Internet Interventions 38 (2024) 100766

Contents lists available at ScienceDirect

Internet Interventions

journal homepage: www.elsevier.com/locate/invent

A web step-based digital solution's impact on physical, cognitive and psychosocial functioning of community-dwelling older adults: A mixed methods randomized and controlled trial

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ARTICLE INFO

Keywords:
Older adults
eHealth
Digital health
Physical functioning
Cognitive functioning

ABSTRACT

Background: As the population ages, innovative responses are urgently needed to promote physical activity at scale. Thus, this study investigated whether a step-based activity mediated by a digital solution impacts the physical functioning of community-dwelling older adults. The secondary aims were to assess whether the same activity impacts cognitive and psychosocial functioning and explore participants' views towards the activity.
Methods: A mixed method, randomized, and controlled study with one group performing a step-based activity using DanceMove (recommended dosage: twice a week for 20 to 30 min for eight weeks) and the other their usual activities. DanceMove was used at the individuals' homes without any direct supervision. Clinical tests and questionnaires administered in person were used to assess participants at baseline, post-intervention, and three-month follow-up. The primary outcome of interest was gait velocity. Secondary outcomes were balance, pain intensity, cognitive functioning, self-efficacy, social support, loneliness, and quality of life. Also, at the end of the intervention, a semi-structured individual interview was conducted with participants in the experimental group.
Results: Seventy participants were randomized to the control ($n = 37$) and experimental ($n = 33$) groups. Of the 33 participants in the experimental group, four did not use the DanceMove at all and two used it for only 3 min. The remaining 26 participants used it for a total time over the eight weeks that varied between 15 and 991 min (mean ± SD = 306.55 ± 258.83 min). The step-based activity was not more effective than usual activities for any of the variables assessed ($P > .05$). Difficulties, positive and negative aspects regarding the digital solution, and reasons for not using it were identified in the interviews.
Conclusions: Eight weeks of a step-based activity mediated by a digital solution did not impact the physical, cognitive, and psychosocial functioning of community-dwelling healthy older adults. However, the activity was enjoyable and safe to be performed at home without direct supervision. Further studies are needed to explore aspects that could modulate the impact of this type of technology-mediated activity.
Trial registration: The study was registered at clinialtrials.gov (NCT 05460039) before the enrolment of the first participant.

Abbreviations: Cont., Control group; EQ-5D, EuroQol-5 Dimension; Exp., Experimental group; FRT, Functional Reach Test; GSES, General Self-Efficacy Scale; ICC, Intraclass Correlation Coefficient; m/s, meters per second; NPRS, Numeric Pain Rating Scale; s, seconds; TMT, Trail Making Test; OSSS, Oslo Social Support Scale.

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https://doi.org/10.1016/j.invent.2024.100766
Received 2 May 2024; Received in revised form 9 August 2024; Accepted 15 August 2024
Available online 21 August 2024

1. Introduction

The ageing of the population is a global phenomenon with associated impairments posing major challenges to the sustainability of the health and social care systems (World Health Organization, 2022). The number of people aged 65 and over has been increasing steadily and is expected to reach 1.5 billion by the year 2050 (United Nations, 2019). Ageing is associated with a higher prevalence of a range of diseases including dementia, cardiovascular and musculoskeletal diseases, which are also negatively associated with older adults' physical, cognitive, and psychological functioning (Trevisan et al., 2019; Costantino et al., 2016; Johnson and Hunter, 2014). Impairments in these domains limit older adults' opportunities for a fulfilling engagement in social, cultural, and intellectual activities (Jin, 2014).

Research has highlighted the benefits of physical activity in reducing the prevalence of common chronic conditions as well as their negative impact on all domains of functioning (Zhu et al., 2016; Szychowska and Drygas, 2022). Nevertheless, only 55,5 % of European older adults exercise regularly and meet the World Health Organization recommendations (Northey et al., 2018). Conceivably, identifying pleasant ways of performing physical activity and exercise may help older adults achieve the recommended levels.

Technology can be used to promote the practice of diverse physical activity types, including dance or stepping (Studenski et al., 2010; Smith et al., 2011). Dance has positive effects on cognitive (Yuan et al., 2022), physical (Liu et al., 2021), and psychosocial (Ho et al., 2018) functions. Older adults perceive dance mediated by technology as having several motor benefits (e.g., greater ease of movement) (Hansen et al., 2024) and non-motor benefits (e.g., reduced stress/anxiety, increased energy, or improved concentration) (Bek et al., 2022). It also enhances balance (Yoong et al., 2024a). Dance or stepping mediated by technology is a complex task that combines visual and auditive stimulation and allows dual-task training for cognitive and physical function (Yoong et al., 2024b; Pichierri et al., 2012; Eggenberger et al., 2016), which seems to have a larger effect on physical and cognitive functioning than single-task training (Ali et al., 2022; Ercan Yildiz et al., 2024). Also, dual-task training may be associated with greater improvements in brain neuronal activity (Wu et al., 2023).

Previous studies using step-based activities mediated by technology show conflicting results: a few suggest a positive impact on the cognitive (Eggenberger et al., 2015; Schoene et al., 2015; Gschwind et al., 2015) and/or the physical function of older adults (Pichierri et al., 2012; Gschwind et al., 2015; Schoene et al., 2013), while others report no impact on these functions (Song et al., 2018; Sturnieks et al., 2024). However, only a few of these studies assessed the independent use of the technology by community-dwelling older adults at their homes (Schoene et al., 2015; Song et al., 2018; Sturnieks et al., 2024). This is particularly relevant as one of the advantages of technology is to allow individuals the freedom and flexibility to integrate physical activity into their daily routines, maximizing the potential for behaviour change (Riffenburg and Spartano, 2018) and minimizing the burden on health services. However, the independent use of technology also poses challenges, including the potential for lower adherence to the intervention due to low accountability (Christensen et al., 2022) and support (Song et al., 2018) from a health professional.

This study's primary aim was to investigate whether a step-base activity mediated by a digital solution (DanceMove) impacts the physical functioning of community-dwelling older adults. Secondary aims were i) to assess whether the same activity impacts cognitive functioning and psychosocial functioning and ii) to explore participants' views towards the digital solution and the step-based activity.

2. Methods

2.1. Ethics and study design

This is a mixed-methods, randomized, and controlled study. It was approved by the Ethics and Deontological Council of the University of Aveiro (27-CED/2022). All participants gave their written and informed consent in the presence of the researcher and after having access to written information on the study and having the opportunity to ask questions by phone, email, or in person. The study was registered at clinialtrials.gov (NCT 05460039) before the enrolment of the first participant.

2.2. Recruitment, eligibility criteria, and sample size

Participants were individuals aged 60 years or older living independently in the community. They were recruited at different Municipalities across Portugal and through advertisements on social media. They were included if they had no cognitive impairment, based on the results of the six-item cognitive screening test (i.e., to be included in the study participants needed to score less than eight on this test) (Abdel-Aziz and Larner, 2015) and reported no history of recent falls and no usual dizziness. The Portuguese version of the six-item cognitive screening test has a sensitivity of 82.78 % and a specificity of 84.84 % (Apóstolo et al., 2018). Participants with cardiovascular disease, with a history of falls or dizziness, or who used a walking aid were excluded to minimize the odds of adverse events (e.g., falls). For practical reasons, individuals with no access to the Internet or no computer were also excluded.

The sample size was calculated using G*Power (3.1.9.7) and the following specifications: a repeated-measures ANOVA with within-between subjects' interactions, an effect size of 0.25, power at 95 %, and alpha at 5 % and considering three measurement points (baseline, post-intervention and follow up) and a correlation among repeated measures of 0.5. This resulted in a total sample of 44 participants (22 in each group), which was added by 25 % to account for potential losses to follow-up, resulting in the need to recruit at least 31 participants in each group.

The effect size for sample size calculation was informed by a subgroup analysis conducted as part of a systematic review being undertaken by our group and not yet published (Stefane et al., 2023). The subgroup analysis used 6 studies that compared an interactive digital solution implicating physical and cognitive skills against usual activities and that used as an outcome of interest the gait velocity, the Timed Up and Go, or a similar test. Of the 6 studies, 4 used a step-based activity. The loss to follow-up rate of 25 % is an informed guess resulting from our experience in previous work with older adults and technology, being higher than that reported by a few previous studies by other research teams (van den Helder et al., 2020; Casuso-Holgado et al., 2023).

2.3. Randomization and concealed allocation

Participants were randomized to study groups on a ratio of 1:1 (intervention or control) using Research Randomizer (https://www.randomizer.org/) by a researcher not involved in the participants' recruitment. Sequentially numbered, opaque, sealed envelopes opened after baseline assessment were used to register the generated sequence.

2.4. Assessment of outcomes

Participants were characterized in terms of age, sex, total number of years of education, and comorbidities (e.g., depression, diabetes, osteoarthrosis, respiratory conditions), using a purposively developed questionnaire. The remaining outcomes were assessed using existing instruments as detailed below. All assessments were performed in person.

2.4.1. Gait velocity test (primary outcome)

Gait velocity was assessed using the four-meter gait velocity test. Participants were required to walk 4 m in a straight line at their normal pace. They were positioned immediately before a mark on the floor signalling the beginning of the path and the timer was started when the participant began walking and stopped when the foot passed the mark signalling the end of the path. The time was measured in seconds and the velocity in meters per second (m/s). A first trial not considered for measurement purposes was allowed and then the test was repeated three times. The mean of these three measurements was considered for statistical analysis. A systematic review concluded that this test is valid and reliable (Intraclass Correlation Coefficient - ICC values generally above 0.90 for intra and inter-rater reliability) (Muñoz-Mendoza et al., 2010).

2.4.2. Functional Reach Test (FRT)

This test was performed with the participant standing near a wall (but not touching it), shoulder on the side of the wall at 90° flexion, elbow extended, hand in a fist, and holding a pen (to facilitate measurements). A tape measure was fixed on the wall at shoulder height. Participants were instructed to perform maximal forward reach without moving their feet. An assessor recorded the starting and ending position, using the pen to facilitate the readings on the tape measure. The difference between the starting and ending positions was taken in cm. A first trial not considered for measurement purposes was allowed and then the test was repeated three times. The mean of these measurements was considered for statistical analysis. This test has high reliability (ICC = 0.83) in older adults without cognitive impairment (Ferreira et al., 2021).

2.4.3. Trail Making Test (TMT)

The Trail Making Test consists of two parts, A and B, each timed separately. Part A asks participants to draw a line connecting the numbers in order, starting at number 1, and ending at number 25. For part B, ordered numbers and letters are connected alternately (e.g. 1 – A – 2 – B - 3 – C…). When an error occurred, this was brought to the participant's attention who was prompted to correct it. Each of the tests was timed with a chronometer. The test stopped when the participant reached the end of the task, or the maximum time allowed for its execution (100 seconds for part A and 300 seconds (s) for part B). A familiarization trial was allowed for each test. TMT provides information on visual search, scanning, speed of processing, mental flexibility, and executive functions (Tombaugh, 2004).

2.4.4. Pain intensity

Participants were assessed for the presence of pain during the last week and when present, its intensity was assessed using a vertical Numeric Pain Rating Scale (NPRS), ranging from 0 (no pain) to 10 (worst imaginable pain). The NPRS is reliable (ICC = 0.82; 95 % confidence interval [CI] = 0.72; 0.89) (Silva et al., 2021) and recommended by the Royal College of Physicians, British Geriatrics Society and British Pain Society to assess pain intensity in older adults (Royal College of Physicians et al., 2007).

2.4.5. General Self-Efficacy Scale (GSES)

This is a 10-item scale designed to assess optimistic self-beliefs to cope with a variety of difficult demands in life (Schwarzer and Jerusalem, 1995). Each item refers to successful coping and implies an internal-stable attribution of success. Responses are given on a 4-point scale. The total score is calculated by the sum of the responses to all 10 items, ranging between 10 and 40, with higher values indicating higher levels of self-efficacy. The scale is reliable and valid (Schwarzer and Jerusalem, 1995).

2.4.6. Oslo Social Support Scale (OSSS-3)

The OSSS-3 comprises three items that inquire about the number of close confidants, the sense of concern from other people, and the relationship with neighbours, with a focus on gauging how readily available and accessible practical support is within one's social network. The total score results from the sum of the individual scores and ranges from 3 to 14, with higher values representing stronger levels of social support (Kocalevent et al., 2018).

2.4.7. The University of California, Los Angeles, Loneliness Scale

The 6-item version of this scale was used. Each item is answered on a 4-point Likert scale; the total score varies between 6 and 24 points, with higher scores indicating higher loneliness. The scale has satisfactory measurement properties (Neto, 2014).

2.4.8. Health-related quality of life measured by the EQ-5D

The EQ-5D assesses health-related quality of life (Rabin and De Charro, 2001). It comprises 5 dimensions of health (mobility, self-care, usual activities, pain/discomfort, and anxiety/depression), with 5 statements (each statement corresponds to a level, and they vary from level 1 – no problem to level 5 - indicating unable to/extreme problems) within each domain (Grandy and Fox, 2008). Participants are asked to choose the statement that best describes their health. Levels are scored from 1 to 5 and a unique health state is defined by combining one level from each of the five dimensions. The EQ-5D summary index is derived by applying a formula that attaches values (weights) to each level in each dimension and varies from country to country. The normative weights for the Portuguese population were used. The Portuguese version of the EQ-5D questionnaire has good reliability and validity (Ferreira et al., 2023).

2.4.9. System Usability Scale (SUS)

The SUS assesses usability from the perspective of the user and consists of 10 individual items, each scored on a 5-point Likert scale. The final score ranges from 0 to 100, with higher values indicating better usability. Odd and even items are scored differently: (i) for odd items, a point from the user response is subtracted; (ii) for even items, five points are added and then subtracted from the value associated with the user response. The scores of all individual items are added and multiplied by 2.5. Higher scores are indicative of higher usability (Martins et al., 2015). SUS was used only at post-intervention.

All outcomes were assessed by a researcher who was not blind to the participants' group. We planned to include the World Health Organization Quality of Life (WHOQOL-BREF) questionnaire, but its results are not reported due to missing answers on a few items.

2.4.10. Interviews

In-person, individual semi-structured interviews were conducted with participants in the experimental group at post-intervention. Interviews were conducted by AIM, a Gerontologist with expertise in conducting interviews with older adults. The interview guide aimed to capture participants' experiences using the digital solution and covered aspects of its usage and perceived impact on the individuals and their routines (Please see Supplementary material 1 for the interview script). For those who did not use the digital solution or used it less than recommended, the reasons associated with their choices were explored.

2.5. Intervention versus control

2.5.1. Control group

The control group received no intervention and was advised to continue activities as usual.

2.5.2. Intervention group

The intervention group was given a stepping mat and access to the digital solution (the DanceMove). At the baseline assessment, a shortcut link to the digital solution was added to the desktop of each participant's computer and they were explained and trained on how to use it. All participants were recommended to use the solution between 20 and 30 min, three times per week, during eight weeks.

The DanceMove was a web-based interface accessed using a username and pin that connects to an external device (a commercial stepping mat). It can be accessed at http://deca-dancemove.ua.pt/ through a login and password). Participants could choose a piece of music from a pool of available music and request researchers for additional music. Participants were on the centre of a mat that mimicked the computer's interface and had to step onto the mat's arrow that appeared on the screen of the computer as the music was played (Figs. 1 and 2). Music was available in three levels of difficulty - the difference between levels of difficulty was the number and velocity of arrows that appeared on the screen, which increased with the level of difficulty. At the end of each music, a score was given that corresponded to the percentage of arrows stepped at the right moment.

A phone call was made to each participant every two weeks to i) ascertain whether the participant encountered any difficulties using the solution, ii) encourage the participant to engage in the intervention, iii) inquire about any adverse event due to the use of the digital solution and iv) give participants the possibility to ask for additional music. Technical issues, which were infrequent, were managed by the research team. These mostly comprised challenges related to the low digital literacy of the participants (4 participants), the malfunctioning of the mat (1 participant), and Internet connection issues (3 participants).

2.5.3. Intervention adherence

Adherence and retention were assessed by the frequency and total time spent using the digital solution and the number of participants who dropped out before intervention completion, respectively.

2.6. Data analysis

2.6.1. Statistical analysis

Participants' characteristics at baseline were summarized using descriptive statistics. We used an intention-to-treat analysis to examine the treatment effect for all outcome measures based on group randomization. Groups were compared using linear mixed models for repeated measures. Covariance types of compound symmetry, first-order autoregressive, and variance components were considered as well as different effects (time and group only; time, group, sex and age; time, group, sex, age and baseline values). The final model included treatment (intervention vs. control), time (3 measurement points: i) baseline, ii) post-intervention and iii) 3-month follow-up), treatment by time interaction, age, sex, and baseline values as fixed effects, and subject as a random effect using the variance components as the covariance structure. This model was selected because it obtained the lowest Akaike's Information Criterion (AIC) value, compared to other models. A subgroup exploratory analysis for the experimental group, comparing

Fig. 1. DanceMove main screen.

Fig. 2. The setup for performing the step-based activity with the mat connected to the DanceMove (this is a picture taken at our laboratory).

participants who used the DanceMove for longer than the mean usage time of the whole group and participants who used it less was performed for the physical (Gait test Velocity and Functional Reach Test) and cognitive (Trail Making Test A and B) variables. An independent sample *t*-test was used for this comparison. The significance level was set at $p < .05$ for all comparisons. This subgroup exploratory analysis was performed only for the physical and cognitive variables because i) due to the nature of the intervention, it was expected that the impact would be on variables directly related to physical and cognitive function and ii) this analysis was not pre-planned.

Data analysis was performed using the Statistical Package for the Social Sciences (IBM, New York).

2.6.2. Content analysis

Interviews were transcribed verbatim. Qualitative data was analysed using inductive content analysis aligned with the approach suggested by Bengtsson (Bengtsson, 2016). An experienced researcher (AGS) read through the transcripts several times, identified meaning units, and aggregated these into groups of units with similar meanings. Each group of meaning units was labelled with a code. Similar codes were aggregated into subcategories and subcategories that were related were aggregated into categories. This process of attributing codes and organizing them into categories and subcategories was reviewed several times. The coding scheme was then reviewed by another researcher (AIM). Both researchers discussed the coding of each unit of significance and a consensus scheme of categories and subcategories was adopted. In addition, the number of participants making statements aggregated into each subcategory was counted.

3. Results

3.1. Participants' enrolment and baseline characteristics

Of 92 individuals screened, 18 were excluded because they did not meet the eligibility criteria (five had no Internet connection at home, 10 had no personal computer, and three had a recent history of falls and dizziness); four did not want to be included in the study. Therefore, 70 participants entered the study and were assessed at baseline and randomized to one of the two groups (experimental: $n = 33$; control: $n = 37$). The percentage of females was 79 % ($n = 26$) in the experimental group and 66 % (n = 25) in the control group; the percentage of those married/living together was 64 % in the experimental group and 65 % in the control group. Four participants (one in the control group and three in the experimental group) dropped out from the study before the post-intervention assessment took place due to: i) health problems unrelated to the study (n = 1), ii) lack of interest in the study (n = 2), and iii) dead (n = 1). Please see Table 1 for a detailed sample characterization and Fig. 3 for the trial flowchart.

3.2. Use of the DanceMove and perceived usability

Of the 33 participants in the experimental group, four did not use the DanceMove at all and two used it for only 3 min. The remaining 26 participants used it for a total time over the eight weeks that varied between 15 and 991 min (mean ± SD = 306.55 ± 258.83 min). Participants using the DanceMove and who also filled the SUS (n = 22; data missing from 4 participants) considered the digital solution to have good usability (minimum score out of 100 was 80: mean ± SD = 91.25 ± 4.93).

3.3. Effect of the intervention

3.3.1. Gait velocity

The DanceMove was not more effective than usual activities for gait velocity (Table 2) and there was no main effect of time ($P > .05$).

3.3.2. Secondary variables

There was a main effect of time for the Functional Reach Test, the TMT A, and the Self-Efficacy Scale suggesting an improvement, but no interaction between time and group (Table 2). No significant effect was found for any of the remaining variables.

A complete case analysis (i.e., the analysis only included participants for which we had no missing data) comparing participants who performed the stepping intervention for longer than the whole mean of the group and those who used it for lower than the whole group mean for the physical and cognitive outcomes did not show any statistical significance (Table 3).

Table 1
Sample characteristics at baseline.

Characteristic	Group	n	Mean (SD)
Age (years)	Control	37	71.59 (4.83)
	Experimental	33	67.85 (4.40)
Formal education (years)	Control	37	8.78 (4.88)
	Experimental	33	12.18 (4.79)
Comorbidities (number)	Control	37	1.78 (1.60)
	Experimental	33	1.73 (1.77)
Painful body sites (number)	Control	22[a]	1.59 (0.85)
	Experimental	19[a]	1.79 (2.07)
Numeric Pain Rating Scale (0–10)	Control	22[a]	4.66 (1.69)
	Experimental	19[a]	4.63 (2.09)
Trail Making Test A (seconds)	Control	37	46.83 (22.87)
	Experimental	32	34.45 (16.39)
Trail Making Test B (seconds)	Control	37	127.49 (69.92)
	Experimental	31	88.35 (54.83)
Gait Velocity Test (m/s)	Control	36	1.22 (0.23)
	Experimental	33	1.28 (0.26)
Functional Reach Test (cm)	Control	36	32.01 (5.19)
	Experimental	33	30.16 (8.30)
General Self-Efficacy Scale (10–40)	Control	37	30.27 (3.79)
	Experimental	33	31.72 (3.60)
Oslo Social Support Scale (3–14)	Control	37	7.24 (1.53)
	Experimental	33	7.24 (1.03)
The University of California, Los Angeles, Loneliness Scale (6–24)	Control	37	12.22 (2.92)
	Experimental	33	10.85 (3.59)
EQ-5D	Control	37	0.93 (0.09)
	Experimental	33	0.96 (0.04)

[a] For painful body sites, the numbers correspond to participants that reported pain in at least one body site and the NPRS (pain intensity) was also calculated only for these participants.

3.4. Interviews

Eighteen participants (four men) from the experimental group agreed to be interviewed. Interviews were audiotaped and lasted between 4 and 21 min (mean (SD) = 9.56 (5.09) minutes). From the data, six main categories were generated: i) difficulties accessing/using the digital solution external to the DanceMove; ii) aspects of the DanceMove that need/could be improved; iii) positive aspects of the DanceMove and of the experience it provided, iv) perceived impact of using DanceMove, v) perception of the physical demands of the stepping activity, and vi) reasons to use DanceMove less than recommended or not use it at all. Participants had difficulties accessing DanceMove because they had forgotten their password, did not have access to Internet, or had old computers. A few considered that the stepping activity was monotonous, that more music and music of different styles could be included in the DanceMove pool of music, and that there was a lack of association between the music rhythm and the frequency of arrows appearing on the computer screen. In contrast, most participants mentioned that DanceMove was easy to use, allowed for an enjoyable activity, appreciated the flexibility of using it at any time of the day, and the fact that it promoted a physical activity routine. DanceMove required the person to concentrate when using it, allowed the person to keep the mind away from worries, and facilitated the loss of weight and improvement of pain and flexibility. However, a few participants also reported that DanceMove had no perceived impact. Regarding the perceived exertion of the step activity, it was perceived by a few as somewhat hard/hard and by others as light. The reasons pointed out for not using or using DanceMove less than recommended included being absent from home or ill/injured during the study period, lack of time, and feeling demotivated or tired. Table 4 summarises the categories and subcategories and gives examples of participants' quotations.

4. Discussion

Our study found no significant differences between the group using the step-based digital solution for eight weeks and the group that did not and continued with their usual activities, suggesting that this activity performed in an uncontrolled environment has no impact on healthy community-dwelling older adults.

The characteristics of the sample, comprising healthy and active older adults with no major physical or cognitive impairments and high health-related quality of life, may help explain the results as the potential for improvement is low, particularly in a relatively short period such as eight weeks. Furthermore, and even though physical activity was not assessed, most participants in both groups already performed physical and cognitive activities as they were recruited through the municipality's services offering activities to older adults such as gymnastic, Pilates or crafting and music classes. Thus, the stepping activity promoted via de DanceMove was an additional activity adding to several other activities already being practiced. This can also explain the slight improvements found in both groups from the baseline to the post-intervention and/or follow-up for the Functional Reach Test, the TMT A test, and the General Self-Efficacy Scale. However, the generally low changes raise questions about its clinical relevance. Another potential explanation for the lack of between-group differences is the lower-than-recommended use of the DanceMove. Although caution is needed when interpreting the results, because the study was not powered for this analysis, the comparison of higher users against lower users does not seem to support this explanation.

Comparing our findings with previous studies that found an impact of stepping mediated by technology on cognitive or physical functioning, there are relevant differences that might explain the different results. Previous studies included older participants, had participants perform the stepping activity mediated by technology for longer and

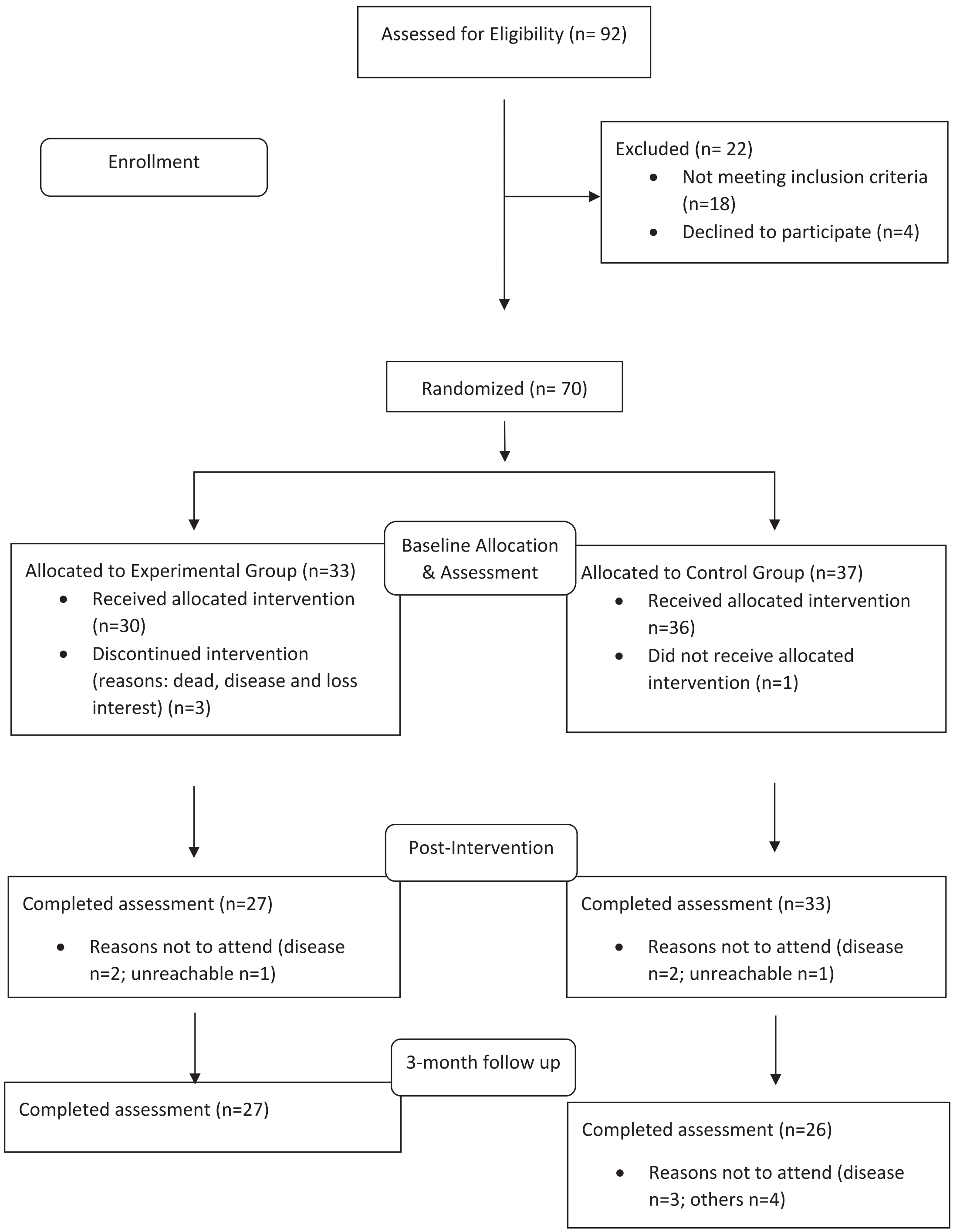

Fig. 3. Trial flowchart.

combined it with other types of exercise or other technology-mediated step-based activity and supervision. In the study of Eggenberger et al. (Eggenberger et al., 2015) participants were 70 years and older and the stepping activity was complemented with strength and balance exercises up to two 1-hour training sessions per week over 6 months. In the study of Gschwind et al. (Gschwind et al., 2015), adults were also older than 70 years old and the intervention consisted of 20 min of stepping mediated by technology for 16 weeks. Pichierri et al. (Pichierri et al., 2012) combined supervised stepping with progressive strength and balance training twice weekly for 12 weeks. Participants in the study of Schoene et al. (Schoene et al., 2015) were also older (mean age 81.5 ± 7) and the intervention consisted of 20-minute sessions including four different games for 16 weeks. Taken together, the current study findings and the previous study findings suggest that longer periods of use and higher dosage might be required for the step-based activity to have an impact on the physical, cognitive, or psychosocial functioning of older adults and its impact is likely to depend on the age and overall functioning of the individuals. Also, its combination with other interventions might bring additional benefits. Future studies should investigate whether these assumptions are verified.

Despite the absence of impact of the stepping activity found in the present study, the interviews suggest that the DanceMove is easy to use and promotes physical activity in a manner that most participants found enjoyable, and flexible to integrate into their routine as each person

Table 2
Estimated marginal means and 95 % confidence intervals for primary and secondary variables.

Variable	Group	Baseline	Post-intervention	Follow up	*P* value[#]		
					Group	Time	G*T
Gait Velocity (seconds)	Exp.	1.27 (1.22;1.33)	1.28 (1.22; 1.24)	1.25 (1.18; 1.31)	0.403	0.722	0.334
	Cont.	1.26 (1.21; 1.31)	1.29 (1.24; 1.34)	1.31 (1.25; 1.37)			
Functional Reach Test (cm)	Exp.	31.36 (29.79; 32.94)	34.88 (33.12; 36.64)	32.16 (30.40; 33.92)	0.347	0.014	0.191
	Cont.	32.08 (30.61; 33.55)	32.76 (31.21; 34.32)	31.52 (29.80; 33.24)			
Trail Making Test A (seconds)	Exp.	37.99 (35.41; 40.56)	35.12 (32.24; 38.03)	34.52 (31.52; 37.51)	0.941	<0.001	0.050
	Cont.	40.14 (37.72; 42.57)	36.69 (34.12; 39.26)	30.53 (27.70; 33.37)			
Trail Making Test B (seconds)	Exp.	102.12 (87.83; 116.40)	105.12 (89.02; 121.23)	100.91 (84.63; 117.18)	0.873	0.571	0.870
	Cont.	105.46 (92.09; 118.83)	108.39 (94.50; 122.29)	97.82 (82.59; 113.06)			
Vertical NPRS (0–10)	Exp.	2.51 (1.71; 3.30)	1.80 (0.93;2.67)	2.37 (1.50; 3.24)	0.560	0.489	0.308
	Cont.	2.68 (1.94; 3.41)	2.66 (1.88; 3.44)	1.96 (1.09; 2.81)			
Self-Efficacy Scale (10–40)	Exp.	31.21 (30.36; 32.05)	31.71 (30.79; 32.64)	31.84 (30.92; 32.77)	0.832	0.041	0.758
	Cont.	30.81 (30.03; 31.59)	31.83 (31.00; 32.64)	31.84 (30.95; 32.74)			
Loneliness Scale (6–24)	Exp.	11.29 (10.54; 12.03)	11.06 (10.24; 11.87)	12.30 (11.48; 13.12)	0.410	0.133	0.308
	Cont.	11.95 (11.04; 12.41)	11.83 (11.11; 12.56)	11.73 (11.16; 12.75)			
EQ-5D	Exp.	0.98 (0.94; 1.00)	0.97 (0.94; 1.00)	0.95 (0.91; 0.98)	0.205	0.358	0.111
	Cont.	0.94 (0.91; 0.97)	0.93 (0.90; 0.96)	0.94 (0.91; 0.98)			
Oslo Social Support Scale (3–14)	Exp.	7.11 (6.73; 7.50)	7.23 (6.81; 7.66)	7.04 (6.62; 7.46)	0.650	0.521	0.947
	Cont.	7.13 (6.77; 7.48)	7.35 (6.98; 7.73)	7.15 (6.74; 7.57)			

Legend: NPRS – Numeric Pain Rating Scale; Exp. – Experimental group; Cont. – Control group.
[#] Baseline values were significant predictors of the results at $P < .001$ for all variables except E5DQ; Sex was also a significant predictor ($P < .05$) of the results for: gait velocity ($P = .020$), EQ-5D ($P = .049$), Functional Reach Test ($P = .003$), NPRS ($P = .017$), and Oslo Social Support Scale ($P = .005$). Age was not a significant predictor of the results, $P > .05$).

Table 3
Experimental within-group comparisons: use of the digital solution above and below the mean (results presented as mean and standard deviation).

Variable	Group	n	Baseline	Post-intervention	Follow up	P value
Gait Velocity (m/s)	Below	14	1.28 (1.13; 1.43)	1.28 (1.17; 1.39)	1.25 (1.11; 1.39)	0.993
	Above	10	1.34 (1.17; 1.52)	1.33 (1.21; 1.46)	1.32 (1.15; 1.48)	
Functional Reach Test (cm)	Below	14	32.53 (28.47; 36.59)	36.59 (33.90; 39.27)	33.07 (29.90; 37.25)	0.875
	Above	10	27.23 (22.43; 32.04)	30.62 (27.45; 33.80)	28.70 (23.76; 33.64)	
TMT A (seconds)	Below	12	32.98 (23.85; 42.12)	31.12 (25.02; 37.21)	31.06 (23.79; 38.32)	0.934
	Above	10	29.93 (18.93; 38.94)	28.40 (21.72; 35.07)	27.74 (19.78; 35.69)	
TMT B (seconds)	Below	13	76.14 (52.97; 99.32)	86.13 (56.49; 115.49)	78.36 (55.70; 101.02)	0.660
	Above	10	75.48 (49.06; 101.91)	74.18 (40.39; 107.97)	79.96 (54.12; 105.79)	

could use it when it was most convenient and that can also be used to promote interactive moments with others (e.g., family). Participants also found that it promoted attention, focus, and concentration. Also, no adverse events were registered during the trial, suggesting that the activity is safe to perform if careful advice is given to participants as was the case in this trial. Nevertheless, a few issues arose that could explain the lower-than-recommended use of DanceMove. Some of these issues were unrelated to the technology and were due to old computers and the low digital literacy skills of the participants. The research team was able to assist with the latter due to close monitoring of individuals. Other reasons external to the technology and study were being away from home, lack of time, and disease. These have also been identified in previous studies (Forsat et al., 2020). Nevertheless, an effort was made to consider participants' scheduled commitments before their inclusion in the study. For example, if the researcher was informed of a planned absence from home, the participant would be scheduled to be included in the study only when the absence ended. Concerning the issues related to the DanceMove, it was found to be monotonous, and a few participants also pointed out that they would have enjoyed having more music or a different type of music. The first aspect could be solved by including more activities/games within the same digital solution. On what regards more choice of music, participants had the option to ask for any music they wanted on the bi-weekly telephone calls. This possibility needs to be emphasized in future studies.

4.1. *Research and practice implications*

Future studies should explore whether factors such as dose, type of

Table 4
Summary of the categories and subcategories extracted from the individual interviews, supporting quotations and number of participants that provided data for each sub-category.

Category	Sub-category	N	Example of quotations
Participants report difficulties accessing/using the digital solution external to the DanceMove	Participants report difficulties accessing the digital solution	5	"One day I forgot the password, but I sent you [the researcher] an email and you helped me."
	Participants own very old computers that did not allow them to use DanceMove	3	"At first, I only did it at my neighbour's house because my computer is too old for the DanceMove…".
	Participants report problems accessing the Internet	5	"I had an Internet issue because they cut the cable in my building, and since then I haven't been able to use the mat [DanceMove], which makes me very upset."
Aspects of the DanceMove that need/could be improved	The activity was repetitive/ monotonous	6	"It was a bit repetitive, always doing the same thing; it starts to get tiring."
	Need for more music or a different type of music	4	"…in the end, I knew the songs by heart, maybe there could be more songs because, as I did them one after the other, it was starting to become repetitive."
	Lack of direct association between the rhythm of the music and the frequency of arrows	2	"…sometimes … I would make mistakes because the music doesn't always match the arrows. I would say to myself, "Why are you going to the rhythm of the music? You have to go at the rhythm of the arrows!""
Positive aspects of the DanceMove and the experience it provided	DanceMove was easy to use and provided a positive experience	12	"It was easy to set up at home."
	Using DanceMove was an enjoyable activity	10	"The impact it had on my life is that I exercised with satisfaction. I mean, I enjoy walking alone, but listening to music and doing exercise that depends on me, gave me an extra sense of satisfaction. I really liked it; for me, it's fun. I love dancing."
	Participants appreciated the flexibility of using DanceMove at any time of the day	12	"I used it every day, only skipping when I didn't have Internet. I did it at any time of the day—sometimes in the morning, sometimes in the afternoon."
	Participants recognised that DanceMove promotes a physical activity routine	8	"The strong point is that we give movement to our legs. A lot of movement, it's good for that. We are there back and forth, and it's good for that."
	Participants appreciated the possibility of the involvement of family members	3	"… I used it with my family as everyone was enthusiastic and wanted to improve from the first to the second level or from the second to the third. It was a kind of competition."
Participants' perceived impact of using DanceMove	Participants recognise that using DanceMove improves and/or requires attention, focus and/or concentration	9	"One thing I felt was that being very unfocused I started to pay more attention because there you have to be focused; your attention has to be there, and I felt that."
	Participants recognise that using DanceMove keeps the mind away from one's problems	2	"No… I would sometimes get distracted. I think the mat is good. It worked well for me, almost like meditation because while doing it, you don't think about other things. … But ultimately, the mat [DanceMove] forces us to focus on that and only that. It's almost like meditation, with the goal of not thinking about anything else, emptying the mind."
	Using DanceMove contributes to lose weight	1	"I feel that it's very effective; I even feel like I've lost weight. If I were more consistent and did it twice a day, I think I would lose a lot of weight!"
	Using DanceMove contributes to decreasing pain intensity	1	"When I started, I had a little pain in my left leg, perhaps due to a lack of exercise, and now I feel it's better, so the impact might have been in that aspect."
	Using DanceMove improves agility	1	"I became more agile; how can I explain? It does the leg movements well; I think it's good for blood circulation."
	Participants believe that using DanceMove has no impact on them because they perform more demanding activities	2	"I engage in more intense physical activity. I think this [DanceMove] was more [targeted] for those who are less active. I grab a hoe in the morning and put it down at noon; I have a plot of land that's 80 m by 15, which gives me a good workout. Just yesterday, I was harvesting potatoes, and I picked them all with a hoe."
Participants' perception of the physical demands of the stepping activity	Participants perceive the use of DanceMove as a physically demanding activity	6	"… it worked the legs because you're standing with one leg supporting the weight, and with the other, you have to move side to side and hit the right spots, so the leg muscles end up… well."
	Participants perceive the use of DanceMove as light physical activity	2	"And physically, it's not possible to get tired unless you do it many times in a row on the most difficult setting, but I've never tried that."
Reasons to use DanceMove less than recommended or not use it at all	Participants were absent from home during the study	2	"I regret not having done more. I was away from home for two weeks, and then when I thought about starting again on the 24th, which was when I returned, that's

(continued on next page)

Table 4 (*continued*)

Category	Sub-category	N	Example of quotations
			when I fell ill and had to stay in bed. Even yesterday, while folding it [the mat], I thought about practicing a bit, but I'm still not well, wasn't in the right frame of mind."
	Participants lacked the time to use DanceMove due to other activities	4	"I just didn't have many opportunities to do it because I would get phone calls that interrupted me, or I was busy. On the days I managed to do it, it was okay."
	Participants did not use DanceMove because they got ill/ injured during the study	2	"But in the end, I gave up on the mat. I had that injury, and then I went to Algarve without taking it, and eventually, I didn't continue."
	Participants felt demotivated due to lower scores	3	"I enjoyed it, but sometimes I would get irritated with myself. I always wanted to score 100, and sometimes I would get 98, sometimes 99."
	Participants gave up using DanceMove because they felt the activity was tiring	2	"I found the most difficult level more interesting; it was much more engaging, and it allowed for more movement. However, it was also at this level that I started giving up because it was where I got more tired."

technology, and baseline participants' characteristics impact the effect of step-based activities mediated by technology, what is the adequate dose, whether the minimum dose to have an impact is similar for both physical and cognitive functioning and who would benefit the most from performing this type of activity. Step-based activities mediated by technology can be performed safely by healthy community-dwelling older adults without supervision and can be used to promote physical activity. However, professionals who recommend its use should consider that, in the short term and when used as the only strategy, it may not impact physical or cognitive functioning. Using it as part of a broader intervention might be a possibility.

4.2. Limitations

The findings of this study should be interpreted considering its limitations. The data collection was not blinded. However, non-blinding of participants tends to exaggerate the effect sizes (Hróbjartsson et al., 2014), and this is unlikely to be a relevant issue in the current study as no between-group differences were found. Participants were relatively healthy and active and, therefore, findings may not apply to less active, frail older adults or older adults with specific diseases. However, physical activity was not assessed, and we cannot quantify the activity level of participants. The lower-than-recommended use of the technology, by a percentage of participants, may have contributed to the absence of between-group differences. However, we believe that the pattern of usage of the digital solution in the present study reflects what would happen in the real world.

5. Conclusions

Eight weeks of a technology-mediated step-based activity showed no significant impact on the physical, cognitive, and psychosocial functioning of community-dwelling healthy and active older adults. However, the activity demonstrated the potential to be performed at home without direct supervision with no reported adverse events. Moreover, most participants found it to be an enjoyable means of promoting physical activity.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.invent.2024.100766.

Funding

This work was supported by the SHAPES (Smart and Health Ageing through People Engaging in Supportive Systems) project funded by the Horizon 2020 Framework Program of the European Union for Research Innovation (grant agreement 857159 - SHAPES – H2020 – SC1-FA-DTS – 2018–2020). Authors AGS, AIM, TS, OR, GS and NPR were all part of the SHAPES project within University of Aveiro. SHAPES was a consortium of 36 partners coordinated by NATIONAL UNIVERSITY OF IRELAND MAYNOOTH. The funders did not play any role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Anabela G Silva reports financial support was provided by SHAPES (Smart and Health Ageing through People Engaging in Supportive Systems) project funded by the Horizon 2020. All authors report a relationship with SHAPES (Smart and Health Ageing through People Engaging in Supportive Systems) project funded by the Horizon 2020 that includes: funding grants. Authors Anabela G Silva, Ana Isabel Martins, Telmo Silva, Óscar Ribeiro, Gonçalo Santinha, and Nelson P Rocha have a potential competing interest related to the fact that they also developed the step-based technology being assessed in the manuscript If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The accomplishment of this work would not have been possible without the participation of various municipalities and entities that facilitated access to the participants, notably: Câmara Municipal da Lourinhã; Câmara Municipal de Albergaria-a-Velha; Centro Comunitário Espaço Aberto, Ovar; Universidade Sénior Rotary Club de São João da Madeira; Junta de Freguesia de Aradas; Universidade Sénior Academia dos Saberes de Aveiro; Universidade Sénior da Gafanha da Nazaré; Academia Velhotes Ativos da Junta de Freguesia de Esgueira, UNISOB – Universidade Sénior de Oliveira do Bairro.

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