast milk to meet their energy needs (Saint et al., 1984), and this is beyond the production capacity of most mothers. Furthermore, breast milk after 6 months of lactation is low in micronutrients, particularly iron and zinc; it is therefore recommended that depending on a child's growth rate, children should be gradually introduced to weaning foods between 4-6 months of age (Cameroon and Hofvander, 1983). At 6 months of age, teeth begin to erupt and a child's digestive system is better able to handle starchy foods (Milla, 1986; WHO, 1988); therefore, this is the optimal time to commence the weaning process. However, weaning is the most stressful period in a child's life and if the correct practices are not followed, weaning can be a major risk factor for malnutrition of children in developing countries (Rowland et al., 1986; Hoare, 1994).

It was found in this study that almost half of the children studied (65.7%) started supplementary feeding at the recommended age of 4-6 months. However, a relatively large proportion of the children (36.4%) started the weaning process too early; before the age of 4 months, with proportionately more mothers in dry season introducing weaning foods to their children earlier than mothers in the wet season. This age is too early for weaning, as a child's alimentary system is not yet ready for the highly starchy foods commonly used for weaning in developing countries. In addition, there is a danger of high incidences of diarrhoeal diseases resulting from contaminated weaning foods prepared with water from unprotected sources.

Although some argue that there may be a small proportion of children who might need supplemental feeding at 2-3 months of age (Waterlow et al., 1980), others (Reddy, 1987) caution on the dangers of introducing food to an infant earlier than 4 months of age due to the prevailing hygiene conditions in developing countries. Uwaegbute (1991) states strongly that there are no physiological, economic, psychological or nutritional advantages in introducing foods to an infant before the age of 4 months. In one of the few randomised intervention studies on this subject, Cohen et al. (1994) found that there were no advantages in introducing supplementary foods to infants even before the age of 6 months. The negative weaning practice of starting the weaning process late, by introducing supplementary foods later than 9 months of age, which has been found to be associated with malnutrition of children (Whitworth et al., 1987), was found to be negligible in this study. Further analysis of the factors influencing the age at introducing solid food revealed that the season had a non-significant influence. In this study it was found that almost a third of mothers (32.0%) weaned their children between the ages of 12-18 months, and more than one quarter (27.9%) weaned their children when aged less than 12 months. However, a relatively large proportion of the children (33.5%) were weaned too early, and further analysis of the factors influencing the age of weaning revealed that the season had a non-significant influence.

7.1.3.7 Weaning Food

The majority of the children (40.6%) started the weaning process on starchy food and plants proteins, and about a quarter (28%) was weaned on starchy food only, most frequently during the wet season. The impact of seasonal fluctuation on the overall nutritional status of a child has been found to be associated with their general health and well-, especially in populations where there is a higher degree of occurrence of moderate to severe under nutrition (Richards et al., 2012). The problem is not lack of love, rather it is ingrained in the overall general poverty and the over-stretched workload of the mother. These mothers need a lot of support (financial and emotional) from the nation, the community and the household to put what they know and what they are taught about childcare and nutrition into practice**.**

7.1.3.8 24-hour Food Recall

Children with PCM consumed excessive amounts of added sugar (91.2%), partially due to the intake of sweetened beverages. Cereal was among the most frequently reported foods in this sample of children, and children's dietary intake of nutrients and food groups decreased as added sugar intake increased. This survey is in agreement with a cross-sectional study among children aged two to five years by Kranz et al. (2005). It is clear that the percentage intake of fruit juice (66.6%) was higher than of other foods, a findings supported by a number of studies **(**Harnack et al., 1999; Frary et al., 2004; Blum et al., 2005; Marshall et al., 2005). Some researchers have noted that changes in beverage pattern consumption also changes nutrient and food intake (Harnack et al., 1999; Marshall et al., 2005; Blum et al., 2005)

The high contribution of carbohydrates in the foods of children is characteristic of food given to children in most of Sudan (Nabag et al., 2013). This is mainly the result of gruels produced from locally-produced staple foods, such as sorghum, wheat and millet. These starch-based foods are characterised by a high water content and low energy and nutrient density. To achieve an intake that is sufficient to meet their energy and nutrient requirements, a child needs to ingest relatively large volumes of such foods (WHO, 1998). The dietary bulk characteristics of food could be an important factor contributing to the aetiology of PEM in children.

In Ethiopia, Getaneh et al. (1998) found that diets that are nutritionally inadequate, especially in animal products were associated with PEM, and children in India often had a low intake of green leafy vegetables and fruits (Singh, 2004). When Iqbal et al. (1999) looked at the intake of Indian children aged 6 to 36 months old they found that children had a high intake of starches, sugar, fats and oils, and lower intakes of vegetables and fruits. Kapur et al. (2005) undertook a study in Delhi and found that cereals, milk, fruits and sugar were some of the foods that were the most preferred.

In this study the supply of dietary carbohydrates, proteins and fat from foods was low, covering 39.8%, 7.9%, 33.8% and 10.2%, respectively, of a child's energy requirements, and on average, the foods currently consumed by children in the study area did not provide an adequate diet. The results of this study indicated that the mean energy intake/day for all the age groups were below the RDA, which for children aged 0-6, 7-12 months, 1-3 and 4-5 years were 219 kcal, 227 kcal, 227kcal and 205 kcal, respectively below the recommended allowances. A similar finding was reported by Vijay et al. (1995) where the average energy intakes were 229 kcal and 384 kcal below the RDA for 1-3 4-6 year olds, respectively. Murphy et al. (1992) stated that the calculated low energy intake reported is likely to be due to the underreporting of food intake. In this study, the percentage of energy obtained from macronutrient sources was not in agreement with the acceptable macronutrient distribution ranges. A study by Barquera et al. (2003) on 1 to 4 year old Mexican children also indicated that the estimated median intakes for energy, carbohydrate, fat, were lower than their requirements, and when evaluating the health status of children aged 3 to 6 years in a South Korean city, Yu (2009) reported that their intake of energy was lower than the recommended dietary reference intakes for Koreans.

However, Ahmadi et al. (2014) assessed the dietary intake of 3 to 5 year old children in Shiraz, Iran and found that the contribution of carbohydrate, protein and fat to the percentage of energy intake corresponded to the rates suggested by the acceptable macronutrient distribution ranges. According to Livingstone et al. (1990) and Mertz et al. (1991), the underreporting of energy intake is approximately 20% compared to the measured energy requirements. However, even when 20% estimated underreporting is included, the mean energy intakes of the children in this study would not be close to the RDA for energy.

The energy from carbohydrates was much higher than the recommended values, while the energy from protein and fat was very much below the recommended values (Ernst, 1985; Weidman et al., 1983). This was due to the higher contribution of energy from carbohydrates towards the total calories (overconsumption of carbohydrates). The low intake of protein and fats observed in this study is concerning, as the average protein and fats intake was well below the RDA for all the age groups, placing these children at nutritional risk. Low protein intakes are frequently accompanied by inadequate amounts of micronutrients, including iron, zinc, calcium and vitamin A (Allen, 1993). According to Leal eta al. (2012), a cross-sectional study in the Kilosa district in Tanzania to determine the feeding practices and extent of wasting and stunting, indicated that carbohydrates contributed most to energy intake (on average 69%), followed by fats (18.6%) and finally protein (on average 12.1%)

The protein content of the foods consumed in this study was inadequate (average 7.9% of the total energy) and the energy density of the foods was found to be very low as a result of the very low fat content of the foods. Whereas the fat consumed attributed to only 13.9% of the total energy intake, traditional starch-based foods were contributing an average of 72.7% of the total energy intake. Because of the very low energy content of the foods, children did not consume enough food as a result of their illness, and were not able to meet their daily energy intake because they consumed a starch-based diet. A low energy intake leads to poor and persistent anorexia, which are markers of increased disease severity. The total energy intake, rather than the relative contribution of carbohydrates, protein, and fat to energy intake, appeared to be the major dietary determinant of PCM in this study, but this finding should be interpreted with caution given the heavily carbohydrate-based Sudanese diet and the possibility that this study lacked power to detect a true difference between the macronutrient categories. Some of the factors that are likely to have contributed to low calorie intake include delayed transition to catch up feeds, failure to appropriately increase feeds, and the infrequent use of nasogastric tube feeding.

In this study, infants and children with PCM did not consume energy and nutrients requirement for several reasons. Some children with PCM may have such severe respiratory problems that they do not have the energy to suck and swallow, and swallowing may increase discomfort resulting in a reduced desire to eat. Sucking and swallowing may be very slow and a child might be unable to take in enough calories before becoming exhausted. Other children may experience severe gastrointestinal difficulties that cause food to be refluxed and vomited. Some children may only eat very specific foods, exhibiting aversions to certain textures, accepting only specific type of foods, and refusing other foods, meaning that sick children often lose or use more water than usual.

The consequence of PCM is a condition in which a child is incapable or refuses to consume adequate quantities of food or drink to maintain their nutritional status (Roth, 2012). Although feeding problems are relatively common in children with PCM, infants and young children who experience adverse feeding reactions, including recurrent vomiting, are especially at risk for feeding problems. Children cannot eat effectively, and exhibit more severe and persistent feeding problems due to a lack of appetite, whilst problems with swallowing, may be recorded as a history of aspiration pneumonia (Roth, 2012).

Children with PCM were found more often to have feeding problems and were more likely to require particular foods, and foods of low texture. Some children rejected all or most foods presented to them, which led to the child not consuming enough food to meet their caloric or nutritional needs. Some children consumed only a very narrow range of food that was not nutritionally adequate, and often refused to consume whole food groups. Some mothers said that their children took food from inside of their mouth although it had previously been accepted, others said that spitting food out of the mouth, pulling food out of the mouth, or tipping the head to let food fall out of the mouths took place, as did reactions that interrupted the presentation of food on a plate.

7.1.4 Distribution of PCM by Child Demographic Factors

7.1.4.1 Gender

The prevalence of PCM was significantly higher among boys (57.51%, p-0.017). Haddad (1999) stated that the difference between boys and girls with regards the prevalence of PCM could be due to genetic factors, whereas other evidence points to the idea that this difference could be due to social, economic, cultural and environmental factors. Moreover, this finding indicates that cultural patterns in Sudan do not favour boys, which may connect with differences in maternal and family care, with better care for girl evident in some parts of the world, such as Africa (Puoane et al., 2001) and China (Li et al., 1999).

The prevalence of marasmic kwashiorkor was higher among girls (62.2%) than among boys (37.8%), which may reflect some parents in the Sudanese community preferring boys over girls, with girls being discriminated against within the family in terms of food distribution and better care, resulting in improved health among boys (Chen et al., 1981). However, marasmus and kwashiorkor, affected more boys than girls. The gender distribution in this study is different to that reported by other researchers, for example Saad (1974) found that marasmus was more common among girls. These findings demonstrate that parents are unable to control the factors that contribute to the prevalence of PCM. A mother's behaviour regarding the care of her children could accidentally result in better care for females, especially during the first few months of life. In Sudan, marasmus was predominant and occurred in early infancy as observed in other studies (Taha, 1979). Female children who experience relatively better care during their first year of life may not suffer marasmus at this age, but possibly develop kwashiorkor later on. In contrast, boys who survived their first year as marasmic patients may go on to develop marasmic kwashiorkor in later years.

7.1.4.2 Child Age

The prevalence of SPCM was found to be lowest (5.4%)in children less than 6 months old and highest (48.3%) for 12-23 month old children. Pairwise chi-squared tests indicated that the prevalence of marasmus was significantly (p-0.001) different for all pairs of age groups, except 36-47 and 45-59 months. According to the WHO, children aged 12-23 months probably suffer from a continuing process of failing to grow, while older children fail to grow and suffer from PCM (Das, 2008). Higher rates of kwashiorkor (69.7%) was observed among children aged 12-35 months, but was absent in children aged 36-47 (0.0%). Further analysis, using multinomial logistic regression indicated that a child's age was an independent predictor of child PCM. The reason why the incidence of marasmus increases at 12 months of age may be due to a deficiency of supplementary foods after six months of age that influences the nutritional status of a child since breast milk alone is not adequate beyond 6 months of age (Das, 2008). Children were six times more likely to become marasmic by 12 months and nine times more likely to develop kwashiorkor by 23 months of age.

7.1.4.3 Child Birth Weight

Birth weight is a causative factor for PCM (Kleynhans et al., 2006) and there is a direct association between maternal health and child nutrition (Teller and Yimar, 2000). In a study by Falbo and Alves (2002), the median birth weight of children in Brazil was 2.80kg, and 42.2% of children with severe malnutrition had low birth weights (Falbo and Alves, 2002). The prevalence of low birth weight babies in Sub-Saharan Africa has been reported as 10% (Ramakrishnan, 2004). In India, low birth weight is related to maternal nutritional factors, such as energy and protein intake during pregnancy, and the weight of the mother before she became pregnant (Ramakrishnan, 2004). Gupta (2008) found that low birth weight babies had a higher risk of developing feeding problems and malnutrition.

In this study the univariate analysis found a significant association between birth weight and the prevalence of PCM (p=0.013) and 35.8% of the children with PCM had a low birth weight. Of these children, 40.4% were marasmic but this is not a very reliable finding, as many births in Sudan are never reported and in regression analysis did not report any association. A study in Kenya of children aged between 12 and 59 months showed that the clinical features of malnutrition were noticed in children that had a weight-for-height of <-3SD (Berkley et al., 2005). In South Africa, children were followed from birth up to three years of age and the results showed a greater height at one year protected a child against stunting. Normal length and weight at one year are very important as this can predict the nutritional status of a child at three years of age (Mamabola et al., 2005).

7.1.4.4 Nutritional Deficiency

It can be expected that children suffering nutritional deficiency may develop PCM, and in Sudan, about 15% of children were severely underweight with the highest prevalence observed in Northern Kordufan (FAO/WFP, 2006). Severe stunting affected 24% of under-fives, and in general, children residing in rural areas were more likely to be affected by stunting. The prevalence of stunting prevalence was higher in the eastern states, while that of wasting varied by region, although almost 4% of all children were affected and it was particularly high in Northern Darfur (FMH, CBS and UNICEF, 2001).

In this study, a high percentage of children (94.4%) had a MUAC of less than 12.5cm, showing severe malnutrition. In a study in Kenya on children aged 12-59 months, the clinical features associated with malnutrition were found in children that had a MUAC of less or equal to 11.5cm (Berkley et al., 2005), and Kikafunda et al. (1998) found that 21.6% of Ugandan children aged 0 to 30 months had a MUAC lower than 13.5cm. The risk factors for a low MUAC were poor health, lack of meat and cow's milk consumption, low energy derived from fat intake, mothers with low educational levels, and older mothers (Kikafunda et al., 1998).

7.1.4.5 Immunisation

In Sudan about 67.2% of children are fully immunised against measles and 36.1% against tuberculosis (Reliefweb, 2006). Overall immunisation coverage has been determined to be about two thirds of the target group (SHHS, 2010). The results of this study showed that 81.1% of malnourished children were up to date with their vaccinations, but 18.9% of children had only been partially vaccinated. Bivariate analysis revealed that about one third of children with kwashiorkor had not received all their vaccinations.

In Ethiopia, 80.2% of children aged 3 to 36 months old were found to be fully immunised and the proportion of malnourished children that were fully immunised in this age group was not different from that of well-nourished children 77.6% (Abate, 2001). In Bangladesh, 77% of children aged between 6 and 60 months received their vaccination against tuberculosis and 82% had received full or partial diphtheria, tetanus, pertussis and polio immunisations, In Bangladesh, about 75% of children were reported to have received their measles immunisations (Iqbal et al., 1999).

Bivariate analysis in this study found a significant relationship with PCM when no vaccines had been given (p-0.036), and a study in Bangladesh supported this finding (Iqbal et al., 1999). These children are more prone to illnesses and infections, which results in a higher chance of developing or worsening PCM. Some studies have found that incomplete immunisations are directly associated with PCM. These studies were undertaken in Ethiopia amongst children younger than five years old (Getaneh et al., 1998), in Uganda in children aged 0 to 60 months (Owor et al., 2000) and in Kenya in children aged 3 to 36 months (Ayaya et al., 2004).

7.1.5 Prevalence of PCM by Maternal Characteristics

7.1.5.1 Maternal BMI

In this study BMI was used as the indicator of maternal nutritional status. The bivariate analysis found a strong relationship (p-0.0001) between maternal BMI and the prevalence of SPCM, as most mothers (61.9%) had a BMI in the range of 18.5 to 24.9 kg/m^2. About one quarter of children with SPCM lived with mothers that had a chronic energy deficiency, while more than 10% (12.5%) were classified as overweight. Obesity was reported in 0.9% of mothers. The nutritional status of mother was independently associated with chronic child malnutrition, and a potential reason may be the inability of thin mothers to provide sufficient breast milk due to their lack of body fat reserves needed to provide milk.

Many studies have supported these findings and James et al. (1999) analysed data from Ethiopia, India and Zimbabwe, and found that 56.3% of households had women with an average BMI of less than 18.5 kg/m^2, while only in 29.9% of the Indian households did children have a normal weight-for-height and the adults an average BMI (James et al., 1999). In contrast, Deleuze et al. (2005) conducted a study in Benin, West Africa and found that 39.1% of mothers of malnourished children were overweight and 15.5% were obese; both an overweight mother and a malnourished child were found in 16.2% of households, whereas only 12.8% of the households had an underweight mother. Households with overweight mothers were socioeconomically more stable. In this study kwashiorkor was higher in underweight mothers (30.6%), and marasmus was lower (11.9%) in children who lived with overweight mothers. This finding is supported by Deleuze et al (2005), who reported that wasting was significantly higher in households with underweight mothers. The NFCS (1999) found that 17% of children were overweight and obese, which was almost as high as for stunting and factors included parental care and not only improvement in food security. This indicates that factors other than the shortage of food may determine children's size (James et al., 1999).

7.1.5.2 Maternal Marriage Age

The age when a mother marries is important, as is when she is pregnant, as younger and older women usually have a higher risk babies that are already malnourished or have other complications (Teller and Yimar, 2000). In this study the majority of mothers (40.6%) were married when they were less than 18 years of age, 41.6% of mothers were 19-24 years old, and 17.8% of mothers were married when they were 25-34 years of age, which showed that they were still in their reproductive cycles. Children whose mothers' ages at birth were <18 and >35 years were more likely to be marasmic than the children of mothers aged 18-24 years. Mosley and Chen (1984) support this finding, as their study reported that children born to mothers aged below 18 and above 34 years are more susceptible malnourishment than those born to mothers aged 18-34 years. The results of the generalised linear model analysis in this study also supported this result.

7.1.5.3 Birth Order

In this study the level of PCM did not differ between the first to third order children but significantly (p-0.0001) increased with an increase in birth order, and the majority (19.5%) of children with PCM were fourth birth order. About 21.1% of the children who were fourth birth order were marasmic. However, a study in Egypt reported no relationship between PCM and birth order (Hamid et al., 1978). The negative association observed in this study might be explained by the fact that first-born children had a period of being an only child and thus experienced better care than later-born children during the growth period. A higher birth order number also implies that a large number of children are already present in a family (Joe, 1969).

In contrast Graham and Morales (1983) demonstrated that of 55 cases of kwashiorkor, 88% were third or later born, and in Colombia, 49% of children with PCM were sixth or later born (Wray and Aguirre, 1968), while Adekunle (2005) stated that the majority of children with kwashiorkor and marasmus were born third or later. An increase in the prevalence of PCM in children of a higher birth order could be due to the fact that the nutrition of children in larger families suffers from food shortages, and also that there is misdistribution of food among all the family members.

A study carried out by Rao et al. (1967) reported a relationship between PCM and third birth order, and the findings of this study are in agreement with this and further supported by the observations of Gopalan (1970) and Mudikhedkar (1976).

7.1.5.4 Birth Interval

In the current study, an inverse pattern was observed according to the birth spacing. For the children with a birth interval of <24 months the level of PCM was 79.1%, while only 4.6% for children with a 36-47 months birth interval. This may be due to the fact that parents can take better care of fewer children and mothers can provide adequate breast milk due to the recovery of their nutritional status between births. These results support previous research that the birth interval has a significant influence on PCM (Nojomi et al., 2004; Sommerfelt et al., 1994).

These observations indicated that the presence of PCM in children may be compounded if their birth is preceded by another birth within three years (Mudikhedkar and Shah, 1976). This explanation is further strengthened by the fact that the prevalence of PCM was lowest in those children who were the eldest. The observations in this study agree with the generally accepted belief that PCM is a 'disease a child gets when the next child arrives or sickness of the deposed child' (Walker, 1995), thereby highlighting the importance of subsequent deliveries. Mudikhedkar and Shah (1976) reported that PEM was reduced among children who had a three or more years spacing with other siblings. This may be associated with other risk factors, such as a mothers' lack of capacity for caring for her children. In addition, the mother herself may be biologically depleted from too many births over a short space of time, and this could also negatively affect the nutritional status of a new-born baby as a result of the inter-generational cycle (Mangiaterra, 2006). Mothers may have no time to recover physically and nutritionally, and these mothers are more likely to deliver low birth weight babies.

7.1.5.5 Tribe and Length of Residence

Several of the maternal characteristics were associated with PCM, including length of residence and tribe. Bivariate analysis found a significant relationship between tribe and PCM (p=0.043), although there is very little information on PCM and tribe for Sudan. Elbushra and Eltom stated that some mothers in Beja tribe introduce supplementary feeding late and exhibit poor weaning habits, which all contribute to a high prevalence of PCM (Elbushra and Eltom, 1989). Belonging to a tribal group can be associated with income too, and another factor may be the tribal influence on living conditions, food taboos and behavioural practices, which may affect nutritional status. Food taboos could also lead to the deprivation of important foodstuffs. Moreover, there may be interplay of factors affecting tribal health, such as the long-term impact of migration, racism and discrimination, poor delivery of health care, differences in culture and lifestyles, and biological susceptibility.

7.1.6 Prevalence of PCM by Socioeconomic Factors

7.1.6.1 Parental Education

In this study 52.4% of mothers had received no formal education, 37.6% had a primary school educational level, 9.2% had secondary school educational level, and only 0.9% of mothers had a university education. Males in a household were better educated than females, and sometimes parents in urban areas were slightly better educated, but the general education level of the urban parent was often very low. Household members in Sudan with a secondary education had fewer children with kwashiorkor and of all the parents only 3% of women and 6% of men had a post-secondary education, (Christiaenson and Alderson, 2001). Falbo and Alves (2002) found that 15.2% of mothers of children hospitalised in the Instituto Materno Infantil de Pernambuco in Brazil were illiterate. The prevalence of marasmus, as well as kwashiorkor and marasmic kwashiorkor, decreased with an increase in the maternal educational level, although the relationship was not significant. The same pattern was observed for paternal education.

7.1.6.2 Maternal Occupation

A significant association between the prevalence of PCM and a mother's working status was identified (p=0.042), although children of employed mothers were less likely to become marasmic. However, Das et al. (2008) reported no significant association between the prevalence of malnutrition and a mother's working status, while Abbi et al. (1991) observed that unskilled labourers had the highest level of underweight children. The prevalence of SPCM was significantly (p-0.001) lowest among children whose mothers were hairdressers. Although an employed mother may have power and could live independently on her income, she has to leave home and this introduces the possibility of a reduction in the frequency of breastfeeding and time spent with her children. Hence an employed mother can have either a positive or a negative effect on a child. Although a woman's employment enhances a household's accessibility to income, it may also have negative effects on the nutritional status of her children, as it reduces a mother's time available for childcare, which then becomes the responsibility of older siblings, who are often below the age of six years (Gulati et al., 2010).

7.1.6.3 Family Income

The growth of infants and younger children throughout the world is related to the socioeconomic environment in which they live. Household income has been shown to influence PCM indirectly (Das et al., 2008). This study also indicated that the family income had a strong inverse relationship (p=0.047) with the prevalence of PCM in children, but the regression analysis did not reflect that the children of wealthier families were less likely to be malnourished than those of poorer families. Income is directly related to the quantity of food obtained by a household, and the mothers of poor families have to work harder and for longer periods, consequently the children receive less attention (Gulati et al., 2010). When considering kwashiorkor specifically, a low household income and inadequate quality and quantity of food are co-factors. Families with a low income are not able to buy foods with high nutritive value, so they eat cheaper food which is less nutritious, leading to weight loss kwashiorkor. In addition, meat, milk and milk products are expensive and the children's intake of animal proteins is less than their requirements, leading to an increased consumption of carbohydrates, and ultimately kwashiorkor.

7.1.6.4 Number of Rooms, Building materials, Presence of Electricity and Waste Disposal

The number of sleeping rooms was also found to be associated with PCM (p=0.038), as more than 35.8% of malnourished children lived in one room and the prevalence of PCM increased with a decreasing number of sleeping rooms. A high population growth rate leads to overcrowding, and consequently the spread of diseases like acute respiratory infections and diarrhoea, which are known causes of malnutrition (Rice et al., 2000). PCM is associated with overcrowding not just because of the transmission of infections, but also because food sharing may be unfavourable for young children. In this study, children with PCM came from families with a low socioeconomic status. For example, 58.6% of the PCM children lived in mud houses, and of these children, 61.2% were marasmic. Further analysis revealed that families who lived in mud houses had a 2.5 times higher likelihood of having marasmic children, a finding consistent with other studies from Bangladesh, Zambia and Nigeria (Ahmed, 1992; Ighogboga, 1992). This could be due to an association between the type of housing and the prevalence of PCM and in this study may be due to the poor construction of houses. Half of the families used lamps for lighting, and children in households with electricity were 70% less likely to be marasmic than those in households without electricity. Households which disposed their waste via public garbage experienced a higher risk having marasmic children in comparison to the other methods of waste disposal. These findings reflect the picture that the worse a household economic status, the higher the prevalence of PCM.

7.1.6.5 Sources of Water and the Presence of Latrines

Sources of water were investigated and it was found that 30% of families of children with PCM bought their water from a water trader, and the bivariate analysis found a strong relationship between sources of water and the prevalence of PCM (p-0.039), although the regression analysis did not support this finding. However, the situation is similar to Ifewara in Nigeria (David and David, 1984), where the major source of drinkable water is a stream, and the entire community has no pipe borne water supply. The apparent lack of association between the source of water and poor childhood nutrition in this study may be ascribed to the probability that children in this community have developed antibodies to the various organisms contaminating the water they consume, thereby leading to a reduction in their susceptibility to water borne diseases like diarrhoea which can lead to PCM. Contaminated feeding can be caused through the use of contaminated water, which is a likely source of pathogens (David and David, 1984). The prevalence of underweight children among communities with a high rate of unhygienic water sources has been reported to be 1.92 times higher than that in communities with a low rate of unhygienic water sources and 1.48 times higher for stunting (UNICEF, 2011). A report on the proportion of each country's population that has access to safe water as a proxy measure stated that improvements in safe water access during the period 1970–95 has decreased the prevalence of malnutrition (Gulati, 2010).

About 50% of children with PCM came from a household without a latrine. Adverse environmental factors may cause malnutrition in children in developing countries, where diarrhoea and other infections are more prevalent (Jitta, 1992; Vella et al., 1992). Children living in households without latrines may suffer PCM, and among the children with PCM in this study, thirty percent of their families burned or buried their home waste. The presence of latrines reduced the probability of a child being marasmic by 55% rather than marasmic kwashiorkor. If this situation accompanies limited access to food, the risk of repeated infections will increase. Unhygienic household conditions cause food contamination, infection and increased malnutrition, while improved sanitation is related to a lower risk of malnutrition (Abate et al., 2001).

7.1.7 Prevalence of PCM According to Child Feeding Practice

The findings of this study revealed that inadequate/improper breastfeeding is a risk factor of PCM and corroborates the findings of another study in the Sudan, which reported that only 33.7% of infants were exclusively breastfed (SHHS, 2007). Some mothers partially breastfeed their children due to physical and emotional reasons immediately after the delivery. Another reason was that women feel bottle feeding provides a larger amount of food to give to a child, and makes it easy for women when they move outdoors (Morrison et al., 2008). This study found that the early introduction of supplementary feeding for infants and the early introduction of solid food were important risk factors for PCM. The results agreed with the SHHS (2007) report and previous studies have also found that breastfeeding has a significant and substantial impact on the overall survival of undernourished children (Taha, 1997). An association has also been reported with a shorter duration of predominant breastfeeding, which could be an example of reverse causality (Saka et al., 2005), whereby children who are ill and malnourished stopped nursing or were provided with other foods.

Children with PCM are more likely to have been born to young mothers and to have had a low birth weight, be born prematurely or be malnourished. Premature or malnourished infants tend to breastfeed less often and have a less vigorous suck (Nahar et al., 2012); this produces less prolactin release and less production of breast milk. Young mothers may lack the skills to solve such breastfeeding problems, leading to an inability to support their infants when food supplies are limited, which in turn leads to malnutrition.

7.1.8 Implications for Brain Development

7.1.8.1 Child Profiles

The results of the study indicated that girls show a higher mean weight-for-age 8.2 and a higher mean height-for-age 74.6 compared 7.9 and 72.2 repectively to boys. A study on wasting in boys and girls in Assam between the ages of 1-3 years by Medhi (2006) showed that 21.2% of the children were categorised as showing signs of wasting, with the highest amount of wasting seen children aged 3 years old (27.8%). In comparison, this study revealed a much lower level of wasting among boys aged 2-3 years old.

7.1.8.2 Vitamin A Supplementation

Vitamin A is necessary for a well-functioning immune system and a deficiency can cause a high risk of morbidity and mortality. In this study the majority of children aged 12-36 months in both the case and control groups received vitamin A supplementation (81.3% case, 91.7% control) but 16.7% of children were not up to date with their vitamin A supplementation. In a study in Durban, South Africa by Coutsoudis et al. (1993) in children aged from 3 months to 6 years, 44% of these pre-school children were found to have a low vitamin A status and 5% had a vitamin A deficiency (Coutsoudis et al., 1993). Vitamin A is directly linked to infections, as well as mortality, and therefore it is important to protect children against illnesses and infections by giving them six monthly doses of vitamin A (Shankar et al., 1999). The coverage for children older than two years of age is still very poor.

7.1.8.3 Medical History

When the current medical history of a child was observed, diarrhoea was present among 72.9% of the children. Gastrointestinal infections are one of the most common infections in children with PEM (Rodríguez et al., 2011) and are especially important among children of weaning age who present with severe or frequent episodes of diarrhoea (Torún and Chew, 2006). It was also observed that 64.6% of the respondents showed signs of fever, vomiting was reported in 41.7% of the children, and a cough was reported in 43.7% of the children. In total, 27.7% of the children had been admitted once before, the majority (64.5. %) were being admitted for the first time, and 6.3% had been admitted three times before. In Ethiopia significantly more malnourished children (13.5%) aged 3 to 36 months had diarrhoea and this was the reason for their admission (Abate et al., 2001). In Brazil, Falbo and Alves (2002) found that diarrhoea was also the main reason for admission in 55.6% of malnourished children, while Cartmell et al. (2005) found that the primary diagnosis of children younger than five years of age admitted to hospital in Gambia was gastro-enteritis (7.5%).

7.1.8.4 Biochemistry Investigations

Biochemical information was not available for all the participants as no new bloods were drawn and only information from blood that had already been taken routinely at admission were used and analysed for the follow up study. During malnutrition low haemoglobin and serum albumin concentrations are common, and these are used as markers of the severity of the clinical illness (Amadi et al., 2005). This study found that most of the children showed lower limits of protein (56.9%), and more than 88% of malnourished children had a low level of albumin (less than 32g/L). About 40% of the children were moderately anaemic with haemoglobin levels of 8.5-10 g/dL and 44.7% were severely anaemic with haemoglobin levels of less than 8 g/dL. In total,, only 12.8% of the children were not anaemic with a haemoglobin level of more than 10 g/dL. This correlates well with the results from a study which stated that predictors of anaemia were low birth weight and an iron deficiency (Mamiro et al., 2005).

7.1.8.5 Nutritional Assessment

From the bivariate analysis of the case and control groups it is clear that the consumption of milk, eggs and meat was low among children affected by PCM. A study by Rao et al. (1959) examined the presence of protein malnutrition among children in south India, and found that a lack of milk, eggs and meat is the primary reason for protein malnutrition. Similarly, a study by Chen et al. (1979) identified that there are seasonal dimensions of PEM in rural

Bangladesh, resulting from the lack of enough cereals as staples and legumes. Patwardhan (1962) and Iqbal et al. (2006) indicated that in third world nations the lack of access to plant protein sources, like legumes, results in PCM. From the bivariate analysis of the case and control groups it is clear that the children afflicted with PCM disorders showed signs of nutritional deficiency. The probability of brain impairment being associated with PCM is increased under conditions when socio-demographic risk factors are also present and may be further increased when there are interactions with multiple low-level food consumption.

7.1.8.6 Neuropsychological Assessment

A study by Chowdhury et al. (2010) identified that the development of gross motor skills in a child is directly dependent on the type of nutrition she/he receives. This is similar to the results observed in this study where the importance of gross motor skills and language skills is clearly understood. A study by Celedon and de Anarca (1979) observed that children with marasmus who were given nutritional rehabilitation recovered their weight-for-age faster than their height-for-age, with 42% being classified as obese at the end of their treatment. Psychomotor development was also significantly improved following treatment, but mainly in the areas of social, language and fine coordination skills. Children with marsasmus, kwashiorkor and underweight children were found to have abnormal fine motor, gross motor and language skills. An extensive span of cognitive shortfalls was established in under-nourished Indian children during an investigation of under-nourished children who were securitized using Gessell's developmental programme from an age of 4 weeks to 52 weeks. Children with undernourishment levels of grade I and II, revealed inadequate progress in all aspects of their behaviour, such as social and personal behaviour, motor movements, adaptive behaviour and language skills (Upadhyaya et al., 1989). This reveals that undernourishment can impact upon various neuropsychological performances at a range of levels, although within the underprivileged section, the educational background of a house and the hope parents pin on their offspring as far as education is concerned are dominant variables. It may be that belonging to a privileged section in society could be beneficial regarding education at home and the hopes and aspirations of the parents.

Persistent PCM resulting in wasting could lead to impediments in the progress of cognitive procedures or in lasting cognitive damages (Kar et al., 2008). Neuropsychological methods reveal that impediment occur in the naturally progressing cognitive procedures, including a lasting cognitive shortfall (Dywan et al 1991). Persistent heightened undernourishment, like stunted height and low weight in infancy, could have a long term effect on the development of the brain, even if the nutrition level increases later on (Waterlow and Rutishauser, 1972). Several investigations have evaluated children of school- age who have been subjected to persistent heightened undernourishment in infancy compared to siblings who were not subjected to undernourishment. These investigations usually reveal that those who were subjected to undernourishment in infancy have a lower IQ, lower cognitive performance and lower accomplishments in school, including difficulties in their behavioural patterns (Grantham McGregor, 1995; Kar et al., 2008). To address this issue the WHO suggests planned studies undertaken in Uganda and Bangladesh have illustrated that providing these incentives could assist in developing cognitive and motor improvement in extensively undernourished children (Kar et al., 2008).

7.1.8.7 EEG Abnormalities

There is growing evidence that PCM in young children contributes to growth retardation of the central nervous system in humans, and significantly impairs motor and sensory nerve conduction, also contributing to motor weakness, hypotonia and hyporeflexia. Experimental studies have proved that nutrition rehabilitation can reverse the effect of PCM on peripheral nerves (Chopra, 1991). This finding is supported by the results of this study which demonstrated that regular treatment and helped improve the overall levels of EEG patterns. Robinson et al. (1995) showed that EEG patterns of malnourished children aged 5-23 months old at admission and discharge showed no significant differences, but significant differences were detected between malnourished and control groups. They stated that electrophysiological abnormalities were associated with chronic rather than acute aspects of malnutrition, and can provide detail of the deviation of brain function from normality (Robinson et al., 1995).

From the evidence in this study it can be postulated that there is a higher prevalence of developmental delay and neurological disabilities in low birth weight, preterm new-borns (Almeida et al., 2002), and a tendency of malnourished children to develop epilepsy has also been reported (Hackett and Iype, 2001). From the results of this study it can be observed that there are representative evidence which is directly associated with the causal relationship between malnutrition and EEG patterns in humans. Therefore, in order to examine the relevance of this hypothesis there is a need for systemic and robust investigations, similar to those already available in laboratory animals requiring more detailed study.

7.1.8.8 Comparison of Outcomes

The study indicated that PCM in children had a significantly higher influence on brain function than the control children (p=0.002), as the majority of children with PCM (70.8%) had an abnormal EEG. All kwashiorkor children, 68.7% of the marasmic children and 42.7% of the underweight children had an abnormal EEG compared to 8.3% of the control group. Malnourishment also had a significantly higher influence on the general neuropsychological domain, such as personal-social, fine motor, language and gross motor skills (p=0.001). The findings showed that marasmus had a significant higher (p=0.001) impact on fine motor coordination (62.5%) as well as gross motor skills (75%) than children with kwashiorkor, those who were underweight and the control group. Kwashiorkor had a significantly higher influence (P=0.001) on personal-social skills (75%) than for children with marasmus, underweight children and the control group, while be underweight had a greater impact on language skills compared to children with kwashiorkor, marasmus and the control group. These findings supported those of Benefice (1990), who stated that normal and thin children scored higher in various tests than children who were under-height, or both under-height and underweight. From a study by Meeks Gardner et al. (1995) it was observed that there a reduction in the overall energy intake of children causes problems in normal neural development resulting in brain related issues; however, a direct relationship between these two attributes could not be arrived at in this study.

EEG results found that 36% of children with kwashiorkor had abnormal electrical activity originating in the temporal or post-temporal areas, and in one child in the parietal region (Neson and Dean, 1975). One study revealed that the mental function and neurointegrative performance in some children suffering from kwashiorkor was impaired several years after recovery (Taori, 1974). However, these studies did not compare the results of neurological, clinical and psychological symptoms.

A study by Galler et al. (2001) examined children during a famine and showed that there is a long term impact on their development. Their study clear shows that there is a direct association between clinical features and neurological symptoms, but this is in contradiction to the results of this study. A study by Wadia and Sinha (2005) observed that a protein calorie deficiency is directly related to EEG abnormalities, and clinical and neuropathological changes. In this study when nutritional attributes were also included a direct cause and effect relationship could be seen only when nutritional attributes were also included.

A neuropsychological estimation would be able to elucidate the performing standard of the activities of the brain in correlation to the impact of under nourishment. The bivariate results found that behaviour changes were found in the focal region, and this result suggests that there was evidence of behaviour problems in children with brain impairment. Trauner et al. (1996) found that in focal lesion patients, regardless of the side of the lesion, the patients tended to have more abnormal scores on scales assessing cognitive function, adjustment and social skills. A shortfall in behavioural patterns, emotional balance and intellect are correlated to the constitutional malformation of various areas of the human brain, and the constitution of the brain and its circuits handle diverse constituents of cognitive procedures (Raven et al., 1998). Undernourishment has lifelong consequences in the sphere of intelligence and actions; however, cognitive procedures, such as decision-making performances, are yet to be completely examined (Kar and Rao, 2004).

Cognitive processes are more severely affected in malnourished children and this suggests diffuse cortical involvement. This is with reference to deficits pertaining to functions mediated by the bilateral temporal cortex (poor performance on tests of comprehension, verbal learning (Kar et al 2008). The differential quality of the cognitive shortfall correlated to PCM illustrates that diverse regions of the brain are negotiated to various levels. A neuropsychological evaluation can define the outline of brain malfunction, and the consequence of a protein-calorie deficiency is merged in an inseparable manner with the outcome of societal drawbacks. The bivariate results suggested that there was evidence of personal/social skills problems (found in the multifocal region) in children with a brain impairment. These findings are supported by Trauner et al. (2001) who reported that when the presence or absence of frontal lobe involvement was taken into consideration, children with frontal involvement had more abnormal scores on scales evaluating cognitive function, whereas those without frontal involvement scored more poorly on scales assessing social skills (Trauner et al., 2001)

The ANCOVA results showed an association between clinical and EEG, and between neuropsyshological disorder and EEG. This finding is consistent with a study by Levav et al. (1995) which stated that nutrition, EEG status and parasite burden showed a consistent effect of the degree of nutrition on neuropsychological performance, particularly language.

7.1.9 Influence of Tribe on Brain Function as a Cofactor

The impact of PEM on brain function is not determined by PCM alone and tribes are an important factor for developing learning and cognitive functions. This study assessed the impact of tribes as a cofactor on brain impairment and also assessed changes after treatment. The results of study revealed that at admission, tribes had an impact on brain function in children with PCM (p-0.001) when nutrition as well as EEG was considered. Children in some tribes may be exposed to various types of malnutrition that have the potential to affect their physical and emotional development in ways that might not be reversible. The study found that tribes had a significant effect on brain development in children with PCM, which means that malnutrition alone did not cause impairment to the brain but the interaction between PCM and tribes has a powerful detrimental effect on children's brain function and behaviour development. It also means that children within some tribes and those who have PCM have a higher probability of experiencing brain problems, with specific factors among tribes playing a major role in affecting brain development. It must be emphasised, however, that while certain factors are often present among tribes where brain impairment occurs, this does not mean that the presence of these factors will always result in brain impairment, and the factors that may contribute to brain impairment in one tribe may not result in brain impairment in another tribe. For example, the specific life situations of some families in specific tribes, such as marital conflict, single parenthood, unemployment, financial stress, and social isolation, may increase the likelihood of the poor delivery of health care (Torún and Chew, 1994; Torún, 2006). While these factors by themselves may not cause brain impairment, they frequently contribute to negative patterns of family functioning (Torún and Chew 1994; Torún 2006). Different factors among tribes may play varying roles in accounting for brain impairment, e.g. a lack of care or lack of emotion. Internal, specific risk factors that affect a tribe may influence a child's behaviour, and certain characteristics of a tribe may mean that mothers place children at greater risk. Tribes and malnutrition may influence brain impairment but were not found to influence brain function, behaviour, or clinical signs.

Poverty and a low purchasing power were the main reasons for malnutrition, but faulty feeding habits arising from ignorance regarding the right kind and right amount of food, superstitions, wrong food beliefs, a lack of knowledge regarding balanced food, sanitation etc., were found to be equally responsible for aggravating the present scenario of malnutrition. However, this research did not establish a causal relationship between tribes and mental development that could facilitate more direct action. Grantham-McGregor (1995) stated that children who suffer from poor nutrition also typically suffer from a range of other environmental difficulties associated with poverty, such as poor housing, poor health-care, weak family and community support systems.

This study further indicated how exactly these children are harmed by PCM and the role that tribes played. While PCM affected brain development, overall clinical features and child nutrition were also affected as well as behaviour. This finding supports a study by Walker et al. (2005), who stated that a lower quality of nutritional intake in low-income infants and toddlers is linked to lower cognition.

Several explanations can be postulated for the association between tribes and PCM and brain impairment. Child factors, such as behaviour problems or parental perceptions of such problems have been associated with an increased risk for a decrease in caring capabilities. These factors may contribute indirectly to child malnutrition when interacting with some tribal characteristics, such as poor coping skills, a poor ability to empathise with children, difficulty controlling emotion, and a lack of knowledge about normal child development, which may result in unrealistic expectations. Negative attitudes and attributions concerning a child's behaviour and inaccurate knowledge about child development may also play a contributing role in brain impairment. For example, mothers who neglect their children have both more negative and higher than normal expectations of their children, as well as less understanding of appropriate developmental norms. The brain develops in part, in response to an infant’s experiences, and if the relationship with their primary caregiver is neglectful, this will have a negative impact on a child’s development of appropriate coping skills (Schore, 2001). The first explanation is that some tribes with a low income create greater family stress, which in turn leads to higher chances of behaviour problem. A second explanation is that tribes with low incomes, despite good intentions, may be unable to provide adequate care while raising children in a high-risk environment with unsafe or crowded housing and inadequate day care. A third theory is that some other characteristics among tribes may make mothers more likely to spend more hours outside home leaving the child to be cared for by their siblings.

Some tribal parents may experience greater isolation, more loneliness, and less social support. Social isolation may contribute to brain impairment because tribal parents have less material and emotional support, do not have positive parenting role models, and feel less pressure to conform to conventional standards of parenting behaviours. It is not clear, however, whether social isolation in some tribes precedes and serves as a contributing factor to brain impairment or whether it is a consequence of the behavioural dynamics of brain impairment. Poor children are more likely to have parents that are less likely (by a factor of three or four) to initiate conversation just to maintain social contact or build vocabulary (Hart and Risley, 1995).

In some tribes, poor parents are more likely to leave their children home alone for extended periods of time, and PCM can result from neglect. Children are also exposed to PCM by being separated from their mothers or caregivers, and this can lead to attachment problems in children, which often manifests later into serious behaviour problems. One of the most stressful events in an infant or child's life is separation from their mothers. A young infant needs to bond with their mother, and this is important not just for an infant's nutritional status, but also for an infant's ultimate successful psychological and emotional development. Children who lack early attachment opportunities have smaller brains and lower IQs (Perry, 2002). The younger a child is when they experience this lack of attachment, the greater the damage, and inadequate care in infancy may lead to disruption of the development of the right hemisphere of the brain (Schore, 2001), the half that is most involved in the processing of emotion. Children facing social problems, such as inadequate care and separation from caregivers due to work may suffer from long-term impairment in how their brain functions.

This study indicates that adequate nutrition can help prevent some of these undesirable outcomes. Four weeks after discharge the associations disappeared. A durable and sustainable improvement in the problem of brain impairment among tribes could be due to an improvement and diversification of household diets, knowledge components, a gain in basic nutrition knowledge, a change in attitude and an enhancement in skills after exposure to scientific information on nutrition, health and child care. An explanation for this finding is that in some tribes, there is greater opportunity for building extended family and cultural kinship relationships that can help prevent attachment disorders. If a child's parents are not emotionally or physically available, then other extended family or community members may become critical objects of attachment for a child. Bonding with a mother can act as a protective factor for a child; however, if children receive inadequate care from their mothers over a period of time, then they may still suffer long-term problems, even though another caretaker steps in (Perry, 2002).

These findings indicate that it may not be the experience of stress itself that has an impact on a mother's risk of lack of care, but rather whether she is able to resolve that trauma. Her locus of control appears to be important in this resolution. In some tribes, teenage mothers in particular, exhibit higher rates of a lack of childcare skills. Other factors such as a lower economic status, lack of social support, and high stress levels also contribute to the link between young parents and child neglect. A lack of care can have devastating consequences for children and families. In terms of prevention and intervention efforts, it is important to identify tribes at increased risk for a lack of childcare. However, the study did not explain the extent to which this relationship persists among those who became mothers as adolescents but are now adults. Such knowledge is important since adolescence is a relatively short period in the lifecycle, but is one that sets the stage for a lifetime of parenting.

7.2 Conclusions

7.2.1 Prevalence of PCM and Seasonal Variation

Sudan stands in a very vulnerable position with one of the highest prevalences of PCM in the world. Based on the results of this study, it is concluded that the wet season in Sudan causes a negative impact on the health of infants and children resulting from low intake of food. This study confirms that the prevalence of PCM is typically subject to seasonal variation, which may be due to the interaction of a number of factors including household characteristics, socio-demographics, child feeding practices and household nutritional consumption.

Prevalence of marasmus was by far the highest among the three syndromes. When the variables were regressed on marasmus and kwashiorkor, the presence of a household latrine was the only variable associated with PCM among children aged 0-59 months in Khartoum; such practices facilitate disease transmission from one individual or area to another.

It was found that dietary diversity is low and the protein content in foods was inadequate for children. The carbohydrate content of the foods, especially the starch content, was too high, resulting in unfavourable dietary bulk properties. The fat content was found to be very low: consequently, the energy density of the foods was very low, much lower than the recommended energy density range for all age groups.

7.2.2 Prevalence of PCM by Demographic Characteristics

Male children are more likely to develop symptoms of marasmus and kwashiorkor than females. This finding confirmed that, among the determinant factors, being male, child age, birth spacing, tribes and reason for introducing solid food remain key risk factors, at least with two forms of PCM. However, this study has not elucidated the factors that place boys at greater risk for PCM compared to girls.

This present study confirms the observations of significant factors in other studies in Sudan that show higher levels of PCM in children under five years, such as gender (Alredaisy, 2012), the age incidence of marasmus and kwashiorkor (Taha et al., 1976), short birth interval (Ahmed et al., 1982) and maternal education (Coulter et al., 1988)

7.2.3 Implications for Brain Development

This study provides good evidence that not only do marasmus and kwashiorkor influence brain development, but also being underweight can result in severe brain impairment
In general, there was during successful treatment an improvement in the EEG, which ran parallel to the improvement in the clinical state and psychological condition

7.3 Recommendations

7.3.1 Strategies to reduce the prevalence of PCM

7.3.1.1 Promotion of hygiene

Sudan should focus on complementary interventions to address the other determinants of protein calorie malnutrition, such as water and sanitation, with the aim of reducing illness from infectious disease.

7.3.1.2Free treatment

As recommended by WHO (WHO, 2007) enough resources should be made available to provide free treatment, as the affected families are often the poorest.

7.3.1.3 Complementary feeding and micronutrient supplementation

The government should provide the resources needed for the management of PCM by making ready-to-use-food assessable to vulnerable and displaced families. Fortified food, vitamin A supplementation, therapeutic zinc, iron fortification of staples, and iodine supplements should be made available. It is important to note that at present there is no infant and young child feeding policy or strategy in Sudan. Given the magnitude of the problem, the development of a detailed plan of action is required. There is also an urgent need to develop a family focused nutrition expertise at various levels of the Ministry of Health structure especially at district and local levels.

7.3.1.4 Behaviour change interventions

Khartoum aims to improve the nutritional intake of infants and children. Sensible efforts are needed to protect and promote weaning; to improve appropriate complementary feeding practices and fill in the nutrient gap by increasing the appropriate use of affordable nutritious complementary foods; to increase the consumption by young children of cereals, legumes and other locally produced weaning foods; to increase meal frequency for children; and, where appropriate, to encourage higher consumption of oil, fat and other items that reduce bulk and increase the energy density of foods fed to children at risk. These measures are likely to have more impact if accompanied by growth monitoring, immunisation, early treatment of common diseases and regular attention to the seasonal variation causes of PCM such as child feeding practices, and household nutritional consumption. Some of these measures can be implemented as part of primary health care.

To have long term effect, the policy should look at the benefits for families and children of a family-centred approach to working with children affected by PCM. Using a family-centred approach, it considers the family in every intervention with children, recognising that supporting the family is one of the most effective means of ensuring the best possible quality of life for the child

7.3.2 Barriers

Implementation of these options requires the delivery of different types of interventions to deal with either existing or future anticipated challenges. All these options encounter different barriers at community, institutional and service delivery levels and at policy levels, as follows:

The diversity of Sudanese communities' cultures is a critical challenge for changing the incorrect maternal and child nutrition habits and practices among the population. Lack of recognition by decision-makers of malnutrition as a critical factor of ill health and as a public health problem, or more broadly as a major obstacle to social development, is a crucial barrier to making it a top priority (UNICEF, 2004).

Consequently, political leaders and decision-makers do not feel encouraged to act upon PCM, and the lack of political commitment makes it difficult for the government to allocate sufficient financial resources to tackle malnutrition (FAO, 2005).

The prevalence of PCM is high among the poor and predominant in children who tend to belong to underprivileged families in the society; such families do not have a strong voice in public debates and decision-making circles (WHO and FMH, 2004)

Lack of integration of civil society groups in nutrition programmes and interaction among governmental and nongovernmental sectors is a major barrier to improving the sector's efforts to improve nutrition

7.3.3 Overall strategies to deal with the above-mentioned barriers

Using different community awareness tools that are based on evidence and pre-implementation analysis is important for bring about change in community awareness and perception about PCM.

It is important to create and develop training materials for medical staff at different levels of the system. Team building is also important to improve health providers' performance.

Improving policies, regulation and participation of the country in international initiatives is a good route to resource mobilisation and better resource allocation.

Efforts must be made to educate parents and present intervention programmes. Developments of coordination tools are important for experience and sharing information and joint working.

7.4 Future Research Directions

This research has targeted a single province, Khartoum, in order to identify the prevalence and determinants of PCM. The results indicate that PCM is a highly prevalent problem in this area requiring a more wide geographical area.

The research results indicate that demographics, social, nutritional factors, feeding patterns, tribe, psychosocial factors as well as EEG patterns are determinants of PCM. Future research in this area should focus on identifying the combined effect of these factors (all of them together and as pairs).

The research results suggest that there is a positive association between neurological factors (EEG results), psychosocial factors as well as diagnosis of PCM. This indicates that addressing intervention programmes which target the nutritional wellbeing of children is not enough. There is therefore a need to develop a holistic programme which promotes the overall physical, mental and emotional health of a child.

The complexity of research on nutrition, brain function, and behaviour is evident, but so too is its potential to generate knowledge that has broad practical application and benefits. Future studies should identify new relationships and better characterise existing ones, while attempting to discover the underlying mechanisms. Although the focus of early studies was on the effects of general malnutrition in children, future studies should focus on specific nutrients and their effects on brain function and behaviour in adults. Experimental (in contrast with correlational) studies offer the best hope of distinguishing nutritional from non-nutritional effects on these critical aspects of function.

Future research should attempt to identify nutrient intakes that will result in optimal performance. One challenge for researchers in this area will be to present their findings in a manner that tempers the public's tendency to uncritically embrace new findings before they are replicated and refined, and to overgeneralise highly specific findings obtained under the controlled conditions of the laboratory.

7.5 Limitations of the Study

A limitation of the present study was that while conducting the interviews, the interviewers depend on the information provided by mothers. Information could thus have been subject to recall bias. However, the interviewers were careful in recording the information they provided and in the interpretation of the results of the study. Even though the mothers were questioned about exclusive breastfeeding, the reported length of exclusive breastfeeding could have been incorrect, as mothers remain ignorant regarding the meaning of exclusive breastfeeding.

When initiating this study there were a few mothers and fathers who were reluctant to sign the consent form and therefore their children could not be included in the study. In a number of cases the mothers or caregivers who signed the consent form refused to come back for follow up and therefore these cases were excluded and replaced with new cases. New cases were selected from sequential patients admitted for treatment. Patients who were scheduled for follow up and failed to keep the appointment had a negative impact on the workflow of the research, by increasing the time taken in establishing the study and increasing the cost of the study.

Due to the logistic problems encountered at the beginning of study concerning obtaining Sudanese ethical clearance, the study started later than planned. The inability to take biochemical samples, due to the limited analytical facilities and the required need for a nonintrusive trial, was also a major drawback.

Some data (milk, meat, fish, eggs) were omitted from the study because of the lack of precise information regarding household food consumption among participating families, possible over-reporting of ‘good’ foods. In addition, parents might have failed to provide complete information, or might have been tempted to alter it somewhat, out of embarrassment or an urge to please or impress the researcher (Lee 2010)

Due to resource constraints, only one 24-hour recall was collected for each participant. Thus the study was unable to assess the adequacy of a diet since the dietary reference intakes were calculated for healthy individuals and are intended as an average daily intake over time. Day-to-day variations of nutrient intake are expected, which cannot be adequately captured in a single 24-hour recall. The small sample size of this study was further restricted by fact that infants who were breastfeeding at the time of the interview could not be included in the nutrition analysis due to an inability to accurately estimate breast milk consumption. There is lack of data on the dietary

The primary limitation of 24-hour dietary recall is that recording consumption for a single day is seldom representative of a person’s usual intake due to day-to-day variation. An extended and more accurate version of this method is that the diet is assessed over a period of three to five days. The weaknesses of 24-hour dietary recall methods are: single observation provides poor measure of individual intake, estimation of portion sizes, bias in recording and memory dependent. However it could be suitable for large scale surveys with low respondent burden.

The study did not examine micronutrients intakes of the patients, because there is lack of data on the micronutrients intake of marasmus and kwashiorkor children

Due to financial constraints the study did not make provision for taking blood samples. The only blood values that were used in the study were routine values available from the files of the children. Not all the children had the same blood tests performed and therefore blood values for were not available for all the children.

Most of the families lived in slum areas and there was no specific address, instead an address was recorded using a description, for instance the nearest canteen, school or clinic. When patients did not attend their follow up an attempt was made to contact them by telephone, although some had changed their number and other did not reply. Visits to their homes were them attempted, but this proved difficult as there was no public transport in these areas, and the road was very narrow, thus necessitating walking or the use of a *carrow* (a board with two wheels drawn or pulled by a horse or a donkey), in addition it was not safe to stay after sunset. Some families were found, but others had moved and no one knew their whereabouts, they may have left Khartoum and travelled to other towns. To avoid these problems in future, it would be useful to have at least three different contact numbers and three different addresses, and to request that patients to not leave the area during the study period. However, in spite of all these limitations, the study yielded useful data and information.

Bias in over reported intake may distort the understanding of actual food consumption. On the other hand, psychosocial characteristics of mothers may associate with the accuracy of dietary self-report. Therefore procedures that use prediction equations to identify mothers who are under-reporters or over-reporters can be utilized to gain an understanding of the systematic bias in samples where objective measures of intake may not be available or feasible. This will be achieved through the examination, rather than exclusion, of under-reporters and over-reporters

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APPEDICES

Appendix A: Ethical Approvals

A1. Demographic and Nutritional Study

Faculty of Medicine
University of Khartoum
Research Board
P. O. Box: 102
Khartoum, Sudan

كلية الطب
جامعة الخرطوم
محلس ابحاث الكلية
ص. ب: ١٠٢ الخرطوم - السودان

Date: 8/4 2009
Ref.: FOM/D/staff member

Dr. Zahra Ahmed
C/O Dr. M. Sirelkhatim Hashim
Department of Paediatrics

Dear Dr. Ahmed

Subject: Ethical Clearance of your project titled: Novel nutritional Treatment of Sudanese children with protein calorie malnutrition)

The Ethical Committee had reviewed your proposal titled: "Novel nutritional Treatment of Sudanese children with protein calorie malnutrition" and following in careful review of the submitted proposal, the committee has approved the proposal based on its fulfillment of the ethical guideline of the Faculty.

I am hereby pleased to inform you that your proposal is ethically approved to start your study.

Dr. Ahmed Mohamedain Eltom
Secretary, Faculty Research Board

UNIVERSITY OF KHARTOUM
FACULTY OF MEDICINE
- 6 APR 2009
DEAN'S OFFICE

A2. Implications for Brain Function Study

Faculty of Medicine
University of Khartoum
Ethical Research Committee
P. O. Box: 102
Khartoum, Sudan

كلية الطب
جامعة الخرطوم
لجنة أخلاقيات البحوث لمجمع العلوم الطبية
ص. ب : 102 الخرطوم - السودان

Ref: FM/DO/EC
Date: 21/6/2012

Ethical Committee

The committee held a meeting & discussed the Research proposal Titled:

Prevalence and Seasonal Variation of Severe Childhood Protein Calorie Malnutrition in Khartoum: Implication for Brain Function

By:

Dr. ZAHRA ELNOUR HASSAN AHMED

Committee decision:

Ethically approved ☑

Ethically not approved ☐

UNIV... KHARTOUM FACUL... F MEDICINE 21 JUN 2012 ...'S OFFICE

Prof. Sheikh Mahgoub
Head of Ethical Committee

Dr. Sulafa KM Ali
Secretary

Appendix B.: Questionnaires

B1. Demographic and Nutritional Questionnaire

- **Study Data:**

  1.1 Date of Interview ____________1.2 Reference Number ________________________
  1.2 Interviewer Number ____
  1.3 Address ____
  1.4 Telephone Number ____

2. Personal Data:

2.1 Name____
2.2 Date of birth____
2.3 Age/month 0-5____6-11____12-23_____24-35_____36-47____48-59____
2.4 Sex Male__________Female_____________
2.5 Child weight _____________ _ 2.6 Child height___________________
2.7 Skin fold thickness______ 2.8 Child birth weight_____2.9 Birth order______
2.9 Space of delivery 2.10 Hospital______2.11_Home _________ __
2.12 Was the child fully vaccinated? Yes____________No___________
2.I3 Is the child on breast milk? Yes____________No__________
2.14 Breast feeding mode from birth to 6 months 1- exclusive breast feeding____2- Partial breastfeeding___ 3- No breastfeeding_____

3. Demographic data of household:

3.1 Age 3.2 Husband ____________3.3 Wife ______________
3.4- Weight 3.5 Husband ____________3.6 Wife ______________
3.7 Height 3.8 Husband ____________ 3.9 Wife _______________
3.10 Body mass index (BMI) wife <18.6_______18.6 -23.8_____>23.9________________
3.11 Age at marriage 1- Husband ______________2- Wife ______________
3.12 Education
3.12.1 Husband None_______Primary _____Secondary___ University__
3.12.2 Wife None______Primary____Secondary___University_____
3.13 Occupation
3.13.1 Husband Employed______________Unemploye _____________
3.13.2 Wife Employed______________Unemployed_____________
3.14 Working activity
3.14.1 Husband Light ___________Moderate________Heavy_________
3.14.2 Wife Light___________Moderate_________Heavy_________
3.15 Number of women he has fathered children with
1_____2____3_____4____
3.16 How many hours does wife spend in various activity?
At home_______________outside home_____________
3.17 –If not employed what are the sources of income?
3.18 How many people contribute to the income? __1_____2____3____4___
3.19 Household income per month
A) Less than 300.00 Sudanese pound ___________
B) 300.00 400.00 ,, ,, ___________
C) 400.00 500.00 ,, ,, ___________
D) More than 500.00 ,, ,, ___________
3.20 How much money do you think you spend on food for the family? ____________
3.21 Ex smoker Husband _________________ Wife __________________
3.22 Number of years in Khartoum _______________________________________
3.23 Original home Town________________________ Village ___________
3.24 Family size Adult ________________ Children_______
3.25 Gender 1- Male _______ 2- Female ________
3.26 Age

1- Male	2- Female
1 _________________________	1 __________________
2 _________________________	2 __________________
3 _________________________	3 __________________
4_________________________	4 __________________
5 _________________________	5___________________

4. Biochemical assessment:

4.1 Hemoglobin ____
4.2 Protein ____
4.3 Serum albumin ____

4.4 Is the head of the household male or female? 1) Male___2) Female___3) No information__
4.5 Three mains problems observed by household
4.6 What are the major problems in your daily life?

Problems (not more than three	Answer
Little income Poor living condition Little food Frequency ill Poor or inadequate water supply Inadequate energy supply Other problems No problems	

5- Socioeconomic household data:

5.1 .Who is mainly responsible for bringing up children?
1) Mother_________2)father_________3)Both mother and father_________
5.2 sister/brothe___________5) grand father___________6)-grand mother________
5.3 Number of pregnancy ____
5.4 How many cases exist with spacing less than 2 years?______________________
5.5 Has any one died in the household? 1) Yes_____________ No______________
5.6- Details of the deceased

Category	1	2	3	4	5
48- Age	0- 11 months	12-35 months	36-59 months	5-54 years	55+
49- Cause of deaths					

5.7 Birth spacing between the ill child and older sibling______________________
5.8 How old was the mother at the first pregnancy? ____________________________
5.9 How old was the mother at the youngest child? ____________________________
5.10 Is the mother pregnant now? 1) Yes_______________2) No______________
5.11 Number of room in the house _______1_________2________3________4____
5.12 Home building material 1) Mud____2) Brtick_____3) Paste Board___
4) Stone________5)Other________________
5.13 Is there running water in the house? Yes____________ No___________
5.14 If no, from where do you obtain water? 1) Public supply outsie________
2) Water trader_____3) other
5.15- Does the house have electricity? Yes: 1) directly from the public supply
2) Via a neighbour____3) No_____4) Other___
5.16- How are garbage/ household waste disposed? 1) Public garbage__2) collection____
3)Burned__________ 4)Buried_______

6. Nutritional survey:

6.1 – Sources of food
1) Purchased____ 2) Homemade_____3) Other_______
6.2- Who does the shopping?
1) Father______ 2) Mother_____ 3) Sibling______4) Other_____
6.3- Where do you go shopping?
1)Supermarket____2)Market___ 3)Smallshop____4)Other_____
6.4- How often do you go shopping?
1)Daily______ _2)Weekly___ _3)Monthly______4) Other_____
6.5- How do you get there?
1) Foot________2) Public transport__3) Car________
6.6- Where do you store your food?
1) Kitchen_____ 2) Living room_____3)Special place_____
6.7- Who normally cook?
1) Husnand______2) Wife___________3) sibling________4) Grand father_____ 5)grand mother ________
6.8- How often do you cook?
1)- Once a day_________ 2) Twice a day_____________
3) Three times a day___________4) Other__________________
6.9- What form of energy is used for cooking? Coal___Wood______Cooker__
6.10- How many meals do you eat? 1______ 2___________3________
6.11- How many snacks do you have? 1________2_______3______4____
6.12-Where do you eat? ____
6.13-Is it comfortable? Yes___________________No_________________

6.14- Which foods are eaten in your household?

Food sources	**Frequency of consumption**
Staple (wheat, durra, sorghum, millet) Legumes Milk Egg Meat Fish Oil Sugar Fresh green leafy vegetables Other fresh vegetable Fruits	

- Never
- Monthly: Once, more than once
- Weekly: once, more than once
- Daily: Once, more than once

6.15-Which special food do you consume during pregnancy?_______________
____
____

6.16- Reasons for eating special food during pregnancy?_____________________
____
____

6.17-Which special food do you consume during lactation?___________________

____

6.18- What are the reasons for eating special food during lactation?_____________
____
____

6.19-What are the most difficult things about feeding family?
1) Little food__________ 2) Little income______3) Frequency ill______
4) Snempolyment________5) Much time spent in getting to work_________
6) Poor living condition___7) Educational problems___8) no or unclear right of residence____

6.20-Despite these difficulties do you think that your family is well fed?
1) Yes_________________2) No__________________________________

6.21- What do you do when the food is small?
1) Share equally____________2) Give the child only________3) Give to Give to husband___________4) Share between mother and children_______

6.22-Who receives best portion?
1) Husband________________2) Children and husband_________________
3) Wife and husband ________4) Share equally________________________

6.23-Who normally eat first in the family?
1) Husban_________2) Wife_________ 3) Boys________4) Girls________

6.24-Is priorty given to____
1) Male___________________________2) Femal_______________________

6.25- When wife's portion is dished?______________________________________
1) Along with husband_____________2) After husband________________
3) After husband and children________4) Non of the above______________

6.26- Does the family eat together or separately?___________________________

6.27-Do member of family eat the same food? ______________________________
1) Yes___________________________2) No_________________________

6.28- If your child receives solid food, at what age did you begin feeding the child the solid food? Tick the relevant box.

1	<4 months	2	>6 months	3	4-6 months
4	Don't know	5	No answer		

6.29- If not on breast milk how old he/she was when completely weaned? Tick the relevant box.

1	Never breastfed	2	6 month -1 year	3	1—1/2 year
4	2-3 year	5	Not your own child		

6.30-What is the reason for starting food supplement?. Tick the relevant box.

1	Unsatisfactory growth	2	Little/week breast-milk	3	_advice
4	Work	5	Breast problem	6	Pregnancy
7	Refusal after bottle	6	Problems of infant	9	Problems of mother

6.31-Why was the breast feeding stopped? Tick the relevant box.

Usual time to stop	Low milk production product	Mother was sick	Other (specify)

6.32 Which weaning food did you start with

6.33-Regardless of whether your child is breast-fed or not, how often your child eaten any solid food in the last 24 hours? Tick the relevant box.

Yes	No	Don't know	No answer

Within the last 24 hours has your child drunk anything in addition to breast milk?
Yes______________________________No_________________________________
In the last 24 hours has your child eaten fruits or vegetable?
Yes_________________No______________________No answer__________________
During the past 24 hours has your child been bottle-fed?
Yes______________________No__________________No answer_________________
How many times did the child eat yesterday? ___1_____2_____3____4___5_____6___
What kind of food did the child eat yesterday?

Key	1	2	3	4
Sources	Own product	purchased	Aid(specify)	Other(specify)

What food do you think is best for your child?

Which fluids do you think are best for your child?

Do you give or avoid special food or fluids, when your child is ill? Yes______No______
(If yes, specify)____

Consumption of the meal/supplement

Items	Sources
Breakfast 1- 2- 3- 4- Lunch 1- 2- 3- 4- Dinner 1- 2- 3- 4-	

Mother's opinion about food consumption

What the amounts of food the child ate yesterday? Normal_______Less than_________
If less/ more give the reason____
Did the child eat form the same dish as sibling, at the main meal time?
Yes________________________________No___________________________________
Do you think is it possible to achieve a good/healthy diet for your self?
Yes_________________No_______________________I don't know________________
Do you think it is possible to achieve a good/healthy diet for your children?
Yes_________________No _______________________I don't know_______________
As a mother how would you improve your own diet
As a mother how would you improve diet for your children?

Blood sample: pre albumin Biochemistry
Hematology
Milk sample: Fat
Protein
Carbohydrates

7) 24-Hour Recall Questionnaire:
Subject name:
Interviewer: _ Date:/200
Would you describe the food that your ate yesterday as typical of your child habitual food intake?
Yes 1 No 2
I want to find out about everything your child ate or drank yesterday, including water or food you pick from the veld. Please tell me everything your child ate from the time he/she woke up to the time he/she went to sleep. I will also ask you how much your child ate.

Time	Description of food and preparation method	Amount	Code
From waking			
During the morning			
Middle of the day (Lunch time)			
Afternoo			
At night (dinner time)			
Before going to sleep			

Do you take any vitamins (tablets or syrup)?
Yes 1 No 2

Give the brand name and dose of the vitamin/tonic

B2. Clinical and Nutritional Questionnaire

1. CHILD INFORMATION

1.1 Date of Interview: ______________ Reference Number: __________________
1.2 Interviewer Number: ____
1.3 Child's name: ____
1.4 Address: ____
1.5 Telephone Number: ____

2. CHILD CHARACTERISTIC 1-4 YEARS OF AGE

2.1 Date of birth: ____
2.2 Age/month: ____
2.3 Gender: Male: ______________________ Female_____________________
2.4. Maternal age: ____
2.5. Maternal age when pregnant with the index child: _________________________
2.6 Place of delivery: Hospital ________________ Home_____________________
2.7. Mode of delivery: Normal___________________ Caesarean________________
2.8. Presentation of delivery the baby: Normal____________ Breech_____________
2.9. Birth order: ____
2.10. Maternal obstetrics: Healthy_______________ Complicated________________
If complicated, what type of complication? Diabetes______ Hypertension____
Infection __________Other__________(specify_________________________
2.11 Number of children: ____
2.12 Are mother and father related by blood? Yes____________ No__________
2.13 Was the child born in Khartoum? Yes____________ No_________
2.14 Tribal origin: ____
2.15 Number of years in Khartoum: _______________________________________

3. MEDICAL HISTORY
3.1 Gestational age: Term ______________ Preterm______
3.2 Birth weight: Heavy___________ Normal_______________ Small______
3.3 Has the child had infections in the past? Yes__________________ No________
3.4 If yes what type of infection the child had? Diarrhoea ___________Respiratory___ infection____________ Measles_____ Other_______________(specify_____:
3.5. Was the child admitted to the hospital**?** Yes _________________No________
3.6. Has the child had other medical illnesses in the past? Yes ____________No_______
If yes, what was the other medical problem? _________________________________
3.7. Has the child had infection before become a malnourished? Yes________No_______

3.8. If yes; what type of infection the child had? Diarrhoea _______ Respiratory_____ infection _______ Measles_______ Other_________(specify: __________)
3.9. Length of present illness before admission: _________________________________
3.10. Is the child fully immunized? Yes____________ No____________

4. CLINICAL EXAMINATION AT ADMISSION

4.1 Child weight: __________________ Child height: ___________________________
4.2 Skin fold thickness: _____________ Head circumference: ______________________
4.3 Behavior: Apathy______Irritability________ Anorexia______Normal_____________
4.4 Pallor: Yes__________________ No_________________
4.5 Hair changes Yes__________________ No_________________
4.6 Moon face Yes__________________ No_________________
4.7 Flaky-pant sign Yes___________________No_________________
4.8. Oedema Yes___________________No________________
4.9. Associated Vitamins deficiency Yes___________________ No_________________
4.10. Associated Infection Yes___________________ No________________
4.11. Growth Retarded Yes___________________ No________________
4.12. Child weight Yes___________________ No________________
4.13. Out Come Death_______Lost to follow________Failure of nutritional_______ Treatment________Readmission____________Well_____________

5. NUTRITIONAL ASSESSMENT: AT ADMISSION

5.1. What does your child eat?

Food sources	**Frequency of consumption**
Breast feeding …………………………	…………………………………
Staple (wheat, durra, sorghum, millet)…	………………………………….
Legumes…………………………………	………………………………….
Milk………………………………………	………………………………….
Milk products……………………………	………………………………….
Egg………………………………………	………………………………….
Meat………………………………………	
Fish……………………………………….	………………………………….
Oil………………………………………..	………………………………….
Sugar………………………………………	………………………………….
Fresh green leafy vegetables……………….	………………………………….
Other fresh vegetable……………………….	………………………………….
Fruits…………………………………………	………………………………….
	………………………………….

- Daily: Once, more than once
- Weekly: once, more than on
- Monthly: Once, more than once
- Never

5.2 What does your child eat for breakfast, lunch and dinner?

Items	Sources
Breakfast……………………………….	…………………………………………….
1-…………………………………………	………………………………………….
2-…………………………………………	…………………………………………….
3-…………………………………………	…………………………………………….
4…………………………………………..	…………………………………………….
Snacks…………………………………….	……………………………………………
……………………………………………	…………………………………………….
…………………………………………….	…………………………………………….
Lunch……………………………………...	…………………………………………….
1-………………………………………….	…………………………………………….
2-………………………………………….	…………………………………………….
3-…………………………………………	…………………………………………….
4-………………………………………….	…………………………………………….
Snacks……………………………………….	…………………………………………….
………………………………………………	……………………………………………

………………………………………………	…………………………………………….
Dinner……………………………………...	…………………………………………….
1-……………………………………………..	……………………………………………
2-…………………………………………….	……………………………………………
3-……………………………………………..	……………………………………………
4-…………………………………………..	…………………………………………….

Eats variety of foods: small portions, i.e., 1–2 Tbsp., ½ c juice, ½ slice of bread
How does your child feel about mealtimes? Happy……………… Angry…………….
Activity plays every day, i.e., crewing, walking, and playing……………………………
5.3 Biochemical assessment
5.3.1. Hemoglobin ____
5.3.2. Protein ____
5.3.4. Serum albumin ____

6. CLINICAL EXAMINATION 4 WEEKS AFTER DISCHARGE

6.1. Child weight: ___________________ Child height: __________________________
6.2. Skin fold thickness: _____________ Head circumference: ______________________
6.3. Behavior: Apathy______Irritability________ Anorexia______Normal____________
6.4. Pallor: Yes___________________No________________
6.5. Hair changes Yes____________________ No________________
6.6. Moon face Yes____________________ No________________
6.7. Flaky-pant sign Yes____________________No________________
6.8. Oedema Yes____________________No_______________
6.9. Associated Vitamins deficiency Yes____________________No________________
6.10. Associated Infection Yes____________________No________________
6.11. Growth Retarded Yes___________________ No________________
6.12. Child weight Yes__________________ No________________
6.13. Out Come Death_____Lost to follow_____Failure of nutritional Treatment____Readmission________Well_______

7. NUTRITIONAL ASSESSMENTS: 4 WEEKS AFTER DISCHARGE

7.1 What does your child eat?

Food sources	Frequency of consumption
Breast-feeding…………………………………………...	……………………………..
Staple (wheat, durra, sorghum, millet)………………….	……………………………..
Legumes…………………………………………………	………………………………
Milk……………………………………………………..	………………………………
Milk products……………………………………………	………………………………
Egg………………………………………………………	………………………………
Meat…………………………………………………….	………………………………
Fish……………………………………………………..	………………………………
Oil……………………………………………………….	………………………………
Sugar……………………………………………………..	……………………………….
Fresh green leafy vegetables…………………………….	……………………………….
Other fresh vegetable……………………………………	……………………………….
Fruits…………………………………………………….	……………………………….

1) Daily: Once, more than once
2) Weekly: once, more than once
3) Monthly: Once, more than once
4) Never

7.2. What does your child eat for breakfast, lunch and dinner?

Items	Sources
~~Breakfast…………………………………~~	~~……………………………………………~~
~~1-……………………………………………~~	~~……………………………………………~~
~~2-……………………………………………~~	~~……………………………………………~~
~~3-……………………………………………~~	~~…………………………………………~~
~~4-……………………………………………..~~	~~……………………………………………~~

~~Snacks~~…………………………………………. …………………………………………… ……………………………………………. ~~Lunch~~………………………………………. ~~1~~ …………………………………………… ~~2~~ ………………………………………… ~~3~~ …………………………………………… ~~4~~ …………………………………………… ~~Snacks~~………………………………………. …………………………………………… …………………………………………… ~~Dinner~~………………………………………. ~~1~~…………………………………………… ~~2~~………………………………………… ~~3~~…………………………………………… ~~4~~ …………………………………………	……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ………………………………………………

Eats variety of foods: small portions, i.e., 1–2 Tbsp ½ c juice ½ slice of bread

How does your child feel about mealtimes? Happy_______ Angry_______

Activity plays every day, i.e., crewing, walking, playing__________________

7.3 Biochemical assessment

5.2.3.1 Hemoglobin:

5.2.3.2 Protein: ____

5.2.3.3 Serum albumin: ____

8. CLINICAL EXAMINATION 12 WEEKS AFTER DISCHARGE

8.1 Child weight: ___________________ Child height: ___________________________

8.2 Skin fold thickness: _____________ Head circumference: ______________________

8.3 Behavior: Apathy______Irritability______ Anorexia_____Normal____

8.4 Pallor: Yes____________________No________________________

8.5 Hair changes Yes____________________No________________________

8.6 Moon face Yes____________________ No________________________

8.7 Flaky-pant sign Yes____________________No________________________

8.8 Oedema Yes___________________ No_______________________

8.9 Associated VD Yes____________________No_______________________

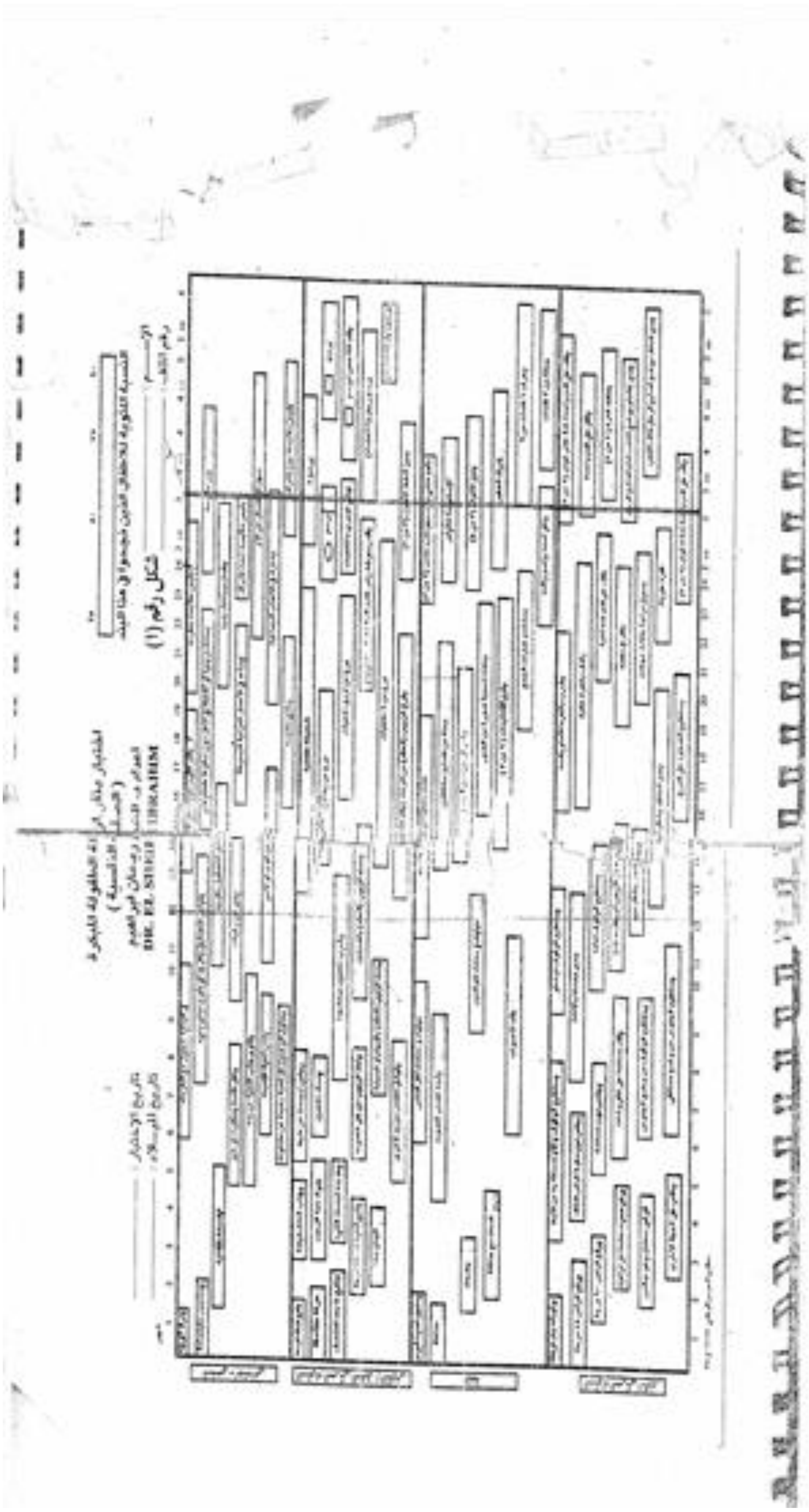
8.10 Associated Infection Yes____________________No_______________________

8.11 Growth Retarded Yes____________________No_______________________

8.12 Child weight Yes____________________No_______________________

8.13 Out Come Death_______Lost to follow________Failure of nutritional Treatment________Readmission__________Well_________

Appendix C: The Denver Scale in Arabic



Annex D: Patient Characteristics at Baseline

D1. Detailed chi-squared analysis of seasonal distribution and household demographics factors

Variable	Wet Season	Dry Season	Total	Chi-Squared	p-value
Child gender					
Male	157(56.5%)	111(59.0%)	268(57.5%)	0.303	0.582
Female	121(43.5%)	77(41.0%)	198(42.5%)		
Child age/months					
0-5	6(2.2%)	19(10.1%)	25(5.4%)	14.50	0.013
6-11	58(20.9%)	37(19.7%)	95(20.4%)		
12-23	139(50.0%)	86(45.7%)	225(48.3%)		
24-35	54(19.4%)	33(17.6%)	87(18.7%)		
36-47	14(5.0%)	7(3.7%)	21(4.5%)		
48-59	7(2.5%)	6(3.2%)	13(2.8%)		
Family size					
2-5	102(36.7%)	113(60.1%)	215(46.1%)	24.959	0.000
6-8	141(50.7%)	61(32.4%)	202(43.3%)		
9-11	31(11.2%)	13(6.9%)	44(9.4%)		
12-13	4(1.4%)	1(.5%)	5(1.1%)		
Number of children <5 yr					
1	18(6.5%)	30(16.0%)	48(10.3%)	**30.931**	0.004
2	102(36.7%)	69(36.7%)	171(36.7%)		
3	158(56.8%)	88(46.8%)	246(52.8%)		
4	0(0.0%)	0(0.5%)	0(.2%)		
Birth order					
1	30(10.8%)	33(17.6%)	63(13.5%)	17.640	0.000
2	38(13.7%)	44(23.4%)	82(17.6%)		
3	(16.5%)	(18.6%)	(17.4%)		
4	56(20.1%)	35(18.6%)	91(19.5%)		
5	54(19.4%)	18(9.6%)	72(15.5%)		
6	32(11.5%)	7(3.7%)	39(8.4%)		
>6	22(7.9%)	16(8.5%)	38(8.2%)		
Mother BMI Kg/m^2					
<18.5	93(33.5%)	58(31.2%)	151(32.5%)	**3.774**	0.287
18.5-24.9	154(55.4%)	115(61.8%)	296(58.0%)		
25.0-29.	29(10.4%)	11(5.9%)	40(8.6%)		
30.0 and above	2(0.7%)	2(1.1%)	4(0.9%0		
Years of residence					
Not living in Khartoum	19(6.8%)	14(7.4%)	33(7.1%)	24.426	0.000
<10 Years	11(68.7%)	133(70.7%)	324(69.5%)		
10-20 years	54(19.4%)	13(6.9%)	67(14.4%)		
>20 years	14(5.0%)	28(14.9%)	42(9.0%)		
Tribes					
Barno	7(2.5%)	5(2.7%)	12(2.6%)	**12.633**	0.364
Dainka	32(11.6%)	22(11.7%)	54(11.6%)		
Fur	26(9.4%)	10(5.3%)	36(7.7%)		
Galeen	10(3.6%)	9(4.8%)	19(4.1%)		
Gawama	7(2.5%)	4(2.1%)	11(2.4%)		
Hawsa	23(8.3%)	10(5.3%)	33(7.1%)		
Mahas	7(2.5%)	7(3.7%)	14(3.0%)		
Masaleet	8(2.9%)	3(1.6%)	11(2.4%)		

Neiur	5(1.8%)	4(2.1%)	9(1.9%)		
Nuba	22(7.9%)	24(12.8%)	46(9.9%)		
Shawayga	11(4.0%)	5(2.7%)	16(3.4%)		
Shuluk	7(2.5%)	7(3.7%)	14(3.0%)		
Tama	3(1.1%)	6(3.2%)	9(1.9%)		
Zabarma	8(2.9%)	1(0.5%)	9(1.9%)		
Other tribes	101(36.5%)	71(37.8%)	172(37.0%)		

D2. Detailed chi-squared analysis of seasonal variation and socio-economics

Variable	Wet season	Dry season	Total	Chi Squared	p-value
Fathers Education					
None	91(32.7%)	62(33.0%)	153(32.8%)	7.178	0.188
Primary	134(48.2%)	77(41.0%)	211(45.3%)		
Secondary	39(14.0%)	40(21.3%)	79(17.0%)		
University	14(5.0%)	9(4.8%)	23(4.9%)		
Mothers Education					
None	143(51.4%)	100(53.2%)	243(52.1%)	8.502	0.031
Primary	114(41.0%)	60(31.9%)	174(37.3%)		
Secondary	20(7.2%)	25(13.3%)	45(9.7%)		
University	1(.4%)	3(1.6%)	4(.9%)		
Mothers Occupation					
Employed	78(28.1%)	38(20.2%)	116(24.9%)	9.007	0.034
Unemployed	200(71.9%)	150(79.8%)	350(75.1%)		
Hour's mothers spent outside home					
2-4 hr (at home)	7 (2.5%)	16(8.5%)	23(4.9%)	8.584	0.004
>4 hr (outside home)	271(97.5%)	172(91.5%)	443(95.1%)		
Family Income/ SP					
<300	169(60.8%)	96 (51.1%)	265(56.9%)	7.159	0.029
300-400	70(25.2%)	46 (24.5%)	116(24.9%)		
400-500	28(10.1%)	30(16.0%)	58(12.4%)		
>400	11(4.0%)	16(8.5%)	27 (5.8%)		
Money spent on food/ SP					
<300	213(76.6%)	143(76.1%)	356(76.4%)	7.759	0.681
300-400	51(18.3%)	34(18.1%)	85(18.2%)		
400-500	7(2.5%)	8(4.3%)	15(3.2%)		
>400	7(2.5%)	3(1.6%)	10(2.1%)		
Number of rooms					
One room	92(33.1%)	78(41.5%)	170(36.5%)	8.584	0.004
2 rooms	153(55.0%)	80(42.6%)	233(50.0%)		
3 rooms	32(11.5%)	23(12.2%)	55(11.8%)		
4 rooms	1(.4%)	7(3.7%)	8(1.7%)		
Presence of Latrine					
Yes	160(57.6%)	102(54.3%)	262(56.2%)	0.469	0.271
No	118(42.4%)	86(45.7%)	204(43.8%)		

D3. Detailed chi-square analysis of seasonal variation and household food consumption

Variable	Wet season	Dry season	Total	Chi Squared	p-value
Bread					
None	36(12.9%)	15(8.0%)	51(10.9%)	6.904	0.075
Once a day	58(20.9%)	54(28.7%)	112(24.0%)		
Twice a day	157(56.5%)	107(56.9%)	264(56.7%)		
Three times a day	27(9.7%)	12(6.4%)	39(8.4%)		
Cereals					

None	2(0.7%)	3(1.6%)	5(1.1%)	8.806	0.032
Once a day	75(27.0%)	69(36.7%)	144(30.9%)		
Twice a day	146(52.5%)	98(50.0%)	240(51.5%)		
Three times a day	55(19.8%)	22(11.7%)	77(16.5%)		
Legumes					
None	12(4.3%)	8(4.3%)	20(4.3%)	75.110	0.000
Once a day	162(58.3%)	48(25.5%)	210(45.1%)		
Twice a day	104(37.4%)	105(55.9%)	209(44.8%)		
Three times a day	0(.0%)	27(14.4%)	27(5.8%)		
Milk/ Week					
None	8(2.9%)	1(.5%)	9(1.9%)	9.971	0.126
Once a week	73(26.3%)	40(21.3%)	113(24.2%)		
Twice a week	42(15.1%)	31(16.5%)	74(15.7%)		
Three times a week	66(23.7%)	45(23.9%)	111(23.8%)		
Five times a week	8(2.9%)	1(.5%)	9(1.9%)		
Seven times a week	69(24.8%)	59(31.4%)	128(27.5%)		
Fourteen times a week	12(4.3%)	11(5.9%)	23(4.9%)		
Milk Product /Week					
None	1(.4%)	5(2.7%)	6(1.3%)	29.876	0.000
Once	108(38.8%)	62(33.0%)	170(36.5%)		
Twice	83(29.9%)	50(26.6%)	133(28.5%)		
Three times	1(0.4%)	12(6.4%)	13(2.8%)		
Five times	77(27.7%)	42(22.3%)	119(25.5%)		
Seven times	8(2.9%)	17(9.0%)	25(5.4%)		
Eggs/ Week					
None	20(7.2%)	6 (3.2%)	26 (5.6%)	32.118	0.000
Once	62(36.7%)	102 (35.6%)	170 (36.3%)		
Twice	67 (24.5%)	41 (21.8%)	1o8 (23.4%)		
Three times	1(0.4%)	12 (6.9%)	13 (3.0%)		
Five times	82 (29.5%)	45(23.9%)	127 (27.3%)		
Seven times	5 (1.8%)	15 (8.5%)	20 (4.5%)		
Meat/ Week					
None	11(4.0%)	2(1.1%)	13(2.8%)	16.130	0.002
Once	75(27.0%)	28(14.9%)	103(22.1%)		
Twice	58(20.9%)	61(32.4%)	119(25.5%)		
Three times	84(30.2%)	58(30.9%)	142(30.5%)		
Four times	7(2.5%)	5(2.7%)	12(2.6%)		
Five times	14(5.0%)	5(2.7%)	19(4.1%)		
Seven times	29(10.4%)	29(15.4%)	58(12.4%)		
Fish/ Month					
None	71(25.5%)	35(18.6%)	106(22.7%)	22.158	0.000
Once	151(54.3%)	80(42.6%)	231(49.6%)		
Twice	22(7.9%)	38(20.2%)	60(12.9%)		
Three times	2(.7%)	1(.5%)	3(.6%)		
Four times	32(11.5%)	34(18.1%)	66(14.2%)		
Oil/ Day					
Once	102(36.7%)	61(32.4%)	163(35.0%)	0.891	0.641
Twice	172(61.9%)	124(66.0%)	296(63.5%)		
Three times	4(1.4%)	3(1.6%)	7(1.5%)		
Sugar/ Day					
Once	97(34.9%)	39(20.7%)	136(29.2%)	16.408	0.001
Twice	92(33.1%)	67(35.6%)	159(34.1%)		
Three times	37(13.3%)	47(25.0%)	84(18.0%)		
Four times	52(18.7%)	35(18.6%)	87(18.7%)		

Green Leafy Veg./Week					
Once	112(40.3%)	54(28.7%)	166(35.6%)	18.339	0.001
Twice	84(30.2%)	54(28.7%)	138(29.6%)		
Three times	66(23.7%)	48(25.5%)	114(24.5%)		
Four times	2(0.7%)	5(2.7%)	7(1.5%)		
Seven times	14(5.0%)	27(14.4%)	41(8.8%)		
Other Veg./ Week					
Once	109(39.2%)	48(25.5%)	157(33.7%)	28.850	0.000
Twice	83(29.9%)	42(22.3%)	125(26.8%)		
Three times	69(24.8%)	65(34.6%)	134(28.8%)		
Four times	7(2.5%)	6(3.2%)	13(2.8%)		
Seven times	10(3.6%)	27(14.4%)	37(7.9%)		
Fruits/ Week					
None	9(3.2%)	5(2.7%)	14(3.0%)	4.700	0 .470
Once	187(67.3%)	118(62.8%)	305(65.5%)		
Twice	59(21.2%)	46(24.5%)	105(22.5%)		
Three	0(0.0%)	3(1.6%)	3(0.6%)		
Five	2(0.7%)	1(0.5%)	3(0.6%)		
Seven	16(5.8%)	12(6.4%)	28(6.0%)		
Fourteen	5(1.8%)	3(1.6%)	8(1.7%)		

D4. Detailed chi-squared analysis of seasonal variation and feeding patterns

Variable	**Wet season**	**Dry season**	**Total**	**Chi Squared**	**p-value**
Breastfed at birth					
Yes	276(99.3%)	186(98.9%)	462(99.1%)	2.479	0.693
No	2(0.7%)	2(1.1%)	4(0.9%)		
Breastfeeding at the time of the study					
Yes	86(31.2%)	74(39.8%)	160 (34.6%)	3.783	0.056
No	190(68.8%)	112(60.2%)	302(65.4%)		
BF mode					
Exclusive	73(26.4%)	34(18.3%)	107(23.2%)	4.932	0.041
Partial	203(73.6%)	152(81.7%)	355(76.8%)		
Age at Receiving Solid Food					
Not started	0(0.0%)	15(8.0%)	15(3.2%)	36.964	0.000
<4	33(11.9%)	46(24.5%)	79(36.4%)		
4-6	203(73.0%)	103(54.8%)	306(65.7%)		
>6	42(15.1%)	24(12.8%)	66(14.2%)		
Weaning Age/m					
On breast milk	85(30.6%)	72(38.3%)	157(33.7%)	6.271	0.016
<6	4(1.4%)	7(4.7%)	11(2.4%)		
6-12	93(33.5%)	73(19.7%	130(27.9%)		
12-18	86(30.9%)	63(33.5%)	149(32.0%)		
18-24	10(3.6%)	8(4.3%)	18(3.9%)		
>24	0(0.0%)	1(0.5%)	1(0.2%)		
Complementary food					
Carbohydrate + animal+ plant proteins	35(12.6%)	30(16.6%)	65(14.2%)	9.397	0.006
Carbohydrate + animal protein	29(10.5%)	22(12.2%)	51(11.1%)		
Carbohydrate + plant protein	114(41.2%)	72(39.8%)	186(40.6%)		
Carbohydrate	81(29.2%)	52(29.3%)	134(29.3%)		
Animal or plant proteins	18(6.5%)	4(2.2%)	22 (4.8%)		

D5. Detailed chi-square analysis of seasonal distribution and 24 hour dietary recall

Variable	Wet season	Dry season	Total	Chi Squared	P-value
Bread	17(8.9%)	2(1.7%)	19(6.3%)	0.668	0.716
Cereals	59(31.1%)	49(43.7%)	108(35.7%)	10.291	0.036
Rice	27(14.2%)	12(10.7%)	39(12.9%)	5.200	0.156
Biscuits	10(5.2%)	1(0.8%)	11(3.6%)	0.629	0.890
Milk	59(31.1%)	40(35.7%)	99(32.2%)	26.618	0.000
Yogurt	29(15.3%)	24(21.4%)	53(18.2%)	11.376	0.044
Meat	14(7.4%)	6(5.3%)	20(6.6%)	1.626	0.202
Chicken	6(3.1%)	1(0.9%)	7(2.3%)	0.467	0.495
Fish	4(2.1%)	1(0,9%)	5(1.6%)	5.000	0.082
Eggs	12(6.3%)	4(3.6%)	16(5.2%)	4.000	0.121
Pulses	34(17.9%)	2(1.8%)	36(11.9%)	18.062	0.000
Potatoes	23(12.1%)	7(6.2%)	30(9.9%)	23.012	0.000
Peeled Oranges	14(7.3%)	8(7.1%)	23(7.6%)	2.406	0.493
Fruit juice	125(65.7%)	46(41.1%)	171(66.6%)	2.828	0.587
Fizzy drink	6(3.1%)	8(7.1%)	14(25.4%)	0.825	0.364
Sugar	179(94.2%)	99(88.3%)	278(92.1%)	1.712	0.634
Oil	5(2.6%)	2(1.8%)	7(2.3%)	1.120	0.571

D6. Detailed chi-square analysis of seasonal **distribution of nutrients intake**

Variable	Wet season	Dry season	Total	Chi Squared	p-value
Energy intake (kcal/day)					
<200 kcal	77(40.5%)	47(42.3%)	124(41.2%)	6.214	0.102
200-300	71(34.4%)	46(41.4%)	117(39.9%)		
300-400	38(20%)	12(10.8%)	50(16.6%)		
>400	4(2.1%)	6(5.4%)	10(3.3%)		
Carbohydrates (g/day)					
<60	133(70.0%)	90(80.4%)	223(37.8%)	5.331	0.98
60-95	53(27.9%)	19(17.0%)	72(23.8%)		
>95	4(2.1%)	3(2.7%)	7(2.3%)		
Protein intake (g/day)					
<4	93(48.9%)	45(40.2%)	138(45.7%)	4.655	0.149
4-8	72(37.9%)	52(46.4%)	124(41.1%)		
8-12	21(11.1%)	9(8.0%)	30(9.9%)		
>12	4(2.1%)	6(5.4%)	10(3.3%)		
Fat intake (g/day)					
<10	183(97.8%)	105(98.1%	288(99.8%)	0.025	0.619
10-15	4(2.2%)	2(1.9%)	6(2.0%)		

D7. Detailed baseline demographic characteristics

Variables	Case (N=48)	Control (N=12)	Total (N=60)
Type of Residence			
Urban	22(37.5%)	4(33.3%)	26(43.3%)
Rural	14(29.2%)	6(50.0%)	20(33.3%)
Peri Urban area	12(25.0%)	2(16.7%)	14(23.3%)
Tribes			
Hawsa	11(26.9%)	1(8.3%)	12(20%)
Nuba	13(27.1%)	4(33.3%)	17(28.3%)
Mahas	0(0.0%)	4(33.3%)	4(6.7%)
Fur	6(12.5%)	1(8.3%)	7(11.7%)

Zagawa	3(6.8%)	0(0.0%)	3(5.0%)
Shukreya	2(4.2 %)	0(0.0%)	2(3.3%)
Other tribes	9(20.2%)	2(0.0%)	11(18.3%)
Falata	4(8.3%)	0(0.0%)	4(6.7%)
Father Age			
21-25	4(8.3%)	1(8.3%)	5(8.3%)
26-35	24(50.0%)	3(25.0%)	27(45%)
36-45	16(33.3%)	7(8.3%)	33(55%)
46-55	4(8.3%)	1(8.3%)	5(8.3%)
Mother Age			
15-20	6(12.5%)	2(16.7%)	8(13.3%)
21-35	27(56.3%)	8(66.6%)	35(58.3%)
36-45	15(31.3%)	2(16.7%)	17(28.3%)
Father Alive			
Yes	48(100%)	12(100%)	60(100%)
No	0(0.0%)	0(0.0%)	0(0.0%)
Mother Alive			
Yes	48(100%)	12(100%)	60(0.0%)
Father Health			
Well	48(100%)	11(91.7%)	59(98.7%)
Unwell	0(0.0%)	1(8.3%)	1(1.3%)
Mother Health			
Well	48(100%)	12(100%)	60(100%)

D8. Detailed baseline socioeconomic characteristics

Variables	Case (N=48)	Control (N=12)	Total (N=60)
Father Education			
Uneducated	12(25.0%)	1(8.3%)	13(21.7%)
Khalwa	13(27.1)	1(8.3%)	14(23.3%)
Primary	15(31.3)	5(41.7%)	20(33.3%)
Secondary	6(12.5)	3(25%)	9(15.0%)
University	2(4.2)	1(8.3%)	3(5.0%)
Mother Education			
Uneducated	20(41.2%)	3(25%)	23(38.3%)
Informal	5(10.1%)	1(8.3%)	6(10.0%)
Primary	20(25%)	6(50%)	26(43.3%)
Secondary	3(6.3%)	2(16.7%)	5(8.3%)
Father Occupation			
Unemployed	4(8.4%)	0(0.0%)	4(6.7%)
Self employed	13(27.1%)	3(25%)	16(26.7%)
Worker	10(20.8%)	2(16.7%)	12(20.0%)
Baker	3(6.3%)	0(0.0%)	3(5.0%)
Brick Maker	3(6.3%)	0(0.0%)	3(5.0%)
Driver	1(2.1%)	2(16.7%)	3(5.0%)
Builder	8(16.7%)	2(16.7%)	10(16.7%)
Police	2(4.2%)	0(0.0%)	2(3.3%)
Farmer	2(4.2%)	0(0.0%)	2(3.3%)
Governmental employee	2(4.2%)	3(25.0%)	5(8.3%)
Mother Occupation			
Unemployed	31(64.6%)	6(50.0%)	37(61.7%)
Government employed	1(2.1%)	1(8.3.0%)	2(3.3%)

Self employed	1(2.1%)	0(0.0%)	1(1.7%)
Housekeeper	8(16.7%)	3(25.0%)	11(18.3%)
Tailor	1(2.1%)	0(0.0%)	1(1.7%)
Tea seller	6(12.6%)	2(16.7%)	8(3.3%)
Father Income			
Good	11(22.9%)	6(50.0%)	17(28.3%)
Satisfactory	15(31.3%)	3(25.0%)	18(30%)
Poor	22(45.8%)	3(25.0%)	25(41.7%)
Mother Income			
Good	3(6.3%)	1(18.7%)	4(6.7%)
Satisfactory	4(4.8%)	1(18.7%)	5(8.3%)
Poor	9(18.8%)	0(0.0%)	9(15.0%)
Nil	32(66.7%)	10(83.3%)	42(70.0%)
Housing Condition			
Good	6(12.5%)	3(25.0%)	9(15.0%)
Satisfactory	17(35.4%)	7(58.3%)	24(40.0%)
Poor	21(41.2%)	1(8.3%)	22(36.7%)
Very Poor	4(8.4%)	1(8.3	5(8.3%)
No. of rooms			
One	21(43.8%)	4(33.3%)	25(41.7%)
Two	20(41.2%)	7(58.3%)	27(45.0%)
Three	6(12.5%)	1(8.3%)	7(11.6%)
>Three	1(2.1%)	0(0.0%)	1(1.7%)
Safe Water Supply			
Yes	26(54.2%)	8(66.7%)	34(56.7%)
No	22(45.8%)	4(33.3%)	26(43.3%)

D9. Detailed baseline maternal characteristics

Variables	**Case (N=48)**	**Control (N=12)**	**Total (N=60)**
Pregnancy related information			
Full	47(97.9%)	12(100.0%)	59(98.3%)
Abnormal	1(2.1%)	0(0.0%)	1(1.7%)
Place of Delivery			
Hospital	13(27.1%)	3(25.0%)	16(26.7%)
Home	35(72.9%)	9(75.0%)	44(73.3%)
Mode of Delivery			
Normal	45(93.7%)	12(100.0%)	57(95.0%)
Caesarean	3(6.3%)	0(0.0%)	3(5.0%)
Presentation of Delivery			
Normal	45(93.7%)	12(100.0%)	57(95.5%)
Breech	3(6.3%)	0(0.0%)	3(5.0%)
Condition of Birth			
Well	46(95.8%)	12(100.0%)	58(96.7%)
Not Well	2(4.2%)	0(0.0%)	2(3.3%)
Neonatal Period			
Infection	8(16.7%)	3(25.0%)	11(18.3%)
Fever	3(2.1%)	0(0,0%)	3(5.0%)
Jaundice	2(4.2%)	0(0.0%)	2(3.3%)
Normal	33(64.6%)	8(66.7%)	41(68.3%)
Others	2(4.2%)	1(8.3%)	3(5.0%)

D10. Detailed nutritional **analysis of case**s **and control**s

Variables	Never	Once/Day	Twice/ Day	>Twice/ Day	Once/ Week	Twice/ Week	>Twice/ Week	Once/ Month	Total
Cereal									0.112
Marasmus	0(0.0%)	8(50.0%)	5(31.2%)	3(18.8%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	16(100%)
Kwashiorkor	0(0.0%)	2(12.5%)	6(37.5%)	8(50.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	16(100%)
Underweight	0(0.0%)	3(20.0%)	5(33.3%)	7(46.7%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	15(100%)
Control	0(0.0%)	2(16.7%)	2(16.7%)	8(66.7%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	12(100%)
Total	0(0.0%)	15(25.4%)	18(30.5%	26(44.1%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	59(100%)
Legumes									0.05
Marasmus	0(0.0%)	10(62.5)	2(12.5%)	2(12.5%)	1(6.2%)	0(0.0%	0(0.0%)	0(0.0%)	16(100%)
Kwashiorkor	0(0.0%)	5(31.2%)	5(31.2%)	6(37.5%)	0(0.0%)	(0.0%)	0(0.0%)	0(0.0%)	16(100%)
Underweight	0(0.0%)	2(12.5%)	7(43.8%)	6(37.5%)	0(0.0%)	(6.2%)	0(0.0%)	0(0.0%)	16(100%)
Control	0(0.0%)	2(16.7%)	6(50.0%)	2(16.7%)	2(16.7%)	(0.0%)	0(0.0%)	0(0.0%)	12(100%)
Total	0(0.0%)	19(31.7%)	20(33.3%)	16(26.7%)	3(5.0%	1(1.7%)	0(0.0%)	0(0.0%)	60(100%)
Milk	0.008								
Marasmus	2(12.5%)	2(12.5%)	1(6.2%)	2(12.5%)	4(25.0%)	3(18.8%)	2(12.5%)	0(0.0%)	16(100%)
Kwashiorkor	2(12.5%)	2(12.5%)	1(6.2%)	2(12.5%)	4(25.0%)	1(6.2%)	0(0.0%)	0(0.0%)	12(100%)
Underweight	3(18.8%)	4(25.0%)	0(0.0%)	1(6.2%)	5(31.2%)	2(12.5%)	1(6.2%)	0(0.0%)	16(100%)
Control	0(0.0%)	3(25.0%)	3(25.0%)	0(0.0%)	4(33.3%)	2(16.7%)	0(0.0%)	0(0.0%)	12(100%)
Total	7(12.5%)	11(19.6%)	5(8.9%)	5(8.9%)	17(30.4%)	8(14.3%)	3(5.4%)	0(0.0%)	56(100%)
Eggs									0.239
Marasmus	4(25.0%)	1(6.3%)	1(6.3%)	0(0.0%)	3 (18.7%)	6(37.5%)	1(6.3%)	0(0.0%)	16(100%)
Kwashiorkor	3(18.7%)	0 (0.0%)	0 (0.0%)	0(0.0%)	9(56.3%)	2(12.5)	2(12.5%)	0(0.0%)	16(100%)
Underweight	4(25.0%)	1(6.3%)	1(6.3%)	0(0.0%)	6 (37.5%)	3(18.7%)	0 (0.0%)	1(6.3%)	16 (100%)
Control	0 (0.0%)	3 (25.0%)	0 (0.0%)	0(0.0%)	3 (25.0%)	5(41.7%)	1 (8.3%)	0(0.0%)	12 (100%)
Total	11(18.3%)	5(8.3%)	2 (3.3%)	0(0.0%)	21(35.0%)	16(26.7%)	4 (6.7%)	1(1.7%)	60 (100%)
Sugar									0.127
Marasmus	1(6.3%)	8(50.0%)	3 (18.7%)	1(6.3%)	2 (12.5%)	1 (6.3%)	0(0.0%)	0(0.0%)	16(100%)
Kwashiorkor	0(0.0%)	3(18.7%)	2 (12.5%)	11(68.7%)	0 (0.0%)	0 (0.0%)	0(0.0%)	0(0.0%)	16(100%)
Underweight	0(0.0%)	6(37.5%)	2(12.5%)	6(37.5%)	2 (12.5%)	0 (0.0%)	0(0.0%)	0(0.0%)	16(100%)
Control	0(0.0%)	4(25.0%)	4 (25.0%)	5 (41.7%)	1 (8.3%)	0 (0.0%)	0(0.0%)	0(0.0%)	12(100%)
Total	1(1.7%)	19(31.7%)	11(18.3%)	23(38.3%)	5(8.3%)	1 (1.7%)	0(0.0%)	0(0.0%)	60(100%)
Fresh veg.									0.06
Marasmus	1(6.3%)	4(25.0%)	1(6.3%)	1(6.3%)	5(31.2%)	4(25.0%)	0(0.0%)	0(0.0%)	16(100%)
Kwashiorkor	0(0.0%)	5(31.2%)	1(6.3%)	1(6.3%)	6(37.5%)	2(12.5%)	1(6.3%)	0(0.0%)	16(100%)
Underweight	0(0.0%)	7(43.7%)	0(0.0%)	0(0.0%)	7(43.7%)	2(12.5%)	0(0.0%)	0(0.0%)	16(100%)
Control	0(0.0%)	4(33.3%)	2(16.7%)	2(16.7%)	2(16.7%)	1(8.3%)	1(8.3%)	0(0.0%)	12(100%)
Total	1(1.7%)	20(33.3%)	4(6.7%)	4(6.7%)	20(33.3%)	9(15.0%)	2(3.3%)	0(0.0%)	60(100%)
Fruits									0.239
Marasmus	1(6.3%)	5(31.2%)	1(6.3%)	1(6.3%)	4(25.0%)	4(25.0%)	0(0.0%)	0(0.0%)	16(100%)
Kwashiorkor	0 (0.0%)	5 (31.2%)	0 (0.0%)	1 (6.3%)	8 (50.0%)	2 (12.5%)	0(0.0%)	0(0.0%)	16(100%)
Underweight	0 (0.0%)	2(12.5%)	0 (0.0%)	2(12.5%)	9 (56.2%)	2 (12.5%)	1(6.3%)	0(0.0%)	16(100%)
Control	0 (0.0%)	2 (16.7%)	0 (0.0%)	3(25.0%)	2 (16.7%)	4 (33.3%)	1(8.3%)	0(0.0%)	12(100%)
Total	1(1.7%)	14 (23.3%)	1(1.7%)	7(11.7%)	23(38.3%)	12(20.0%)	2 (3.3%)	0(0.0%)	60(100%)
Meat									o.o6
Marasmus	3(18.7%)	1(6.3%)	0(0.0%)	5(31.2%)	5 (31.2%)	1(6.3%)	1(6.3%)	0(0.0%)	16(100%)
Kwashiorkor	1(6.3%)	2 (12.5%)	0(0.0%)	6 (37.5%)	3(18.7%)	3 (18.7%)	0(0.0%)	1(6.3%)	16(100%)
Underweight	0(0.0%)	3(20.0%)	0(0.0%)	10(66.7%)	0(0.0%)	2(13.3%)	0(0.0%)	0(0.0%)	15(100%)
Control	0 (0.0%)	6(46.1%)	2(15.4%)	2(15.4%)	2 (15.4%)	1(7.7%)	0 (0.0%)	0(0.0%)	13(100%)
Total	4 (6.7%)	12 (20.0%)	2(3.3%)	23(38.3%)	10(16.7%)	7(11.7%)	1 (1.7%)	1(1.7%)	60(100%)

Fish									0.177
Marasmus	10(62.5%)	1(6.3%)	0(0.0%)	3(18.7%)	1(6.3%)	1(6.3%)	0(0.0%)	0(0.0%)	16(100%)
Kwashiorkor	12(75.0%)	0(0.0%)	0(0.0%)	1(6.3%)	0(0.0%)	3 (18.7%)	0(0.0%)	0(0.0%)	16(100%)
Underweight	5(31.2%)	0(0.0%)	1(6.3%)	4 (25.0%)	0 (0.0%)	2 (12.5%)	3(18.7%)	1(6.3%)	16(100%)
Control	3 (25.0%)	0(0.0%)	0(0.0%)	5 (41.7%)	1(8.3%)	1(8.3%)	2(16.7%)	0(0.0%)	12(100%)
Total	30(50.0%)	1(1.7%)	1(1.7%)	13(16.7%)	2(3.3%)	7(11.7%)	5(31.2%)	1(1.7%)	60(100%)

D11. Distribution of clinical profiles of cases and controls

Variables	**Yes**	**No**	**Total**	**p-value**
Pallor				
Marasmus	11(68.8%)	5(31.2%)	16(100.0%)	0.001
Kwashiorkor	9(56.2%)	7(43.8%)	16(100.0%)	
Underweight	10(62.5%)	6(37.5%)	16(100.0%)	
Control	0(0.0%)	12(100.0%)	12(100.0%)	
Total	30(50.0%)	30(50.0%)	60(100.0%)	
Hair change				
Marasmus	13(81.2%)	3(18.8%)	16(100.0%)	0.0001
Kwashiorkor	12(75.0%)	4(25.0%)	16(100.0%)	
Underweight	10(62.5%)	6(37.5%)	16(100.0%)	
Control	1(8.3%)	11(91.7%)	12(100.0%)	
Total	36(60.0%)	24(40%)	60(100.0%)	
Skin depigmentation	3(18.8%)	13(81.2%)	16(100.0%)	0.0001
Marasmus	11(68.8%)	5(31.2%)	16(100.0%)	
Kwashiorkor	4(25.0%)	12(75.0%)	16(100.0%)	
Underweight	0(0.0%)	12(100.0%)	12(100.0%)	
Control	18(30.0%)	42(70.0%)	60(100.0%)	
Total	3(18.8%)	13(81.2%)	16(100.0%)	
Moon Face				
Marasmus	4(25.0%)	12(75.0%)	16(100.0%)	0.0001
Kwashiorkor	14(87.5%)	2(12.5%)	16(100.0%)	
Underweight	4(25.0%)	12(75.0%)	16(100.0%)	
Control	0(0.0%)	12(100.0%)	12(100.0%)	
Total	22(36.7%)	38(63.3%)	60(100.0%)	
Flaky Paint				
Marasmus	2(12.5%)	14(87.5%)	16(100.0%)	0.651
Kwashiorkor	5(31.2%)	11(68.8%)	16(100.0%)	
Underweight	3(18.8%)	13(81.2%)	16 (100.0%)	
Control	0(0.0%)	12(100.0%)	12(100.0%)	
Total	10(16.7%)	50(83.3%)	60(100.0%)	
Skin lesion				
Marasmus	1(6.2%)	15(93.8%)	16(100.0%)	0.001
Kwashiorkor	9(56.2%)	7(43.8%)	16(100.0%)	
Underweight	3(18.8%)	13(81.2%)	16(100.0%)	
Control	0(0.0%)	12(100.0%)	12(100.0%)	
Total	13(21.7%)	47(78.3%)	60(100.0%)	
Associated Infection	2(12.5%)	14(87.5%)	16(100.0%)	0.305
Marasmus	3(18.8%)	13(81.2%)	16(100.0%)	
Kwashiorkor	4(25.0%)	12(75.0%)	16(100.0%)	
Underweight	0(0.0%)	12(100.0%)	12(100.0%)	
Control	9(18.8%)	51(81.2%)	60(100.0%)	
Total	2(12.5%)	14(87.5%)	16(100.0%)	

D12. Detail neuropsychological indicators for cases and controls

Variables	Normal	Mild	Moderate	Severe	Total
Personal-Social					
Marasmus	0(0.0%)	5(31.3%)	3(18.8%)	8(50.0%)	16(100.0%)
Kwashiorkor	0(0.0%)	1(6.3%)	3(18.8%)	12(75.0%)	16(100.0%)
Underweight	0(0.0%)	1(6.3%)	7(43.8%)	8(50.0%)	16(100.0%)
Control	7(58.3%)	3(25.0%)	1(8.3%)	1(8.3%)	12(100.0%)
Total	7(11.7%)	10(16.7%)	14(23.3%)	29(48.3%)	60(100.0%)
					p-value=0.001
Fine Motor					
Marasmus	0(0.0%)	1(6.3%)	5(31.3%)	10(62.5%)	16(100.0%)
Kwashiorkor	0(0.0%)	0(0.0%)	9(56.3%)	7 (43.8%)	16(100.0%)
Underweight	0(0.0%)	1(6.3%)	4(25.0%)	11(68.8%)	16(100.0%)
Control	8(66.7%)	2(16.7%)	1(8.3%)	1(8.3%)	12(100.0%)
Total	8(13.3%)	4(6.7%)	19(31.7%)	29(48.3%)	60(100.0%)
					p-value=0.001
Language					
Marasmus	0(0.0%)	2(12.5%)	8(50.0%)	6(37.5%)	16 (100.0%)
Kwashiorkor	0(0.0%)	1(6.3%)	7(43.8%)	8(50.0%)	16 (100.0%)
Underweight	0(0.0%)	3(18.8%)	4(25.0%)	9(56.3%)	16 (100.0%)
control	7(58.3%)	4(33.3%)	0(0.0%)	1(8.3%)	12 (100.0%)
Total	7(11.7%)	10(16.7%)	19(31.7%)	24(40.0%)	60(100.0%)
					p-value=0.001
Gross motor					
Marasmus	0(0.0%)	2(12.5%)	2(12.5%)	12(75.0%)	16(100.0%)
Kwashiorkor	0(0.0%)	0(.0%)	6(37.5%)	10(62.5%)	16(100.0%)
Underweight	1(6.3%)	3(18.8%)	2(12.5%)	10(62.5%)	16(100.0%)
Control	7(58.3%)	3(25.0%)	0(0.0%)	2(16.7%)	12(100.0%)
Total	8(13.3%)	8(13.3%)	10(16.7%)	34(56.7%)	60(100.0%)
					p-value=0.001

D13. Relationship between the clinical indications and EEG results

Variables	Generalised	Focal	Multifocal	Focal and multifocal	Normal	Total	Total
Behaviour disorder							0.023
Yes	4(8.3%)	11(22.9)	7(14.5%)	8(16.6%)	18(37.5%)	48(100%)	
No	0(0.0)	1(8.3%)	0(.0%)	0(.0%)	11(91.6%)	12(100%)	
Muscle wasting							0.571
Yes	2(5.8%)	7(20.5%)	6(17.6%)	4(11.7%)	14(44.1)	32(100%)	
No	2(7.6%)	5(19.2%)	1(3.8%)	4(15.3%)	14(53.8%)	26(100%)	
Growth retarded							0. 253
Yes	0(0.0%)	3(23%)	3(23%)	0(0.0%)	7(53.8%)	13(100%)	
No	4(8.5%)	9(8.5%)	4(8.5%)	8(17%)	22(46.%)	47(100%)	
Associated VD							0.345
Yes	0(0.0%)	3(37.5%)	2(25.0%)	1(12.5%)	2(25.0%)	8(100%)	
No	4(20.0%)	9(17.3%)	5(9.6%)	7(13.4%)	27(51.9%)	52(100%)	
Associated infection							0.170
Yes	0(0.0%)	2(22.2%)	2(22.2%)	3(3.3%)	2(22.2%)	9(100%)	
No	4(7.8%)	10(19.6%)	5(9.8%)	5(9.8%)	27(52.9%)	51(100%)	
Other Skin Lesion							0.083
Yes	2(15.3%)	2(15.3%)	2(15.3%)	4(30.7%)	3(23%)	13(100%)	
No	2(4.2%)	10(21.2%)	5(10.6%)	4(8.5%)	26(55.3%)	47(100%)	

Flaky paint							0.602
Yes	0(.0%)	4(33.3%)	1(8.3%)	2(16.6%)	5(41.6%)	12(100%)	
No	4(8.3%)	8(16.6%)	6(33.3%)	6(12.5%)	24(50%)	48(100%)	
Moon face							0.013
Yes	4(18.0%)	5(22.7%)	2(9.0%)	5(22.7%)	6(27.2%)	22(100%)	
No	0(.0%)	7(18.4%)	5(13.1%)	3(7.8%)	23(60.0%)	28(100%)	
Skin depigmentation							0.041
Yes	2(10.0%)	4(20%)	1(5%)	6(30%)	7(35%)	20(100%)	
No	2(5.0%)	8(20.0%)	6(15.0%)	2(5.0%)	22(55.0%)	40(100%)	
Hair change							0.391
Yes	3(8.1%)	7(18.9%)	5(13.5%)	7(18.9%)	15(40.5%)	37(100%)	
No	1(4.3%)	5(21.7%)	2(8.6%)	1(4.3%)	14(60.8%)	12(100%)	
Pallor							0.869
Yes	2(6.2%)	6(19.3%)	5(16.1%)	4(12.9%)	14(42.1%)	31(100%)	
No	2(6.8%)	6(20.6%)	2(6.8%)	4(13.7%)	15(51.7%)	29(100%)	

D14. Detailed pre and post neuropsychological indicators at admission and 4 weeks later

Personal-Social at admission	**Normal**	**Mild**	**Moderate**	**Severe**	**Total**
Personal social					
Mild	0(0.0%)	4(66.7%)	2(33.3%)	0(0.0%)	6(100.0%)
Moderate	0(0.0%)	5(41.7%)	5(41.7%)	2(16.7%)	12(100.0%)
Severe	0(0.0%)	10(37.0%)	13(48.1%)	14(14.8%)	27(100.0%)
Total	0(0.0%)	19(42.2%)	20(44.4%)	6(13.3%)	45(100.0%)
					p-value = 0.224
Fine motor					
Mild		1(50.0%)	1(50.0%)	0(0.0%)	2(100.0%)
Moderate	1(5.9%)	9(52.9%)	6(35.3%)	1(5.9%)	17(100.0%)
Severe	0(0.0%)	5(19.2%)	16(61.5%)	5(19.2%)	26(100.0%)
Total	1(2.2%)	15(33.3%)	23(51.1%)	6(13.3%)	45(100.0%)
					p-value = 0.013
Language					
Mild	0(0.0%)	2(40.0%)	3(60.0%)	0(0.0%0	5(100.0%)
Moderate	0(0.0%)	11(64.7%)	6(35.3%)	0(0.0%)	17(100.0%)
Severe	1(4.3%)	11(47.8%)	9(39.1%)	2(8.7%)	23(100.0%)
Total	1(2.2%)	24(53.3%)	18(40.0%)	2(4.4%)	45(100.0%)
					p-value = 0. 833
Gross motor					
Mild	0(0.0%)	3(60.0%)	2(40.0%)	0(0.0%)	5(100.0%)
Moderate	0(0.0%)	2(22.2%)	5(55.6%)	2(22.2%)	9(100.0%)
Severe	2(6.5%)	13(41.9%)	12(38.7%)	4(12.9%)	31(100.0%)
Total	2(4.4%)	18(40.0%)	19(42.2%)	6(13.3%)	45(100.0%)
					p-value = 0.024

D15. Pre and post clinical indications on admission and 12 weeks after discharge

Variable	Neuropsychological Indicators after 12 weeks				Total
	Normal	Mild	moderate	Severe	
Personal social					p-value=0.747
Mild	1(16.7%)	5(83.3%)	0(0.0%)	0(0.0%)	6(100.0%)
Moderate	2(15.4%)	8(61.5%)	3(23.1%)	0(0.0%)	13(100.0%)
Severe	5(20.8%)	13(62.5%)	3(12.5%)	1(4.2%)	24(100.0%)
Total	8(18.6%)	24(65.1%)	6(14.0%)	1(2.3%)	43(100.0%)
Final motor					p-value=0.958
Mild	0(0.0%)	2(100%)	0(0.0%)	0(0.0%)	2(100.0%)
Moderate	2(13.3%)	10(66.7%)	3(20.0%)	0(0.0%)	15(100.0%)
Severe	4(15.4%)	17(65.4%)	5(19.2%)	0(0.0%)	26(100.0%)
Total	6(14.0%)	29(67.4%)	8(18.6%)	0(0.0%)	43(100.0%)
Language					p-value =0.006
Mild	2(40.0%)	3(60.0%)	0(0.0%)	0(0.0%)	5(100.0%)
Moderate	4(23.5%)	13(76.5%)	0(0.0%)	0(0.0%)	17(100.0%)
Severe	3(14.3%)	9(42.9%)	9(42.9%)	0(0.0%)	21(100.0%)
Total	9(20.9%)	25(58.1%)	9(42.9%)	0(0.0%)	43(100.0%)
Gross motor					p-value =0.889
Mild	1(100.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(100.0%)
Moderate	1(20.0%)	3(60.0%)	1(20.0%)	0(0.0%)	5(100.0%)
Severe	1(11.1%)	6(66.7%)	2(22.2%)	0(0.0%)	9(100.0%)
Total	9(31.0%)	17(58.6%)	2(6.9%)	1(3.4%)	44(100.0%)

D16. Pre and post comparison of focal activity at admission and 12 weeks after discharge

Focal Patterns after admission	Focal Activity after 12 weeks		Total
	LFoShA	Normal	
Focal slow activity	(0.0%)	3(100.0%)	3(100.0%)
Left focal sharp activity	0(0.0%)	3(100.0%)	3(100.0)
Right focal sharp activity	0(0.0%)	2(100.0%)	2(100.0%)
Frontal slow activity	0(0.0%)	4(100.0%)	4(100.0%)
Right central temporal slow activity	0(0.0%)	1(100.0%)	1(100.0%)
Focal sharp activity	0(0.0%)	2(100.0%)	2(100.0%)
Frontal sharp and slow activity	0(0.0%)	1(100.0%)	1(100.0%)
Left sided frontal sharp activity	0(0.0%)	3(100.0%)	3(100.0%)
Normal	1(3.4%)	22(96.6%)	23(100.0%)
Total	1(2.1%)	41(97.9%)	42(100.0%)
			p-value = 0.541

D17. Pre and post comparison of multifocal activity at admission and 12 weeks after discharge

Mulifocal patterns after admission	Multifocal activity after 12 weeks		Total
	PTShA	Normal	
BiFrCShA	(0.0%)	1(100.0%)	1(100.0%)
RCPTShA	(0.0%)	1(100.0%)	1(100.0%)
LTMFoShA	(0.0%)	1(100.0%)	1(100.0%)

MFoShA	(0.0%)	4(100.0%)	4(100.0%)
LPTShA	(0.0%)	1(100.0%)	2(100.0%)
RFrCTShA	(0.0%)	1(100.0%)	2(100.0%)
LSiMFoShA	(0.0%)	2(100.0%)	2(100.0%)
FrPCShSlA	(0.0%)	1(100.0%)	1(100.0%)
LCPTShA	(0.0%)	1(100.0%)	1(100.0%)
BiFrShSlA	(0.0%)	1(100.0%)	1(100.0%)
MFoShSlA	(0.0%)	1(100.0%)	1(100.0%)
Normal	1(3.0%)	26(97.0%)	27(100.0%)
Total	1(2.1%)	41(97.9%)	42(100.0%)
p-value = 0.546			

D18. Estimated marginal means for the dependent variable clinical indicator

Clinical indicator	Mean	Std. Error	95% Confidence Interval	
			Lower Boundary	Upper Boundary
Marasmus	2.155[a]	0.111	1.932	2.377
Kwashiorkor	2.554[a]	0.110	2.334	2.775
Underweight	1.973[a]	0.111	1.750	2.196
Control	1.007[a]	0.127	0.753	1.261
a. Covariates appearing in the model are evaluated at the following values: Tribe = 3.82.				

D19. Estimated marginal means for the dependent variable behaviour disorder

Diagnosis	Mean	Std. Error	95% Confidence Interval	
			Lower Boundary	Upper Boundary
Marasmus	1.481[a]	0.133	1.215	1.747
Kwashiorkor	1.745[a]	0.132	1.482	2.009
Underweight	6.004[a]	0.152	5.700	6.308
Control	1.833	0.133	1.566	2.100
a. Covariates appearing in the model are evaluated at the following values: Tribe = 3.82.				

D20. Estimated marginal means for the dependent variable first EEG

Diagnosis	Mean	Std. Error	95% Confidence Interval	
			Lower Boundary	Upper Boundary
Marasmus	1.713[a]	0.086	1.541	1.885
Kwashiorkor	2.006[a]	0.085	1.836	2.177
Underweight	1.784[a]	0.086	1.612	1.957
Control	1.078[a]	0.098	0.882	1.275
a. Covariates appearing in the model are evaluated at the following values: Tribe = 3.82.				

D21. Estimated marginal means for the dependent variable neuropsychological disorder

Diagnosis	Mean	Std. Error	95% Confidence Interval	
			Lower Boundary	Upper Boundary
Marasmus	3.288[a]	0.174	2.938	3.638
Kwashiorkor	3.669[a]	0.167	3.334	4.005
Underweight	3.506[a]	0.176	3.153	3.858
Control	1.717[a]	0.193	1.330	2.104
a. Covariates appearing in the model are evaluated at the following values: Tribe = 3.82.				

D22. Estimated marginal means for the dependent variable nutrition

Diagnosis	Mean	Std. Error	95% Confidence Interval	
			Lower Boundary	Upper Boundary
Marasmus	1.662[a]	0.196	1.269	2.056
Kwashiorkor	2.370[a]	0.194	1.980	2.760
Underweight	2.507[a]	0.225	2.057	2.9572
Control	2,293	0.203	1.886	2.700
a. Covariates appearing in the model are evaluated at the following values: Tribe = 3.86.				