Postural Stability in Cyclists

Abstract

Aim: Age-related loss of postural stability (or balance) is a main contributing factor to hospital admissions for falls in the elderly, with a sharp decline in balance starting in the fifth decade of life. Core stability exercises have been well documented as having a positive effect on balance, but the effect of cycling on balance has not been widely considered. With the continued increase in uptake of recreational cycling this investigation could offer valuable insight, with implications for fall risk reduction in later life. The progression of portable technology offers opportunity to transfer clinical balance testing to the field. The study used the SWAY™ app on a mobile phone to investigate balance in two different disciplines of recreational cycling - road cycling (RC) and mountain biking (MTB). It aimed to ascertain whether cycling promotes better balance as compared with an age-matched sedentary control (CN), and which cycling discipline promotes the better balance.

Methods: 42 adults (53 ± 7 y), RC N = 14, MTB N = 14, and CN N = 14, balanced with eyes closed in five stances as instructed by the SWAY app on a mobile phone held to the chest, which gave the mean of five stances as a total balance score.

Results: RC had significantly better balance than CN ($p < 0.001$); MTB had significantly better balance than CN ($p = 0.004$); RC had significantly better balance than MTB ($p = 0.046$).

Conclusion: MTB balance was worse than RC balance, but both cycling groups were found to have better balance scores than the control. These findings have implications for public health, as cycling, an inexpensive and accessible activity already known to offer substantial health benefits, could additionally help maintain postural stability and potentially reduce risk of falls in later life.

Keywords: balance, elderly, falls, SWAY app

Introduction

Physical activity is an everyday essential aspect in promoting the health of an individual (Powell, Paluch and Blair 2011), but with ageing, the ability to be physically active declines along with an increased risk of falling (Milanovic et al. 2013). Falls in the elderly are a leading cause of injury and death and a major public health issue (Ambrose, Paul and Hausdorff 2013); with the ageing population in the UK increasing, an estimated 24% of the population will be in the over 65 years age group by 2037 (Howdon and Rice 2018). As a result, the number of elderly hospitalisations related to falls is increasing, creating an economic burden on healthcare provision (Howdon and Rice 2018). Studies have consistently reported that age-related balance disorders are a main predictor of future falls (Ambrose, Paul and Hausdorff 2013; Ganz et al. 2007), and balance has been reported to decline with age (Kanekar and Aruin 2014) from approximately 40 years (Ghahramani et al. 2105; Goble and Baweja 2018).

It is known that balance can be enhanced by exercise (Sherrington and Henschke 2013; Sherrington et al. 2016) such as yoga, Pilates, and Tai Chi (Hu et al 2016), but whether cycling can have an effect on balance has not been widely investigated. Cycling, as a form of physical exercise or a means of transport, is accessible to all ages and offers substantial health benefits. According to the 2015 Outdoors Participation Report covering 15 activities across 8.9 million people (English and Leeson 2015), mountain biking (MTB) /cyclocross is the fourth most popular outdoor activity (after strenuous walking, camping, and mountaineering). Swimming, road cycling (RC) and going to the gym were reported as the main other activities enjoyed by all outdoors participants. MTB also had the highest once a week participation of 19 outdoor sports (Sport England 2019). Based on the reporting that RC and MTB are the two most popular disciplines in cycling, this study aims to ascertain whether recreational cycling can enhance balance ability, thereby potentially helping to reduce the longer-term risk of falls in later life.

Balance and Postural Stability

A high proportion of falls in the elderly are due to a reduction in balance and postural stability (Iwasaki and Yamasoba 2015; Foster 2018). Imbalance can be caused by age related deterioration in any of the factors - visual, vestibular, somatosensory or muscular - associated with postural stability; increasing the risk of falls leading to injury or death. Human upright standing, however simple a motor skill it appears, is in fact intrinsically unstable requiring complex sensory feedback mechanisms to maintain the upright position (Fuchs 2018). Balance, often thought of as a static process, is actually a highly integrated dynamic process involving multiple neurological pathways of the vestibular, visual and somatosensory systems (Hwang et al. 2016). Balance can be defined as ‘an even distribution of weight enabling someone (or something) to remain upright and steady' (Pollock et al. 2000). It is a concept, and it requires an operational definition (Ragnarsdóttir 1996) to anchor it to an observable and measurable event. Stability is described as the state of remaining unchanged in the presence of forces that would normally change the state; it has also been defined as the property of returning to an initial state upon disruption (Riemann and Lephart 2002). In sports medicine, balance is often described as postural equilibrium, postural stability, or postural control, which can be operationally defined as ‘the ability to maintain equilibrium in a gravitational field by keeping or returning to the center of mass over the base of support' (Horak 1987). In this study the terms ‘balance’ and ‘postural stability’ are used interchangeably.

Maintenance of postural stability includes sensory detection of body movements, integration of sensorimotor information within the central nervous system (CNS), and execution of appropriate musculoskeletal responses (Fuchs 2018) in order to recover equilibrium; it is therefore a biomechanical interaction between the body and its environment, the position of which is sensed by combining visual, vestibular and somatosensory inputs. These movements required to maintain postural stability are referred to as balance strategies, of which the CNS has multiple at its disposal. They are utilised depending on the quantity of stabilisation required, the predictability of movement, and the perceived risk of injury (Horak 1987). It can also be said that they are utilised according to 'training' (Lamoth, van Lummel and Beek 2009; Williams, Murray and Powell 2016) as different levels of anticipatory muscle recruitment will take place (Dakin and Bolton 2018). For example, a 'feedforward' or anticipatory postural control mechanism will occur in those accustomed to 'balancing', whilst a 'feedback' or compensatory movement will occur in those that are unaccustomed; with older individuals using different muscle strategies to younger individuals (Kanekar and Aruin 2014). The two most commonly employed balance strategies are hip and ankle (Winter 1005) - hip strategy being used more often when the perturbation is bigger, and ankle strategy employed against smaller perturbations (Panjan and Sarabon 2010).

Age-Related Loss of Postural Stability

In compiling normative data for the 'Unipedal Stance Test', Springer, Marin and Cyhan (2007) reported that in the age group of 40-49 years there was a decrease in balance in the eyes-closed condition, and a sharp decline in the eyes open condition at age 50 years. A main finding of this research was that the difference in unipedal stance test times was not gender specific, but was related to age. Goble and Baweja (2018) also reported a significant increase in postural sway in the 40-49 years age group, which continued to increase throughout subsequent years of participant groups; however, although this study had a very large sample size (6280) and reportedly is the second-largest postural sway data ever recorded, the authors had no direct oversight of the data collection, and the results relied on self-reported adherence to test protocol, so had little inter-rater reliability.

Another relevant finding by Enderlin et al. (2015) was that the age at which the ability to recover balance (for fall avoidance) decreases significantly at approximately 51 years. Balance declines with age, it is undeniable, and the ageing population is increasing. The present study looks at the balance of cyclists in the age group 45 to 60 years as it has been documented that the decline in balance occurs within this age range (Grous 2012).

Balance Assessment

There are several methods of assessing the ability to balance via postural control, some using expensive lab-based equipment for example the Biodex Balance System™ (Biodex Medical Systems Inc.), or the Equitest® System (Natus Medical Inc.); and some using more clinic-based methods for example the Star Excursion Balance Test (SEBT) (Bell et al 2011) or the Balance Error Scoring System (BESS) (Gribble eta al. 2013). With rapid advancements in technology combined with the increasing popularity of personal gadgetry and wearable technology, software for clinical testing is being developed in the form of apps for mobile platforms. One such app is SWAY™ Balance System (SWAY) designed for use on a mobile phone, which uses a traditional method of balance testing to give a score.

The Balance Error Scoring System (BESS) was originally designed to assess athletes with concussion; however, it is now a widely used method of assessing postural stability. It assesses postural control on a score of 10, in three positions with eyes closed - double-leg stance, tandem stance and single-leg stance - on a hard surface and repeated on a foam surface. A modified version of the BESS (mBESS) assesses only on a hard surface. The SWAY app uses the mBESS in its balance testing by utilising the phone's portable accelerometer to measure balance of a participant in the anterior/posterior and medial/lateral planes to give a quantitative balance assessment. As the testing conditions require eyes to be closed, as in the traditional mBESS, the user must rely only on somatosensory and vestibular input to maintain balance, as all oculomotor input is blocked. This method of assessment is intended for use by health care professionals for quantitative functional limitation assessment, fall risk assessment, and for supporting post-injury return-to-play decisions.

The force plate has been repeatedly established as a reliable method of measuring postural sway - expressed as the movement of the CoP over time - with eyes closed conditions showing better reliability than eyes open conditions (Bauer et al 2008; Rogind et al 2003; Walsh et al 2006). However, although a growing body of research has validated the SWAY app against the Biodex System (Han, Lee and Lee 2016; Patterson et al 2014), the BESS (Staab et al 2012) and against other forms of balance testing (Ormerod 2013), the SWAY app, being a relatively newly developed software, has been subject to little high-level validity/reliability testing, and none to date have validated against the force plate. A systematic review by Pinho et al (2019) of instruments that assess postural stability, suggests that of nine papers reviewed, reliability and reproducibility were limited by the lack of assessment protocol information. The two studies testing SWAY were deemed of ‘low quality’ at the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies; and at the 10-Point Checklist for Balance Assessment Protocols they reported one to be ‘fairly detailed’ and the other ‘poorly detailed’. Pinho et al. (2019) concluded that most of the studies lacked a direct ‘gold standard’ sensor comparison, and highly encourage further studies which include test-retest.

Cycling

Prior to the lockdown caused by the Covid-19 pandemic, a nationwide increase in commuter and recreational cycling was reported in sources such as the ‘Active Lives Survey’ (Sport England 2019), the ‘British Cycling Economy Report’ (2015), ‘Cycling Trends Update’(Transport for London 2019). Cycling is an inexpensive mode of transport (Karanikola et al. 2018) which has minimal impact on the environment (Woodcock et al 2018). In London, 2018 saw the highest growth in cycling volume since monitoring began (in 2015) with an average daily volume of over 4 million cycle-km (Transport for London 2019) and is a low-impact alternative to running (Bauman and Rissel 2009) for those looking to ‘keep fit’. Cycling as a mode of travel allows individuals to incorporate physical activity into their daily routine, and has been repeatedly evidenced as having beneficial effects on health and well-being (Götschi, Garrard and Giles-Corti 2016; Batcir and Melzer 2018)), however there has been little research examining the effect of cycling on balance.

Modes of Cycling, Riding Position, and Terrain

There are many different disciplines in cycling both on-road and off-road including RC, MTB, bicycle motocross (BMX), BMX-trick riding, cyclocross, touring, time trial, track cycling, fixed gear cycling, gravel riding, comfort/commuter cycling, unicycling, tandem cycling, recumbent cycling, tricycling (Bicycle Riding 2022). According to the 2015 Outdoors Participation Report (English and Leeson 2015) (which surveyed 15 activities across 8.9 million people) MTB/cyclocross is the fourth most popular outdoor activity after strenuous walking, camping, and mountaineering. Swimming, road cycling and going to the gym were reported as the main other activities enjoyed by all outdoors participants. MTB also had the highest once a week participation of 19 outdoor sports (Sport England 2019).

The two most popular disciplines in cycling, RC and MTB, have differences beyond the type of bicycle used. In RC the cyclist rides in a stable position, mostly seated with minimal changes in body position on a predictable road surface. RCs will spend most of the time with three points of contact between the body and the bicycle: feet, hands, and seat, MTB involves more time with only two points of contact: feet and hands (Kronisch and Pfeiffer 2002). MTB requires the rider to often be out of the saddle to handle the rough terrain, climbing, ascending, jumps, berms, drop-offs etc; on differing surfaces - hard packed dirt, mud, gravel, sand, rocks; at varying speeds and gradients (Eldesoky et al 2017). The difference in demands of these two types of cycling are likely to result in different balance stimulus, with MTB more likely to require a different level of postural control to maintain a stable body position in controlling the bike, as a reaction to the increased proprioceptive input experienced from unstable ground and unpredictable surroundings.

Aims of research

It is known that postural stability and balance is enhanced by exercise (Sherrington and Henschke 2103) due to its effect on cognitive function and neuroplasticity. This study uses the SWAY app on a mobile phone to investigate postural stability in different disciplines of recreational cycling. It aims to ascertain whether recreational cycling promotes better balance, thereby potentially helping to reduce the longer-term risk of falls in later life. This study proposes that RC and MTB promote better balance than an age-matched sedentary control (CN), and that MTB promotes better balance than RC, with the suggestion that MTB will have better balance due to the more unpredictable nature of the activity. To date no research has been conducted to compare the postural stability of individuals in these cycling disciplines using the portable balance assessment tool SWAY. A single user-friendly mobile phone app with no other equipment needed, SWAY is an affordable and highly portable method of assessing the balance of individuals in a clinical, athletic, or recreational setting. The relevance for public health is considerable as not only can cycling be easily included in the lives of ordinary people being inexpensive and easily accessible; the proposed method of assessing balance is also user friendly, portable, quick and inexpensive compared to laboratory testing.

Methods

Participants

28 recreational cyclists (Table 1) (commuting, weekend or odd-day cycling, active for a minimum of 1 year, not professional) were randomly selected from a population of cyclists from South London cycling clubs, having been invited by email to participate in the study. N = 14 Road Cycling (RC) and N = 14 Mountain Biking (MTB), male/female, age 53 ± 7 y; free from any lower limb injury in the past 6 months; were not currently suffering from any condition that causes dizziness; and were not regularly taking part in any regular balance exercise e.g., Pilates, volunteered to take part. Participants' stature and mass were recorded and it was checked that the participants had not consumed alcohol within 12 hours or coffee within 1 hour prior to testing. N = 14 age-matched non- cyclists were randomly selected as the control group (CN); exclusion criteria were lower limb injury in the past 6 months, and taking part in regular balance training or exercise e.g., Pilates. Power analysis of a similar study (Eldesoky et al 2017) estimated a sample size of three groups of 15 participants, with an effect size of 0.8, and an alpha of 0.05.

Table 1. Participant Demographic Information

	Male (n)	Female (n)	Age (y ± SD)	Stature (cm ± SD)	Mass (kg ± SD)
RC	5	9	50 ± 4	169 ± 9	68 ± 11
MTB	11	3	51 ± 4	178 ± 9	78 ± 15
CN	5	9	52 ± 3	171 ± 10	72 ± 9

Equipment and Materials

Participants were asked to complete a questionnaire which categorised three different modes of cycling, RC, MTB, and 'both' (B) meaning that they regularly participated both in road cycling and mountain biking. Those that ticked 'both' were put into the MTB group, as this category included, but was not restricted to, MTB. The location of the balance testing for cyclists was outside at Herne Hill Velodrome in London, on flat ground; and for non-cyclists any location on flat ground. The Sway app had been subject to eco-validity testing prior to this study, which confirmed the validity of using the Sway app outside.

One Apple iPhone XS (version iOS 13.3) was used throughout for all balance data collection and by the same researcher. The balance assessment app used was Sway (SWAY Medical, Tulsa, OK, Oklahoma), and the iPhone XS accelerometer was verified prior to testing by placing the device on a hard, horizontal surface with the screen facing up, and running the in-app Hardware Verification Test.

Procedure

After ethical approval, written informed consent was obtained once the participant information sheet had been read. No names were stored with the collected data - participants were allocated numerical identifiers. Age, stature and mass was collected via the questionnaire and input to the Sway app. Participants were asked to remove their shoes and perform a series of balance tests whilst holding the mobile phone to their chest with both hands following the instructions on the phone. The mobile phone then ran a balance test within the SWAY app which required the participant to stand (no shoes) and balance in five different stances in succession, with eyes closed. Each of the stances took 10 seconds, and were as follows: feet together, tandem right, tandem left, single leg right, single leg left. The participants were allowed one set of familiarisation tests before the study tests.

Statistical Analysis

Statistical analysis was carried out using SPSS version 28.0.0.0 (Chicago, IL, USA), with a significance level set at $\alpha < 0.05$. The dependent variable (DV) was balance, and the independent variable (IV) was cycling discipline, with three independent groups - MTB, RC, CN. The Shapiro-Wilk test was used to test for normality of distribution and the Levene's test for homogeneity of variance. As all parametric assumptions were met, a one-way analysis of variance (ANOVA) was performed to test for difference in balance between the means of the three independent groups. Post hoc testing was performed using Bonferroni correction to determine which groups differed from each other.

Results

The one-way ANOVA showed that there was a significant difference in the mean balance scores across the three groups (Table 2) $F(3, 42) = 18.060$, $p = < 0.001$. Post hoc comparisons of mean balance score by cycling group using the Bonferroni correction indicated that: RC balance was significantly better than MTB balance ($M = 14.09^{\dagger}$) $p = 0.046$**.** RC balance was significantly better than CN balance ($M = 33.24^{\dagger}$) $p = <0.001$**.** MTB balance was significantly better than CN balance ($M = 19.14^{\dagger}$) $p = 0.004$. (†Units = balance score out of 10).

Table 2. Mean differences in cycling type

Cycling Type	Mean (SD)	Mean Difference		*p*
RC	82.85 (11.81)	RC-MTB	14.09	0.046*
		RC-CN	33.24	< 0.001***
MTB	68.76 (13.09)	MTB-RC	-14.09	0.046*
		MTB-CN	19.14	0.004**
CN	49.61 (18.33)	CN-RC	-33.24	< 0.001***
		CN-MTB	-19.14	0.004**

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Eta squared calculation gave a very large between group effect size of $\eta^2 = 0.48$. Post hoc comparisons stated that both RC (mean 82.85) and MTB (68.76) were better than CN (49.61) indicating that both cycling groups balance was significantly better than the control balance. However, balance of MTB was worse than RC by 14.09 (Fig. 1).

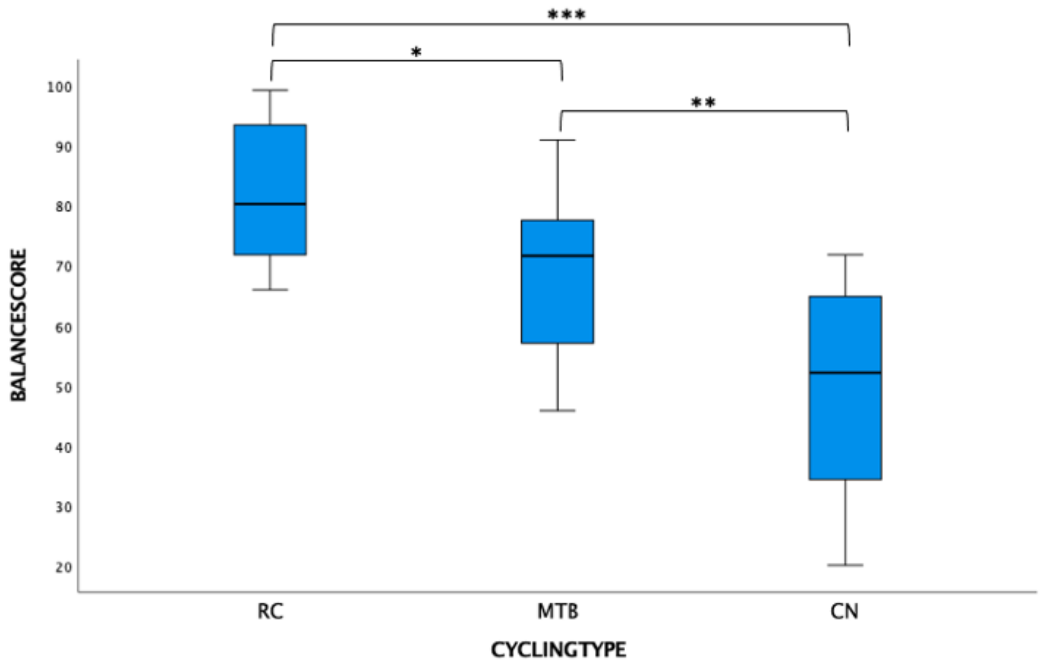

Figure. 1. Mean Balance Score (units out of 100) by Cycling Group (Error bars: 95% CI)
(*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$)
Note: asterisks indicate significant difference of scores between cycling groups

Discussion

The study investigated the postural stability of two disciplines of recreational cycling, MTB and RC, against a non-cycling control, using the SWAY app on a mobile phone to assess balance. It aimed to ascertain whether cycling activity promoted better balance ability, and which of the two cycling disciplines had the better balance, with the suggestion that MTB would be better due to the more unpredictable nature of the activity.

The findings showed a significant difference in balance scores between all three groups, and that the cycling groups RC and MTB both had significantly better balance scores than the non-cycling age-matched control; however, the balance of RC was significantly better than that of MTB contrary to the proposal. Mean SWAY balance scores for the RC group were 82.5 (score out of 100), and MTB mean scores were 68.76, both significantly better than the control group mean score of 49.61.
In order to quantify the results and give an indication of what the scores mean on a universal level, it is necessary to compare with normative data. Goble and Baweja (2018) in their large-scale study, accumulated balance scores from 6280 healthy adults (20 - 100 years) and produced stratified percentile rankings to be used as normative data for postural sway measurement. They found that the balance ability of males and females began to significantly decrease at the 40-49 years age group, and continued to do so throughout the subsequent age groups. Balance scores were based on CoP length (cm) recorded by the BTrackS™ Assess Balance system software (validated against several methods of CoP measurement), however it is not possible to compare this data with the results of the current study as the percentile rankings calculated hold no balance score value. In order to compare data, the current study would need to test the balance of participants across the age groups of 20 - 100 years and calculate percentile rankings. Likewise, data collected by Springer, Marin and Cyhan (2007) from 549 healthy subjects confirmed an age-related decline in balance ability, but their data was collected as unipedal balance in seconds, so again cannot be successfully compared to the present study's SWAY app balance scores in units out of 100.

A white paper by SWAY's Brek Wilkins (2020) collected, inter alia, balance data from 165,492 SWAY app users to develop normative data on balance. The current study results can be compared with these data, as Wilkins' study uses scores out of

100, with the RC group's mean score of 82.85 falling within the reported 'average' score band from the Wilkins SWAY study (Table 3), and the MTB group's mean score of 68.76 also just falling within the 'average' boundary, although on the lower limits. The non-cycling control group however, with a mean score of 49.61 is considered below average as falls below the 10th percentile shown on the Wilkins study. When considering what is 'average' in terms of a balance score, the normative data from the Wilkins SWAY study should perhaps be taken with caution when extrapolating to the general public. As the SWAY app is designed for baseline testing in sports teams (and the study population was taken from 'SWAY users') it should be assumed that a large majority of the app users are therefore athletes to some degree. This would have a significant effect on their overall ability to maintain balance, and scores may appear elevated as such.

Balance Strategies

Balance is known to involve neurological pathways of the vestibular, oculomotor, and somatosensory systems, which send integrated information from the environment to the CNS to elicit appropriate musculoskeletal responses. The vestibular system includes the apparatus of the inner ear and detects motion of the head, and the oculomotor system provides visual input. The maintenance of balance relies heavily on oculomotor input - this is cut off during the balance testing in this study

Table 3: Normative Balance Scores (out of 100) - extracted from 'Normative Sway Balance and Cognitive Assessment Data'[56]. Scores between 25th and 75th percentile are considered "average"

	Mean	SD	10th	25th	75th	90th
Males (N = 261) Age 41-50 y	78.5	17.2	54.2	69.5	91.3	96.9
Females (N = 238) Age 41-50 y	80.2	15.4	58.7	72.2	92.0	96.1
Males (N = 158) Age 51-60 y	74.2	15.8	50.4	64.6	86.8	92.8
Females (N = 163) Age 51-60 y	75.4	17.5	50.7	65.1	88.8	95.5

by closing the eyes, therefore the participant must rely on information only from the vestibular and somatosensory systems in order to maintain balance. The somatosensory system is a complex subcomponent of human motor control and includes proprioception, which provides afferent information from peripheral areas of the body, via numerous and different proprioceptors, regarding the position of joints and limbs (Riemann and Lephart 2002). This ascending afferent information travels via dorsal lateral tracts of the spinal cord to the motor cortex of the brain. Here it is interpreted and an appropriate response is executed via descending efferent pathways to the postural muscles, to adjust the body position in order to maintain postural control(Mancini and Horak 2010). These muscle actions can differ depending on such things as the stabilisation required, the predictability of movement, and the perceived risk of injury and are known as balance strategies.

The two most common balance strategies are the ankle and the hip strategy (Horak and Nashner 1986; Winter 1995). Muscle activity in the ankle strategy begins at the ankle and extends upwards to the hip then trunk; and the strategy restores balance by utilising compensatory movements around the ankle joint to restore the body's center of mass. Conversely, the hip strategy activity, which involves larger and more rapid shear forces, is in the opposite direction, starting at the trunk and hip, with little to no activity at the ankle (Horak and Nashner 1986). The ankle strategy is more commonly used to compensate for small perturbations, the hip strategy when perturbations are larger (Panjan and Sarabon 2010). A study by Cohen et al. (1996) that reported an age-related decline in balance ability, also reported an age-related change in movement strategy, with older participants utilising a wider range of strategies than younger participants to maintain balance. This reflected previous findings by Gu et al. (1996) who reported that older individuals tended to have 'larger excursions from the center of mass' and developed larger 'support reaction changes' than the younger during balance tasks; with the younger individuals regaining postural stability more rapidly, and the older utilising larger joint torques and increased use of trunk motion to maintain balance. As the current study looked at balance in the age-group 45 - 60 years, it would be expected that the individuals would utilise a variety of balance strategies, although these were not recorded. The results might suggest that the worse (lower) the balance score, the larger the excursion from the center of mass, and therefore the larger the movements needed to regain control of the center of mass over the base of support.

The control systems of feedback should also be considered when investigating balance. The 'feedforward' or anticipatory postural control mechanism, and the 'feedback' or compensatory mechanism, are strategies used by the CNS to manage internally or externally generated perturbations of the body (Kanekar and Aruin 2014). These feedback systems involve stimulation at proprioceptor level, afferent neural transmission, integration of input at the cortical level of the brain, and efferent transmission of signals, eliciting a neuromuscular response (Reimann and Lephart 2002a). Predictable disturbances will elicit activity of muscles in an anticipatory fashion, in order that the potential effects of the anticipated disturbance are minimised. With unpredictable disturbances the compensatory mechanism is employed; this occurs after the disturbance and is intended to restore stability (Park, Horak and Kuo 2004). In most circumstances a combination of both exists, such as in the maintenance of postural stability (Reimann and Lephart 2002a).

Factors Affecting Balance Testing

It was shown that MTB had worse balance than RC, contrary to the hypothesis, and a number of reasons are explored. To achieve optimal performance and comfort on a bicycle, the rider must adapt their body position in order to optimise their center of mass over the base of support whilst on the bicycle. For a road cyclist, body position and therefore center of mass, is relatively static and stable with three points of contact between the body and the bicycle - feet, hands, seat (Kronisch and Pfeiffer 2002), most of the time; the body only shifting posteriorly or anteriorly on downhill or uphill sections of road, and tilting laterally on curves. These required position changes are usually predictable as the rider is able to clearly see the road ahead. In MTB, the rider is often out of the saddle, with only two points of contact (feet and hands), in order to manage the unpredictable terrain and environment at varying speeds and gradients (Eldesoky et al 2017). Handling this unpredictable terrain requires spontaneous, rapid and constant shifting of body mass in order to regain the center of balance on the bike which is moving erratically over the uneven surface; it would therefore be reasonable to assume that MTB riders might employ movement strategies that incorporate much larger ranges of movement in the upper body than would the RCs. When balance testing, the MTB riders may use these larger movement strategies that they are accustomed to in maintaining their balance for the duration of the testing, which may include hip strategies rather than ankle strategies. During balance testing with the SWAY app, the device is held at the chest and collects movement data at this level, and therefore would be more sensitive in detecting movement strategies higher up the body, resulting in a lower balance score. The systematic review by Pinho et al. (2019) in assessing mobile devices apps for postural balance testing, suggested that there was not enough evidence to conclude that these apps have discriminatory accuracy. It is a logical assumption then that the app held at chest level would be less able to detect the smaller strategic movements at ankle level, therefore reporting higher (better) scores for participants that employ ankle strategies to maintain balance.

Anticipatory and compensatory mechanisms are differently employed depending on the circumstance of the disturbance. It has also been suggested that they are utilised according to training. One study (Lamoth, van Lummel and Beek 2009) reported gymnasts as having superior postural control skills to ‘physical education students and ‘regular bachelor students’; and another (Williams, Murray and Powell 2016) reported that surfers exhibited unique postural strategies compared to basketball players, the variables here being athletes who train on an unstable (surfing) v stable (basketball) surface. As such, different levels of anticipatory muscle recruitment will take place during the maintenance of balance with a feedforward’ or anticipatory postural control mechanism occurring (to retain balance) in those accustomed to ‘balancing’, and a ‘feedback’ or compensatory movement occurring (to recover balance), more in those that are unaccustomed (Dakin and Bolton 2018). The data collection for the RC in the present study occurred mainly at a velodrome on cyclists that also took part in track cycling sessions. A popular challenge for track cyclists is the ability to hold a ‘track stand’ for the longest time possible, this being the ability to balance the bicycle whilst stationary (Wardle, Gregory and Cazzolato 2014). It is not known how many of the RC participants in the present study were able to perform this skill, or to what ability, but with this skill being a complex challenge to balance, it would therefore be an influencing factor in the balance ability and subsequently the scores of the participant during testing.

Adventure sports such as MTB (Immonen et al 2017) are commonly linked with risk-taking (Breivik 2010) as described in a study (Roberts, Jones and Brooks 2018) which reported that only 0.5% of the participants (N = 1,484) indicated there was ‘no risk’ in their MTB participation. Inherent in high-risk sports is the risk of injury, as reported in a study on the 2016 Olympic Games (Soligard et al. 2017), where MTB was in the top three sports with the highest injury incidence, and RC ranking 25th on the list of 39 sports. Although the current study excluded participants that had a ‘lower limb injury in the past six months’, this does not, however, take into account unconsidered chronic dysfunction that could have occurred through past and repeated injury from MTB (Miller 2017). This may subsequently be a factor in the participant’s ability to maintain balance, and as the injury data reports higher injury rates in MTB (Soligard et al. 2017), this could suggest a discrepancy between the functional balance ability of MTBs and RCs. Additionally, the fact that MTBs purportedly have less perceived risk of danger (Roberts, Jones and Brooks 2018), could raise the suggestion that their fear of losing balance during the balance test would be lower than RCs, so they might ‘fall’ for longer before attempting to regain balance and therefore more upper-body sway would be detected during the testing.

Another factor to consider is the unequal frequency of males and females in the current study, with only 3 females out of 14 in the MTB group, but 9 out of 14 in the RC group. Although these figures might represent the reported disproportion of women in MTB (Roberts, Jones and Brooks 2018) compared to RC, it is a confounding factor in the present study as the balance scores of males and females were not separately analysed, and it has been consistently reported that women have better balance than men in the older age groups (Goble and Baweja 2018; Wiśniowska-Szurlej et al. 2018). This factor may therefore have affected the results when comparing the means of the cycling groups.

A final consideration is that the data collection for the present study took place after the Covid-19 lockdown periods of 2020 and 2021, with a sample population from London. The initial restrictions on outdoor activity preventing people from leaving their homes for more than one hour, and the ban on driving to locations for exercise, may have had a large impact on MTBs and their opportunities to travel to areas where MTB could take place. RCs on the other hand, were able to continue to ride out from their homes; thus suggesting that MTBs were less able to continue their activity during this lockdown period. Subsequently at the time of testing MTBs may not have had the same exposure to their cycling activity as RCs, and a detraining effect could have occurred, as similarly reported in a study (Toulotte, Thevenon and Fabre 2006) of older adults over three and six months of detraining after balance training.

Limitations and Further Research

The main limitation of the present study is the small population size; however, the effect size suggests that results could be replicated in larger sample sizes. Further larger scale studies are required to replicate findings of the present study and help to reduce a gender effect in balance results. Longitudinal studies would examine whether observed improvements in balance had a significant effect on reduction of falls in later years. Future research should also address gender specific balance testing, and broader sample populations with more defined categorisation of pre-existing abilities in terms of balance. Longitudinal postural stability studies on pre and post cycling would further identify the long-term effects of cycling on balance. The SWAY app also includes reaction time and impulse control in its battery of tests - a recommendation is to compare these other abilities pertaining to age-related loss, in MTB and RC populations. The SWAY app has been subject to little high-level validity/reliability testing; a recommendation is to validate the SWAY app against the gold standard force plate, and further ecological validation is required for use outside.

Conclusion

Although this study found MTB to have worse balance than RC, it concluded that both groups of cyclists in the age range of 45 - 60 y appeared to have better balance than age-matched non-cyclists. Previous literature confirms that the steady age-related deterioration in balance shows a sharp decline around the age of 50 y. Cycling participation has been increasing in the UK in recent years as a mode of travel and of exercise or recreation. Regardless of which mode cycling is used for, if the inclusion of cycling in regular activities can significantly enhance balance ability in the 45 - 60 y age group, this has positive implications for helping to reduce the incidence of falls in later life, reducing the strain on public health services. Furthermore, the SWAY app used to assess balance in the present study is a mobile and reliable method of balance testing, and offers the opportunity to easily test balance outside the confines of a laboratory or clinic.

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