Title

Let's Move with Leon. A randomised controlled trial of a UK digital intervention to improve physical activity in people with a musculoskeletal condition.

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Abstract

Objective: This paper present a real-world evaluation of a digital intervention, 'Let's Move with Leon', designed to improve physical activity and health-related quality of life in people with a musculoskeletal condition.

Study design: A pragmatic randomised controlled trial.

Methods: After randomisation and withdrawals were removed, 184 participants were assigned to receive the digital intervention with 185 assigned to a control group. Self-reported physical activity was the primary outcome. Health-related quality of life, the number of days completing strength-based exercises per -week, the capability, opportunity, and motivation to be active, and step count were secondary outcomes. Outcomes were assessed over 4, 8 and 13-weeks.

Results: Significant improvements were seen for self-reported physical activity at 13 weeks, reported strength days at 8 weeks, perceptions of physical capability and automatic motivation to be active at 4 and 8 weeks. No improvements were seen in step count or health-related quality of life over the control group.

Conclusion: Digital interventions such as 'Let's Move with Leon' have the potential to increase physical activity in people with a musculoskeletal condition, however, improvements are likely to be small. Small improvements in physical activity may not be enough to improve HRQoL.

Keywords

Physical activity; Musculoskeletal condition; COM-B; Digital Behaviour Change Interventions; Health Improvement.

Introduction

Physical activity has many benefits for people with a musculoskeletal condition, such as pain reduction, improved physical function and mental wellbeing, and protection against other long-term conditions such as heart disease and diabetes.[1–6] It is estimated that 18.8 million people in the UK have a musculoskeletal condition, many are not active to the required levels, with between 33% and 49% classified as completely inactive.[7]

Digital interventions may improve physical activity in older adults[8] but there is limited evidence in people with arthritis[9] highlighting the need for robust evaluation of such interventions. UK charity Versus Arthritis developed a digital intervention to support people with a musculoskeletal condition (Inflammatory arthritis, Osteoarthritis, chronic or long-term joint pain, Osteoporosis or weakening of the bones) to become physically active, taking an evidence-based approach. Using the COM-B model, which postulates that capability, opportunity and motivation need to align to influence behaviour, and the Behaviour Change Wheel to facilitate intervention development, a digital intervention was created.[10,11]

The digital intervention, 'Let's Move with Leon' (LMWL), is comprised of 12 pre-recorded YouTube exercise sessions, each lasting around 30 minutes in length, details of which are sent weekly over email, coupled with a 35-page Activity Tracker, which can be printed or completed digitally. The LMWL videos encourage supplementary outdoor activity. Intervention users have access to an online Activity Hub which provides introductory videos, videos on how to get started with the programme, and videos on how to get up and down from the floor safely. Users can access a frequently asked questions section, an online community, and information about the benefits of physical activity. The use of intervention functions, behaviour change techniques, and implementation approaches are reported elsewhere.[11] This paper present a real-world evaluation of LMWL assessing the intervention's effectiveness at improving physical activity and health-related quality of life (HRQoL).

Method

Study design

A randomised controlled design is recognised to provide the best possible measure of effectiveness and was therefore selected for this evaluation. The evaluation was registered and an International Standard Randomised Controlled Trial Number obtained.[12] The evaluation was conducted and is reported in accordance with the Consolidated Standards of Reporting Trials.[13] A favourable ethical opinion was received from the London Metropolitan University School of Social Sciences and Professions Ethics committee in February 2021.

Recruitment and randomisation

Adult participants (aged 18-years and above) with a musculoskeletal condition, who could read English, provide consent, were computer and internet literate with a working email account were eligible to take part. Digital consent was obtained following the British Psychological Society ethics guidance for internet-mediated research.[14]

Participants were recruited using Facebook advertising between 1 August and 6 September 2021. Two-thousand, eight-hundred and thirty-six participants expressed an interest in the study and were sent further participant information; 541 provided consent with 389 providing complete baseline data. Randomisation took place following the collection of baseline information. Interested participants were asked at the expression of interest stage to confirm that they had not taken part in 150 minutes or more physical activity that raised their breathing rate in a normal week, and that they had not participated in a Versus Arthritis physical activity programme within the last 12 months.

Participants were randomised by the principal investigator using simple randomisation to receive the LMWL intervention, or a survey to collect data on the outcome measures; 195 participants were assigned to the intervention group, and 194 to the control. Twenty participants withdrew from the study and had their data removed; 9 in the control (6 due to ill health, 3 due to joint replacement operations); 11 in the intervention group (7 due to ill health, 2 due to joint replacement operation, 1 due to digital literacy, 1 no longer interested in taking part) resulting in 184 in the intervention group and 185 in the control. Participant information was collected on date of birth, gender, ethnicity, musculoskeletal condition and time since diagnosis to assess baseline characteristics between groups.

Data collection and outcome measures

The evaluation assessed the following outcomes:-

1. Physical activity using the Active Lives Short Measure
2. The number of days completing strength-based exercises per-week using the Active Lives Short Measure
3. HRQoL measured using the EQ5D-5L
4. Participant's *capability, opportunity* and *motivation* (components of the COM-B model) to be physically active assessed using a six-item questionnaire based on the work of Keyworth *et al.*[15]
5. Step count was assessed by participants smartphones (if they had one) using the 'Pedometer α - Step Counter' app
6. Usage data was collected for the intervention components (email, video, activity tracker, and the social networking options).

Self-reported physical activity was the primary outcome. The study was powered to see a 10% increase in minutes of physical activity over 13 weeks from baseline measures. All measures were collected over email using Qualtrics™; reminders were sent by email and text message. Participants were asked to report any adverse consequences from study involvement to the principal investigator; no adverse consequences were reported.

Data analysis

Data were analysed using intention-to-treat analysis with multiple imputation used for missing data. The exception was for step-count where per-protocol analysis was performed. Data were analysed at weeks 4, 8 and 13-weeks in the intervention and control groups, and 6 months post intervention in the intervention group only to assess maintenance of any changes. Usage data were analysed descriptively, coupled with regression analysis to identify those more likely to use the intervention videos from baseline measures of age, gender, ethnicity, physical activity and strength days, HRQoL and COM-B component scores.

The t-test was used to assess between group and within group differences for improvements (or not) from baseline to weeks 4, 8 and 13 for all outcome measures. A ceiling of 840 minutes per-week (14 hours or 2 hours per day) was placed on the levels of self-reported physical activity. Usage of the LMWL video component was correlated against the improvements in all outcome measures over 13 weeks but excluding step-count data as this constituted a more limited data set.

Let's Move with Leon was developed using the COM-B model, assuming that the COM-B model could predict physical activity behaviour. Therefore, physical activity was correlated against capability, opportunity and motivation to be active at the end of the intervention period of 13-weeks in the intervention group, assessing the link between theory and behaviour.

Results

The flow of participants through this study is presented in Figure 1. The baseline characteristics of the participants are presented in Table 1. The baseline characteristics were broadly similar across groups. Despite asking participants to confirm that they did not complete 150minutes of moderate intensity activity (or more) in a normal week, 35 participants were classified as active at baseline, 17 in the intervention group, 18 in the control. These participants were not excluded from the study and are included in the analysis.

Figure 1: Flow of participants through the evaluation

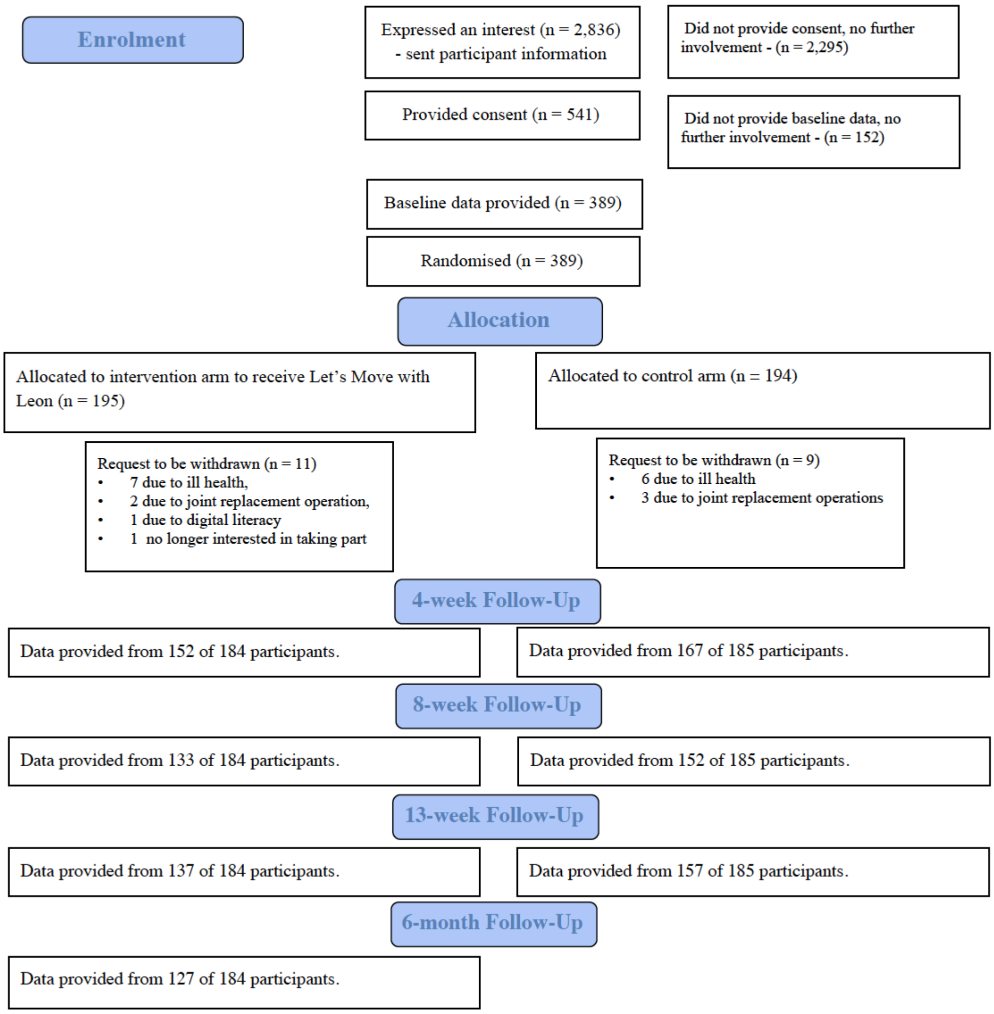

Table 1: Participant characteristics

		Intervention	%	Control	%	Total	%
Gender							
	Male	7	3.80	4	2.16	11	2.98
	Female	176	95.65	180	97.30	356	96.48
	Non-Binary	0	0.00	1	0.54	1	0.27
	Prefer not to say	1	0.54	0	0.00	1	0.27
Age							
	<20	0	0.00	0	0.00	0	0
	20-34	3	1.63	2	1.08	5	1.36
	35-44	8	4.35	10	5.41	18	4.88
	45-54	35	19.02	31	16.76	66	17.89
	55-64	75	40.76	74	40.00	149	40.38
	65-74	50	27.17	61	32.97	111	30.08
	75-84	12	6.52	6	3.24	18	4.88
	85+	1	0.54	1	0.54	2	0.54
	Mean	60.57		61.26		60.91	

Ethnicity						
White	180	97.83	181	97.84	361	97.83
All other ethnicities	4	2.17	4	2.16	8	2.17
Time since diagnosis						
No diagnosis	12	6.52	8	4.32	20	5.42
Less than 4 weeks ago	3	1.63	0	0.00	3	0.81
4 weeks up to 1 year	12	6.52	17	9.19	29	7.86
1 year to 5 years	63	34.24	52	28.11	115	31.17
More than 5 years	90	48.91	107	57.84	197	53.39
Other	4	2.17	1	0.54	5	1.36
Condition						
Inflammatory arthritis or autoimmune disease	65	35.33	65	35.14	130	35.23
Osteoarthritis	125	67.93	124	67.03	249	67.48
Chronic or long-term/ ongoing joint pain	116	63.04	107	57.84	223	60.43
Osteoporosis/ thinning/ weakening of the bones	17	9.24	11	5.95	28	7.59
Another form of joint pain	33	17.93	44	23.78	77	20.87
Data not provided	1	0.54	0	0.00	1	0.27
Multiple conditions (included within the above numbers)	122	66.30	119	64.32	241	65.31
Physical activity						
Inactive	134	72.83	119	64.32	253	68.56
Moderately active	33	17.93	48	25.95	81	21.95
Active	17	9.24	18	9.73	35	9.49
Mean mins of moderate/vigorous intensity	44.18		55.82			
Mean strength days (over 7 days)	1.15		1.28			
Mean step count (7 days)	29756.98		27755.01			
Health related quality of life[a]						
Mean health utility score	0.52		0.53			
Physical activity behavioural components[b]						
Capability (physical)	5.48		5.76			
Capability (psychology)	8.27		8.35			
Opportunity (physical)	7.05		7.19			
Opportunity (social)	6.48		6.30			
Motivation (reflective)	5.14		5.46			
Motivation (automatic)	4.76		5.10			

a. Scale – 0.594 to 1
b. Scale 1 to 10

Participants were not representative of the UK population of people with a musculoskeletal condition being significantly over representative of females (96.5% compared to 55.9%), white people (97.8% compared to 91.7%), with a slightly younger profile (63.1% aged between 35 and 64 years and 35.5% aged 65 and over compared to 49.6% and 34.1% respectively) and a greater number classified as inactivity (68.6% compared to 49%).[7] It is postulated that the characteristics of participants (predominantly female and white) reflects the audience likely to engage with the charity through Facebook marketing.

Outcomes

The outcome measures are presented in Table 2.

Table 2: Change in outcome measures

Outcome and period	Intervention	Control	Difference (95% CI)
Change in physical activity minutes per week			
Baseline to Week 4	68.79***	42.02**	26.77 (-8.06 to 61.60)
Baseline to Week 8	64.93***	38.89**	26.04 (-5.60 to 57.68)
Baseline to Week 13	69.78***	29.98**	39.80 (7.02 to 72.59)+
Baseline to 6 months	53.75**		
Change in strength days per week			
Baseline to Week 4	0.69***	0.40**	0.29 (-0.12 to 0.71)
Baseline to Week 8	0.75***	0.24	0.51 (0.10 to 0.91)+
Baseline to Week 13	0.61***	0.33*	0.28 (-0.16 to 0.72)
Baseline to 6 months	0.91***		
Change in HRQoL (health-utility score - point specific measure - scale -0.59 to 1)			
Baseline to Week 4	0.07***	0.04**	0.03 (0.00 to 0.07)
Baseline to Week 8	0.08***	0.05***	0.03 (-0.01 to 0.07)
Baseline to Week 13	0.06***	0.05***	0.01 (-0.02 to 0.05)
Baseline to 6 months	0.05***		
Change in physical capability (scale 1 to 10)			
Baseline to Week 4	0.46**	-0.02	0.48 (0.02 to 0.95)+
Baseline to Week 8	0.54**	-0.02	0.56 (0.04 to 1.08)+
Baseline to Week 13	0.47*	0.17	0.3 (-0.23 to 0.82)
Baseline to 6 months	0.22		
Change in psychological capability (scale 1 to 10)			
Baseline to Week 4	-0.21	-0.31*	-0.1 (-0.30 to 0.52)
Baseline to Week 8	-0.22	-0.26	-0.04 (-0.36 to 0.46)
Baseline to Week 13	-0.35*	-0.48**	-0.13 (-0.29 to 0.54)
Baseline to 6 months	-0.40		

Change in physical opportunity (scale 1 to 10)			
Baseline to Week 4	-0.10	-0.29	-0.19 (-0.34 to 0.72)
Baseline to Week 8	-0.18	-0.18	0.00 (-0.54 to 0.54)
Baseline to Week 13	-0.20	-0.17	0.03 (-0.59 to 0.53)
Baseline to 6 months	-0.17		
Change in social opportunity (scale 1 to 10)			
Baseline to Week 4	0.21	0.22	-0.01 (-0.54 to 0.54)
Baseline to Week 8	0.17	0.31	-0.14 (-0.68 to 0.41)
Baseline to Week 13	0.00	0.28	-0.28 (-0.84 to 0.27)
Baseline to 6 months	0.11		
Change in reflective motivation (scale 1 to 10)			
Baseline to Week 4	0.63***	0.44*	0.19 (-0.34 to 0.73)
Baseline to Week 8	0.68***	0.43*	0.25 (-0.29 to 0.79)
Baseline to Week 13	0.45*	0.34	0.11 (-0.47 to 0.69)
Baseline to 6 months	0.68**		
Change in automatic motivation (scale 1 to 10)			
Baseline to Week 4	0.42*	-0.21	0.63 (0.08 to 1.18)+
Baseline to Week 8	0.59**	-0.11	0.70 (0.18 to 1.22)++
Baseline to Week 13	0.52**	0.06	0.46 (-0.09 to 1.02)
Baseline to 6 months	0.44*		
Change in weekly step count[a]			
Week 4	2931.75*	3537.98	-606.23 (-5048.45 to 3836.00)
Week 8	1251.34	3323.43*	-2072 (-6931.34 to 2787.33)
Week 13	3908.91	2782.42	1126 (-4098.88 to 6531.87)

a. Missing data was imputed for all outcomes with the exception of weekly step count which was assessed on a per-protocol basis where matched pairs were available

Within group	* p=<0.05	Between group	+ p=<0.05
	** p=<0.01		++ p=<0.01
	***p=<0.001		

Significant improvements were seen in self-reported moderate to intense physical activity between groups at 13 weeks and in the number of strength days performed each week at 8 weeks. However, the objective measure of weekly steps did not show any significant difference. The intervention group reported significant improvements over the control in the behavioural components of physical capability and automatic motivation at 4 and 8 weeks but not at 13 weeks.

Within group analysis of the before and after data shows significant improvements at all time points from baseline measures and also at 6-month follow up in the intervention group for self-reported physical activity minutes, strength days per week, HRQoL, and the behavioural components of physical capability, reflective and automatic motivation. The control group reported significant improvements in self-reported physical activity minutes, and HRQoL at weeks 4, 8 and 13, and at weeks 4 and 13 for strength days per week.

Table 3 outlines the use of the LMWL components at weeks 1, 4, 8 and 13.

Intervention use

Table 3: Intervention usage over 13 weeks

					% of total participants[a]	
		Yes	No	Blank	Yes	No/Blank
Week 1	Opened email	129	13	42	70.11%	29.89%
	Watched video	83	46	55	45.11%	54.89%
	Used tracker	26	102	56	14.13%	85.87%
	Accessed social network site	20	121	43	10.87%	89.13%
Week 4	Opened email	105	32	47	57.07%	42.93%
	Watched video	83	22	79	45.11%	54.89%
	Used tracker	24	76	84	13.04%	86.96%
	Accessed social network site	14	120	50	7.61%	92.39%
Week 8	Opened email	76	35	73	41.30%	58.70%
	Watched video	54	22	108	29.35%	70.65%
	Used tracker	8	65	111	4.35%	95.65%
	Accessed social network site	5	106	73	2.72%	97.28%
Week 13	Opened email	85	48	51	46.20%	53.80%
	Watched video	54	31	99	29.35%	70.65%
	Used tracker	5	77	102	2.72%	97.28%
	Accessed social network site	13	119	52	7.07%	92.93%

a. It was assumed that if the question was not answered then the participants did not use the intervention component

The usage data suggests that only 70.11% of participants engaged with the intervention in week 1 of the study, with only 45.11% watching the first video. Even fewer used the activity tracker (14.13%) and the social networking opportunities (10.87%). The number of people engaging with the intervention decreased over time. Usage of the LMWL video over the 13 weeks showed a weak yet significant correlation with the 13 week improvement in strength days (r^2=0.186, $p<0.05$). No other correlations were found.

Regression analysis suggested that those who were older (OR:0.09, 95% CI 0.02 to 0.16, p=0.01) and with a higher automatic motivation score at baseline (OR:0.39, 95% CI 0.06 to 0.71, p=0.02) were more likely to make use of the videos; no other relationships were found.

Relationship between COM-B component and physical activity behaviour

The correlations between COM-B component and self-reported physical activity are presented in Table 4.

Table 4: Correlation of the COM-B components to physical activity minutes in the intervention group

End of intervention - Week 13	R value
Capability - Physical	.25***
Capability - Psychological	.16***
Opportunity - Physical	.13**
Opportunity - Social	.16***
Motivation - Reflective	.27***
Motivation - Automatic	.42***

**p=<0.01; *** p=<0.001

Discussion

Robustly developed evidence-based interventions for changing physical activity only, rather than multiple lifestyle behaviours, with a focus on integration into everyday life have been shown to be effective.[16] This trial found that LMWL improved self-reported physical activity over 13 weeks. However, whilst a positive trend is seen in objectively measured step count, no significant difference is observed. A 2018 systematic review from Griffiths *et al.*[9] of the effect of interactive digital interventions on physical activity in people with inflammatory arthritis supports this, reporting no significant difference in objectively measured physical activity, but improvement in self-reported physical activity. It is noted that use of smartphone data to track steps, as in our trial, can have high variability[17] and therefore comparison to other objective measures should be interpreted with caution. All studies included in the review by Griffiths *et al.* (2018)[9] had a sample size of less than 160 total participants, smaller than this evaluation. Three-hundred and sixty-nine participants are included in this evaluation, of which 171 provided step count data at 13 weeks (91 in the control, 80 in the intervention group); it could be that the sample size of 171 was not large enough to pick up small changes in this outcome.

The number of days completing strength-based exercises increased significantly over 8 weeks. Interestingly, strength days continued to increase within the intervention group at 6 months whereas self-reported physical activity declined. The 6-month follow-up fell within the winter months which may explain this. Other digital interventions are identified in the extant literature that include a strength component to their programme, however, the frequency of days performing strength based exercises are not reported so it is not possible to draw comparison.[18–25] LMWL did not improve HRQoL a finding supported in the wider literature.[9,26] As explained by Griffiths *et al*. (2018)[9] HRQoL is multifaceted and improving physical activity in isolation may not be enough to influence this outcome.

Berry *at al.* (2018) [16] identify that intervention usage is poorly reported in the extant literature. This research reviewed usage of the LMWL components; 72.3% of participants made use of at least one LMWL video, 27.2% used 8 videos or more, much lower than that reported for other digital behaviour change interventions.[16,27] The rate of intervention use declined over time, as is common.[16] It is a concern that 27.7% of participants did not make use of any videos. This suggests that the LMWL intervention does not meet the needs of many; a process evaluation is required to better understand this. Those who did not engage with the first exercise video were more likely to disengage with the programme highlighting the need for early engagement. Data collected in this trial suggests that older people and those more motivated are more likely to have higher intervention engagement, this warrants consideration by digital behaviour change intervention designers.

The relationship between use and outcomes is inconclusive,[28,29] however, greater usage *may* result in small improvements in physical activity particularly in regard to strength. It is possible that a sense of commitment to a physical activity programme, with the regular monitoring of outcomes, could be enough to facilitate behaviour change regardless of levels of engagement in the programme itself.[30]

The Behaviour Change Wheel has been used previously to develop a digital intervention to improve physical activity in people with diabetes,[31] however, it is believed that the use of this approach in the development of LMWL is the first in people with musculoskeletal conditions.

Therefore, it is difficult to draw comparison to the wider literature on the specific behavioural components of the COM-B model which sits at the centre of the Behaviour Change Wheel.

LMWL significantly improved perceived physical capability at 8 weeks over a controlled comparison; improvements in physical function from physical activity in people with a musculoskeletal condition are widely reported.[2] The baseline measures for the psychological capability domain were the highest across all of the COM-B components, with scores of 8.27 and 8.35 in the intervention and control groups respectively. It is argued that these high scores suggest that participants attracted to this research had good knowledge on the benefits of being active, therefore, improvements in this area were less likely to occur. However, a decrease in this behavioural component in both intervention and control groups was unexpected. This domain includes sufficient knowledge, memory, attention, decision making skills and the mental stamina to be active. It is possible that the repeated data collection processes, which took between 8 and 10 minutes to complete, could have created some mental fatigue and impacted the mental stamina of participants over time. Further, the timing of the study may have played a part. Participants started the programme at the end of the summer months, finishing during winter. As the LMWL videos encouraged supplementary outdoor activity, poor weather could have impacted on the mental stamina to take part in physical activity outside and in general.[32] This too could explain the slight negative movement of the physical opportunity scores in the intervention and control groups.

The social opportunity domain includes the support from friends and family. This behavioural domain remained relatively stable across both the intervention and control groups, with no significant changes. This findings is supported by the previous analysis of secondary data.[11] A challenge of digital interventions is to create the social interaction that participants would experience in a face-to-face setting; the lack of use of online forums and social media in such digital interventions is supported by Webb *et al*. (2019).[33]

The physical opportunity domain includes having the time and sufficient resources to be active. As with the social opportunity domain, no significant changes were reported. Scores for physical opportunity could be considered high at baseline, with scores of 7.05 and 7.19

out of 10 for the intervention and control groups respectively and therefore less amenable to change.

Baseline scores for the behavioural components of reflective (5.14 intervention and 5.46 control) and automatic motivation (4.76 intervention and 5.10 control) were the lowest when compared to the other behavioural components. The intervention group reported significant within group improvements in reflective motivation, with the improvement maintained at 6 months. However, the control group also showed a significant within group improvement at 4 and 8 weeks. No significant differences were reported between groups. This suggests that simply monitoring physical activity may be enough to increase the desire to be physically active, at least in the short-term.[34] Similarly, a propensity for making exercise a habit was evidenced by improved automatic motivation, being active without having to be reminded or having to think about it, in the intervention group when compared to the control group at 4 and 8 weeks.

The COM-B component of automatic motivation had a significant moderate correlation to physical activity at 13-weeks in the intervention group; all other COM-B components had a significant yet weak correlation. Research into the predictive validity of the COM-B model for physical activity suggests that the motivation component is the most important directly explaining 49% of the variance.[35] Howlett *et al*.[35] argue that the COM-B model performs well against other commonly used theories to explain physical activity. Our trial suggests that the usefulness of the COM-B model as a basis for intervention design in regards to physical activity remains unclear.

Implications for practice and future research

To the knowledge of the authors, this is the first pragmatic trial investigating the impact of a digital intervention on the components of physical activity behaviour using the COM-B model. Physical activity interventions based on the COM-B model should be robustly evaluated to add to the limited evidence on its use and usefulness. Standard measures should be used to collect data on the COM-B components to allow for comparison across intervention studies.[15]

Digital behaviour change interventions have the potential to increase physical activity,[8,27] however, improvements are likely to be small. Digital behaviour change interventions such as LMWL are likely to attract those that are inactive, ready to make a change, who have a knowledge of why physical activity is important. Digital interventions that are tailored to the individual are suggested to be effective;[9] whilst participants set their own goals and targets in LMWL, there is no specific tailoring to the participants; a change in this area may help increase the impact of the intervention. Engagement should be monitored closely as creating a sense of commitment to a programme with regular monitoring may be enough to instigate a change regardless of intervention engagement.

Future research and practice should consider the usage, adherence and attrition of digital interventions, even when participants are self-selecting. Comparisons between digital interventions and face-to-face delivery also warrant investigation.[27] Creating a sense of commitment and the monitoring of behaviour could be useful behaviour change techniques in supporting people to become more active.

This evaluation demonstrates that smartphone accelerometers can provide a useful mechanism to collect objective step-count data. It is acknowledged that smartphones are not a research grade objective measure, however, they offer a low-cost opportunity to evaluate physical activity programmes alongside self-reported measures which are known to over-report physical activity. Further, smartphone interventions have shown promise in improving physical activity; [36] this offers an additional opportunity for future digital intervention development.

Strength and limitations

The sample size in this evaluation is larger than other identified digital intervention trials.[18–25] However, the sample is not representative of the wider population of people with musculoskeletal conditions in the UK, therefore, caution is advised when generalising the findings. A further limitation is that follow-up in this evaluation was only for 6-months. Ideally, behaviour change interventions should be followed up for at least a year.[37]

This study had one primary outcome, that of self-reported physical activity. It could be argued that with multiple analyses of secondary outcomes that a study wide correction was necessary. We have taken the view of Perneger[38] "describing what was done and why, and discussing the possible interpretations of each result, to enable the reader to reach a reasonable conclusion." (p.1237)

This trial demonstrates that it is possible to use smartphone accelerometers as a tool to support data collection in regards to physical activity, albeit step count only. It is acknowledged that not all will possess a smartphone, or know how to monitor steps, however, we contend that this offers an alternative to self-reported physical activity. As we have shown, the choice of activity measure can have important consequences for the outcome of physical activity trials.

In summary

Digital interventions such as LMWL have the potential to increase physical activity in people with a musculoskeletal condition who are aware of the benefits of being active. However, improvements in physical activity are likely to be small and intervention usage sporadic. Small improvements in physical activity on their own are likely to be insufficient to deliver sustainable improvements to broader quality of life.

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Competing interest

There are no competing interests to declare.

Author contributions

JW was the principal investigator for this trial. The trial was designed by JW and DS. The data was collected by JW. The data analysis was completed by JW and DS. The manuscript was drafted by JW with DS providing final approval.

References

1. National Institute of Health and Care Excellence. *Falls in older people: assessing risk and prevention. Guidance.* NICE, London (2013). Available from: https://www.nice.org.uk/guidance/cg161

2. Ellis Benjamin, Garrett Anna, Marshall Tim. *Providing physical activity interventions for people with musculoskeletal conditions.* Department of Health, Public Health England, Arthritis UK, NHS England, London (2014)

3. Metsios GS, Lemmey A. Exercise as Medicine in Rheumatoid Arthritis: Effects on Function, Body Composition, and Cardiovascular Disease Risk. Journal of Clinical Exercise Physiology. 2015 Mar 1;4(1):14–22.

4. Hurkmans E, van der Giesen FJ, Vliet Vlieland TP, Schoones J, Van den Ende ECHM. Dynamic exercise programs (aerobic capacity and/or muscle strength training) in patients with rheumatoid arthritis. Cochrane Database Syst Rev. 2009 Oct 7;2009(4):CD006853.

5. O'Dwyer T, O'Shea F, Wilson F. Exercise therapy for spondyloarthritis: a systematic review. Rheumatol Int. 2014 Jul;34(7):887–902.

6. Smith SM, Soubhi H, Fortin M, Hudon C, O'Dowd T. Managing patients with multimorbidity: systematic review of interventions in primary care and community settings. BMJ. 2012 Sep 3;345:e5205.

7. Versus Arthritis. The State of Musculoskeletal Health 2021 [Internet]. Versus Arthritis, London (2022). Available from: https://www.versusarthritis.org/about-arthritis/data-and-statistics/the-state-of-musculoskeletal-health/

8. Stockwell S, Schofield P, Fisher A, Firth J, Jackson SE, Stubbs B, et al. Digital behavior change interventions to promote physical activity and/or reduce sedentary behavior in older adults: A systematic review and meta-analysis. Experimental Gerontology. 2019 Jun 1;120:68–87.

9. Griffiths AJ, White CM, Thain PK, Bearne LM. The effect of interactive digital interventions on physical activity in people with inflammatory arthritis: a systematic review. Rheumatol Int. 2018;38(9):1623–34.

10. Michie S, van Stralen MM, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Implementation Science. 2011 Apr 23;6(1):42.

11. Webb J, Horlock R, Ahlquist A, Hall A, Brisby K, Hills S, et al. The reach and benefits of a digital intervention to improve physical activity in people with a musculoskeletal condition delivered during the COVID-19 pandemic in the UK. Perspect Public Health. 2022 Apr 3;17579139221085098.

12. ISRCTN - ISRCTN14174108: An evaluation of the effects of a digital web-based intervention on the physical activity of people with a musculoskeletal condition [Internet]. Available from: https://www.isrctn.com/ISRCTN14174108

13. Schulz KF, Altman DG, Moher D, for the CONSORT Group. CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials. Ann Int Med 2010;152. Epub 24 March.

14. British Psychological Society. *Ethics Guidelines for Internet-Mediated Research*. BPS, Leicester (2017). Available from: https://www.bps.org.uk/news-and-policy/ethics-guidelines-internet-mediated-research-2017

15. Keyworth C, Epton T, Goldthorpe J, Calam R, Armitage CJ. Acceptability, reliability, and validity of a brief measure of capabilities, opportunities, and motivations ("COM-B"). Br J Health Psychol. 2020 Sep;25(3):474–501.

16. Berry A, McCabe CS, Muir S, Walsh N. Digital behaviour change interventions to facilitate physical activity in osteoarthritis: a systematic review. Physical Therapy Reviews. 2018 May 4;23(3):197–206.

17. Presset B, Laurenczy B, Malatesta D, Barral J. Accuracy of a smartphone pedometer application according to different speeds and mobile phone locations in a laboratory context. Journal of Exercise Science & Fitness. 2018 Aug 1;16(2):43–8.

18. Allen KD, Arbeeva L, Callahan LF, Golightly YM, Goode AP, Heiderscheit BC, et al. Physical therapy vs internet-based exercise training for patients with knee osteoarthritis: results of a randomized controlled trial. Osteoarthritis Cartilage. 2018 Mar;26(3):383–96.

19. Alasfour M, Almarwani M. The effect of innovative smartphone application on adherence to a home-based exercise programs for female older adults with knee osteoarthritis in Saudi Arabia: a randomized controlled trial. Disabil Rehabil. 2022 Jun;44(11):2420–7.

20. Allen KD, Woolson S, Hoenig HM, Bongiorni D, Byrd J, Caves K, et al. Stepped Exercise Program for Patients With Knee Osteoarthritis : A Randomized Controlled Trial. Ann Intern Med. 2021 Mar;174(3):298–307.

21. Bennell KL, Nelligan R, Dobson F, Rini C, Keefe F, Kasza J, et al. Effectiveness of an Internet-Delivered Exercise and Pain-Coping Skills Training Intervention for Persons With Chronic Knee Pain: A Randomized Trial. Ann Intern Med. 2017 Apr 4;166(7):453–62.

22. Bennell KL, Nelligan RK, Rini C, Keefe FJ, Kasza J, French S, et al. Effects of internet-based pain coping skills training before home exercise for individuals with hip osteoarthritis (HOPE trial): a randomised controlled trial. Pain. 2018 Sep;159(9):1833–42.

23. Gohir SA, Eek F, Kelly A, Abhishek A, Valdes AM. Effectiveness of Internet-Based Exercises Aimed at Treating Knee Osteoarthritis: The iBEAT-OA Randomized Clinical Trial. JAMA Netw Open. 2021 Feb 1;4(2):e210012.

24. Pelle T, Bevers K, van der Palen J, van den Hoogen FHJ, van den Ende CHM. Effect of the dr. Bart application on healthcare use and clinical outcomes in people with osteoarthritis of the knee and/or hip in the Netherlands; a randomized controlled trial. Osteoarthritis Cartilage. 2020 Apr;28(4):418–27.

25. Williams QI, Gunn AH, Beaulieu JE, Benas BC, Buley B, Callahan LF, et al. Physical therapy vs. internet-based exercise training (PATH-IN) for patients with knee osteoarthritis: study protocol of a randomized controlled trial. BMC Musculoskeletal Disorders. 2015 Sep 28;16(1):264.

26. Skrepnik N, Spitzer A, Altman R, Hoekstra J, Stewart J, Toselli R. Assessing the Impact of a Novel Smartphone Application Compared With Standard Follow-Up on Mobility of Patients With Knee Osteoarthritis Following Treatment With Hylan G-F 20: A Randomized Controlled Trial. JMIR Mhealth Uhealth. 2017 May 9;5(5):e64.

27. Patten RK, Tacey A, Pile R, Parker A, De Gori M, Tran P, et al. Digital self-management interventions for osteoarthritis: a systematic scoping review of intervention characteristics, adherence and attrition. Archives of Public Health. 2022 Mar 31;80(1):103.

28. Bossen D, Veenhof C, Van Beek KE, Spreeuwenberg PM, Dekker J, De Bakker DH. Effectiveness of a Web-Based Physical Activity Intervention in Patients With Knee and/or Hip Osteoarthritis: Randomized Controlled Trial. J Med Internet Res. 2013 Nov 22;15(11):e257.

29. Trudeau KJ, Pujol LA, DasMahapatra P, Wall R, Black RA, Zacharoff K. A randomized controlled trial of an online self-management program for adults with arthritis pain. J Behav Med. 2015 Jun;38(3):483–96.

30. Michie S, Richardson M, Johnston M, Abraham C, Francis J, Hardeman W, et al. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. Ann Behav Med. 2013 Aug;46(1):81–95.

31. Smith R, Michalopoulou M, Reid H, Riches SP, Wango YN, Kenworthy Y, et al. Applying the behaviour change wheel to develop a smartphone application 'stay-active' to increase physical activity in women with gestational diabetes. BMC Pregnancy Childbirth. 2022 Mar 26;22:253.

32. Wagner AL, Keusch F, Yan T, Clarke PJ. The impact of weather on summer and winter exercise behaviors. J Sport Health Sci. 2019 Jan;8(1):39–45.

33. Webb J, Peel J, Fife-Schaw C, Ogden J. A mixed methods process evaluation of a print-based intervention supported by internet tools to improve physical activity in UK cancer survivors. Public Health. 2019 Oct;175:19–27.

34. Thorup CB, Grønkjær M, Spindler H, Andreasen JJ, Hansen J, Dinesen BI, et al. Pedometer use and self-determined motivation for walking in a cardiac telerehabilitation program: a qualitative study. BMC Sports Sci Med Rehabil. 2016 Aug 18;8:24.

35. Howlett N, Schulz J, Trivedi D, Troop N, Chater A. A prospective study exploring the construct and predictive validity of the COM-B model for physical activity. J Health Psychol. 2019 Sep;24(10):1378–91.

36. Domin A, Spruijt-Metz D, Theisen D, Ouzzahra Y, Vögele C. Smartphone-Based Interventions for Physical Activity Promotion: Scoping Review of the Evidence Over the Last 10 Years. JMIR Mhealth Uhealth. 2021 Jul 21;9(7):e24308.

37. National Institute of Health and Care Excellence. Behaviour change: individual approaches. Guidance. NICE, London (2014). Available from: https://www.nice.org.uk/guidance/ph49

38. Perneger TV. What's wrong with Bonferroni adjustments. BMJ. 1998 Apr 18;316(7139):1236–8.