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A novel cognitive-motor exercise program delivered via a tablet to improve mobility in older people with cognitive impairment – *StandingTall* Cognition and Mobility

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ABSTRACT

Background: Evidence-based interventions to improve mobility in older people include balance, strength and cognitive training. Digital technologies provide the opportunity to deliver tailored and progressive programs at home. However, it is unknown if they are effective in older people, especially in those with cognitive impairment.
Objective: The aim of this study was to examine the efficacy of a novel tablet-delivered cognitive-motor program on mobility in older people with cognitive impairment.
Methods: This was a 6-month single-blind randomised controlled trial of older people living in the community with subjective and/or objective cognitive impairment. Participants randomised to the intervention were asked to follow a 120 min per week balance, strength and cognitive training program delivered via an app on an iPad. Both the intervention and control group received monthly phone calls and health fact sheets. The primary outcome measure was gait speed. Secondary measures included dual-task gait speed, balance (step test, FISCIT-4), 5 sit to stand test, cognition (executive function, memory, attention), mood and balance confidence. Adherence, safety, usability and feedback were also measured.
Results: The planned sample size of 110 was not reached due to COVID-19 restrictions. A total of 93 (mean age 72.8 SD 7.0 years) participants were randomised to the two groups. Of these 77 participants returned to the follow-up clinic. In intention-to-treat analysis for gait speed, there was a non-significant improvement favouring the intervention group (β 0.04 m/s 95% CI -0.01, 0.08). There were no significant findings for secondary outcomes. Adherence was excellent (84.5%), usability of the app high (76.7% SD 15.3) and no serious adverse events were reported. Feedback on the app was positive and included suggestions for future updates.
Conclusion: Due to COVID-19 the trial was under powered to detect significant results. Despite this, there was a trend towards improvement in the primary outcome measure. The excellent adherence and positive feedback about the app suggest a fully powered trial is warranted.

1. Introduction

Adequate mobility in old age is important to maintain independence in activities of daily living and participate in leisure activities (Callisaya and Verghese, 2018). Gait speed is commonly used to measure mobility objectively, and slow gait speed is associated with a number of adverse outcomes including disability (Perera et al., 2016), falls (Callisaya et al., 2011) hospitalisation and increased need for care (Montero-Odasso

Abbreviations: RCT, randomised control trial; MoCA, Montreal cognitive assessment; PKMAS, ProKinetics Movement Analysis Software; COWAT, Controlled Oral Word Association Test; FICSIT-4, Frailty and Injuries Cooperative Studies of Intervention Techniques test.

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et al., 2005). There are a number of factors that contribute to slow gait speed, with two of the most modifiable being muscle weakness and poor balance (Callisaya et al., 2009; Tiedemann et al., 2005). Cognitive ability is also important for maintaining gait speed, having a role in responding quickly to perturbations, being able to carry out a secondary task, and analysing and decision-making in complex environments (Jayakody et al., 2020; Martin et al., 2013a). In line with this, poorer cognition, especially the domains of executive function and processing speed, are associated with slower gait speed (Martin et al., 2013a) and risk of falls (Muir et al., 2012; Martin et al., 2013b). Importantly, having subjective or objective cognitive impairment in combination with slow gait speed increases the risk of falls to a greater extent than slow gait speed alone (Martin et al., 2013b; Callisaya et al., 2016).

In people with cognitive impairment, exercise alone or in combination with cognitive training can improve mobility (Lam et al., 2018; Zhang et al., 2019). Technology may provide a novel way to deliver interventions and enhance adherence and enjoyment for older people in their own homes, with the additional benefit of incorporating behaviour reinforcements such as feedback on performance and goal attainment (Valenzuela et al., 2018). The *StandingTall* program is an app that delivers a tailored and progressive balance and strength program to prevent falls in older people, with incorporated feedback and goal setting (Delbaere et al., 2015; Taylor et al., 2020). Recently, the app was modified to include the addition of cognitive exercises (inhibition, working memory and task shifting) that are performed in combination with the balance exercises. However, the efficacy of the app on mobility in people with cognitive impairment has not been examined.

Therefore, the aim of this study was, in people with subjective cognitive decline and/or objective cognitive impairment, to: (i) examine the efficacy of a 6-month *StandingTall* program on improving known fall risk factors – single-task gait speed (primary outcome measure), dual-task gait speed, balance, strength, reaction time and cognitive function; (ii) examine the adherence, acceptability, safety and satisfaction of the program; and (iii) determine feasibility for a larger study examining efficacy on risk of falls.

2. Materials and methods

2.1. Design

This was a two-arm parallel-randomised controlled trial (RCT) with 6-months follow-up carried out in Hobart, Tasmania, Australia. The trial was approved by the Human Research Ethics Committee (Tasmania) Network (H0016983) and prospectively registered on the Australian and New Zealand Clinical Trials Registry (ACTRN12618001062213). Funding was provided by the National Health and Medical Research Council (1135761).

2.2. Participants

Participants were recruited through general practitioners, hospital geriatric clinics, advertisements in the local newspaper, talks at retirement villages and other community organisations. Inclusion criteria included: >60 years of age; willing to adhere to the study procedures for 6-months and attend the pre- and post-clinics; cognitive impairment (a subjective cognitive decline over past 5 years and/or a Montreal Cognitive Assessment [MOCA] scores between 19 and 26 and/or a medical diagnosis of mild cognitive impairment); ability to walk in own home without a gait aide or furniture. Exclusion criteria included dementia, a score of <19 on the MOCA or a MOCA between 19 and 26 and a score of >9 on the Functional Activities Questionnaire. Other exclusion criteria included an unstable medical condition precluding exercise, other neurological conditions (e.g. Parkinson's disease, multiple sclerosis or stroke), residing in a nursing home, participating in another clinical trial that would bias the outcomes or participating in an exercise program designed to improve balance, and life expectancy <12 months. Written informed consent was obtained from all participants.

2.3. Randomisation and masking

Participants were randomised after baseline assessment. Randomisation was stratified by age (<70 or ≥ 70 years) and sex with permuted blocks of ten. A research nurse not involved in the assessment of outcomes or the intervention carried out the randomisation using a central automated allocation procedure based on computer-generated random numbers. Outcomes assessors were blinded to study group assignment.

2.4. Procedures

2.4.1. Both groups

Both the control and intervention group received monthly health information fact sheets via post on topics such as eyesight, diet, footwear and physical activity for the duration of the trial. Both groups also received a monthly phone call to ask about falls (see outcomes).

2.4.2. Intervention group

Intervention group participants received an iPad with the *StandingTall* program. The program consisted of progressively more difficult balance, strength and cognitive exercises tailored to the person. Participants were provided with an internet connection if they did not have one at home. An initial visit (1−2h) by an exercise physiologist or physiotherapist was undertaken to explain the use of the equipment, to ensure a safe location to exercise, to carry out an initial balance assessment via the app to tailor the program to the person's ability, and carry out one 10-min exercise session. Follow-up visits to review progress and features of the app occurred in weeks 2 and 8 (<1 h) and then by monthly phone calls. The program built to a total of 2 h of balance exercises per week (from 40 min in weeks 1 and 2, to 120 min from week 9 onwards), with cognitive dual-tasking exercises added in week 8 (see Fig. 1 for examples of the exercises; range of >6000 exercise variations). Balance exercises incorporate movement of the centre of mass, narrowing of base of support, minimising upper limb support, turning and changing directions, ankle/hip and stepping strategies, challenging vision, sensation and vestibular systems and stepping up and over objects. Cognitive tasks are added to balance exercises by using auditory and visual cues. Three core executive functions are engaged: inhibition (the ability to consciously override automated or dominant responses), working memory (the ability to hold, process, and manipulate information in mind) and task shifting (the ability to switch flexibly between tasks or mental sets). Safety measures included setting up the environment (e.g. near a table or chair for support; appropriate footwear; exclusion of foam or box exercises if deemed unsafe; use of carer/partner if required; instructions to keep a phone nearby; information leaflet on what to do in the case of a fall). Participants were also provided with an instruction booklet that included information on safe exercise tips and use of the iPad and the app. The difficulty of the balance and cognitive exercises progressed (in complexity and length) automatically, based on participant's self-reported rating of each exercise. The app provided videos and instructions for each exercise. Each exercise was repeated three times. Participants could choose the time they wished to exercise (e.g. 10, 15, 20, 25 or 30 min) to reach the weekly time goal. Feedback on adherence to participants was available through the app via a weekly counter and a graph, and to researchers via a dashboard following data transfer to a secure server kept by Neuroscience Research Australia. Other features of the app included exercise notification reminders and (optional) individualised goal setting.

2.5. Outcomes

All participants were assessed at baseline and 6 months.

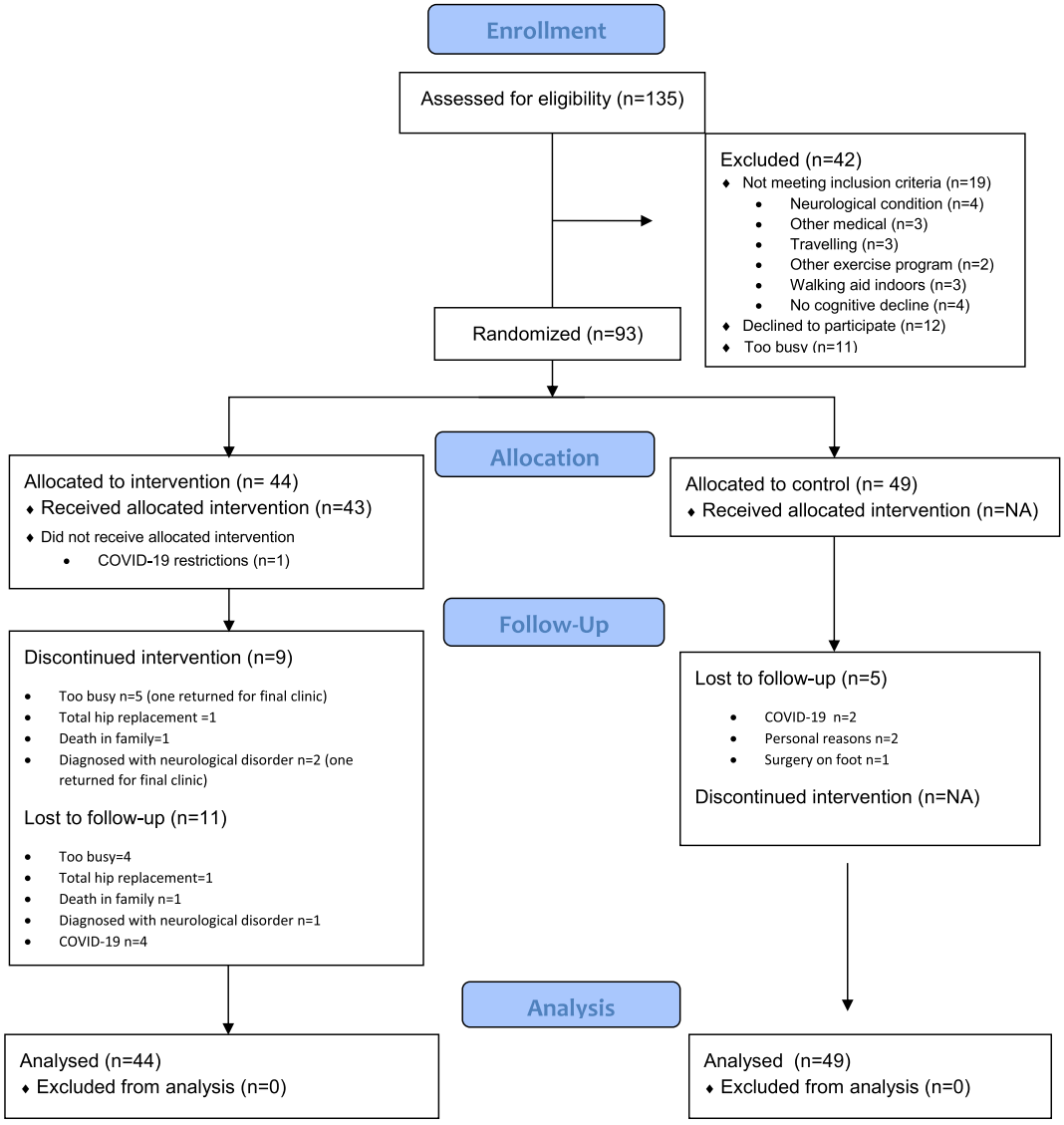

Fig. 1. Consort statement.

2.5.1. Primary outcome

Gait speed (m/s) was measured on a 6.4 m Zeno electronic walkway (Zenometrics LLC, Peekskill, NY) with ProKinetics Movement Analysis Software (PKMAS). Participants completed four walks that started 1.5 m before and finished 1.5 m after the walkway to allow for acceleration and deceleration.

2.5.2. Secondary outcomes

Dual-task gait: Gait speed (m/s) was measured as described above while performing a secondary cognitive task (counting backwards in 3 s and alternating letters of the alphabet). *Cognitive function* was obtained with a comprehensive neuropsychological battery that included the Trail Making Test, Victoria Stroop task, Controlled Oral Word Association Test (COWAT) animals, Digital Symbol Coding tests and the Hopkins Verbal Learning Test (Lezak, 1995); *Muscle strength* with the 5 sit to stand test; *Balance* with the 15 s step test and the Frailty and Injuries Cooperative Studies of Intervention Techniques test (FICSIT-4) (Rossiter-Fornoff et al., 1995); *Balance confidence* with the Activities Balance Confidence Scale and *Mood* with the Geriatric Depression Scale (Yesavage et al., 1982). Other information to describe the sample at baseline included age, sex, self-reported medical history, activities of daily living (Instrumental Activities of Daily Living – Prevention instrument) (Galasko et al., 2006) and Lifespace with the Life-space questionnaire (how far and often a person goes outside of their home) (Baker et al., 2003). *Falls* were obtained monthly via a phone call for six months and were defined as 'an unexpected event in which the

participant comes to rest on the ground, floor or lower level' (Lamb et al., 2005).

2.5.3. Process outcomes

In the intervention group, *usability* of the app was assessed with the System Usability Scale (Bangor et al., 2008) and *feedback* about the app features were obtained with a structured questionnaire developed by the researchers. The questionnaire included a five-point Likert scale regarding the overall rating of the program and friendless, as well as open ended questions about reasons for participation in the study, benefits of the app and what participants liked or didn't like about the program. *Exercise adherence* (volume, frequency) was monitored for 6 months. Adherence was calculated as a percentage of the minutes prescribed for that week. If a participant withdrew then adherence was calculated until the date of withdrawal. *Adverse events* were defined as a fall or cardiac event during the exercise program or a musculoskeletal injury potentially or definitely due to the program.

2.6. Statistical analysis

2.6.1. Sample size

For the primary outcome of gait speed a sample size of 110 was calculated to provide sufficient power (90%, 2-tailed, $p < 0.05$) to detect a clinically meaningful difference of 0.1 m/s (SD 0.15) between groups allowing for a 10% drop out (Perera et al., 2006). For other measures a sample of $n = 110$, 80% power (2-tailed $p < 0.05$) provided power to detect effect sizes as low as 0.269 (using the F-test).

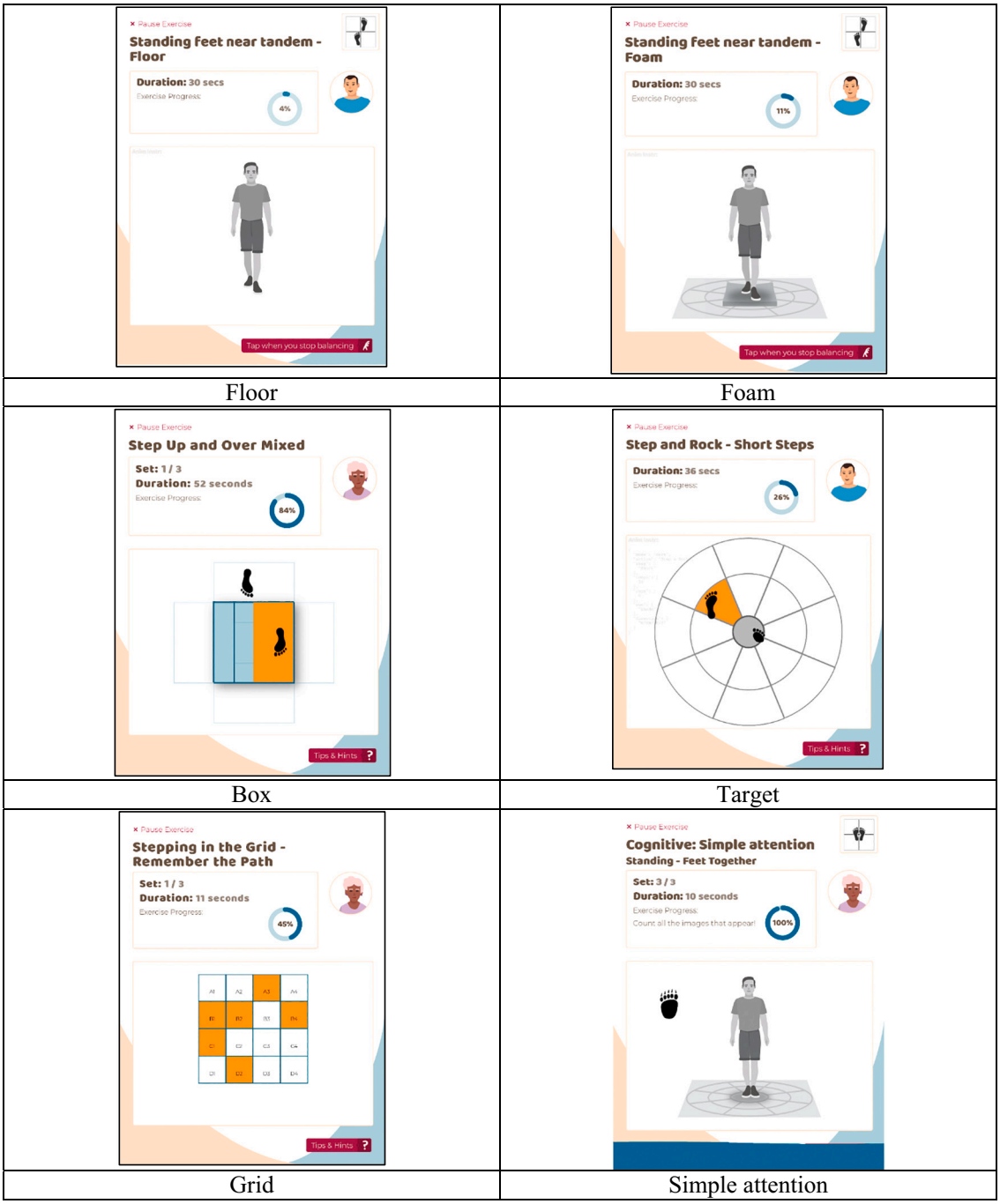

Fig. 2. Examples of exercises from the *StandingTall* program.

2.6.2. Analysis plan

Numbers of participants screened, eligible, having baseline and follow-up assessment, withdrawals and numbers included in the analyses were reported in accordance with the CONSORT flow chart. The characteristics of the sample at baseline were summarised overall and by group using the means and standard errors for continuous measures and by frequencies and percentages for categorical variables. Linear mixed effect models and intention-to-treat analyses were used to assess the effect of time for each group and group×time on outcomes reporting beta-coefficients and 95% confidence intervals in an unadjusted model. A second model was examined including age and sex and additionally any covariates identified as being clinically different between groups at baseline. In sub-analyses, we repeated the analysis for the primary outcome excluding those who adhered to less than 70% of the program. Open-ended questions were reported descriptively to highlight themes in responses.

3. Results

Over 12 months (April 2019–March 2020), 135 participants were screened for eligibility, of whom 93 (mean age 72.8 SD 7.0 years; 42% male) were randomised and assigned to the intervention or control group (Fig. 2 CONSORT statement).

3.1. Impact of COVID-19

The planned sample size of 110 was not achieved due to COVID-19 restrictions halting the ability to run face-to-face clinics and home visits. One participant allocated to the intervention was also unable to start due to social distancing restrictions. No follow-up clinics were able to run between the end of March 2020 and July 2020. Participants were invited to return for the final clinics in mid July 2020 after easing of some COVID-19 restrictions, but some participants declined due to on-going concerns. Recruitment did not recommence due to the on-going uncertainty of the pandemic. Fig. 1 provides reasons for withdrawal, with 77 participants returning to the final clinic.

3.2. Primary outcome

Baseline characteristics of the sample are summarised in Table 1. There were some notable clinical difference between groups for the proportion of past falls, diabetes and pain levels. Statistical tests between groups for characteristics were not performed in-line with the CONSORT statement (Schulz et al., 2010). Table 2 provides the unadjusted means and standard errors for the primary and secondary outcomes at baseline and 6 months, the mean change over time in each group and the adjusted (Model 1 unadjusted; Model 2 adjusted for age, sex, pain, diabetes and past falls) between group differences. The results did not meaningfully differ between the unadjusted and adjusted results. There was no significant difference between groups for the primary outcome measure of gait speed (β 0.04 m/s 95% CI -0.01, 0.08; p = 0.09). In sub-analysis excluding those whose adherence to the program was less than 70% (n = 9) did not meaningfully change the results (β 0.04 95%CI -0.01, 0.08; p = 0.09).

3.3. Secondary outcomes

There was also no other significant differences for secondary outcome measures. Over the 6-month period, falls were reported by 29% (13.7% had multiple falls) of the intervention group and 22.4% of the control group reported a fall (8.1% had multiple falls). As the sample was heterogeneous in relation to cognition, we carried out an a-posteriori analysis stratifying the sample by the MoCA (≥ 26; <26) (Nasreddine et al., 2005). There was one significant finding (out of 19 comparisons) of greater improvement in gait speed during the dual-task numbers test favouring the intervention group (Supplementary Table 1).

Table 1
Characteristics of the sample (n = 93).

Characteristic	Total		Intervention		Control	
	n	93	n	44	n	49
Age, years (mean, SD)	72.8	7.0	72.9	7.2	72.8	6.9
Male (n, %)	39	41.9	17	38.6	22	44.9
Education, years (mean, SD)	14.9	4.2	15.5	4.9	14.4	3.3
Caucasian (n, %)	90	96.8	44	100	46	94
Wifi or internet at home (n, %)	87	95.6	41	95.4	46	95.8
Self-reported medical history (n, %)						
Hypertension	38	41.3	14	31.8	24	50.0
Limb pain	43	46.2	23	52.3	20	40.8
Diabetes	6	6.5	1	2.3	5	10.2
Heart condition	26	28.6	11	26.2	15	30.6
Trans ischaemic attack	8	8.6	3	6.8	5	10.2
Lung condition	19	20.4	8	18.2	11	22.5
Depression	17	18.4	8	18.6	9	18.4
Falls past 12 months	33	35.5	19	43.2	14	28.6
Fear of falling	31	33.3	15	34.1	16	32.7
Objective questionnaires (mean, SD)						
Lifespace	88.2	14.8	88.7	14.0	87.7	15.7
Activity Balance Confidence Scale	86.7	16.3	87.9	14.9	85.6	17.6
Geriatric depression scale	1.8	2.3	1.4	1.6	2.2	2.7
MOCA	26.2	2.4	26.4	2.4	26.1	2.5
>26 (n, %)	50	53.8	24	54.6	26	53.1
24–26 (n, %)	29	31.2	15	34.1	14	28.6
<24 (n, %)	14	15.1	5	11.4	9	18.4
Activities of daily living	2.8	0.3	2.8	0.2	2.8	0.4

MOCA: Montreal Cognitive Assessment.

3.4. Process outcomes

3.4.1. Adherence

The overall adherence to the program in the intervention group was 84.5%. Of participants completing the full intervention period (n = 30) the adherence was 91.5% over the 6 months. In those that did not complete the full period (n = 11) adherence was 69.5%.

User experience questionnaire.

The average score on the system usability scale was 76.7/100 (SD 15.3). The percentage of participants reporting a subjective benefit of the program (yes/no) was 89.1%. Overall ratings on the program were as follows: 32.4% rated it as very good, 54.0% as good and 13.5% as neither good nor bad. User-friendliness of the program was rated as follows: 27.0% as very good; 54% good and 18.9% as neither good nor bad. No participants rated the overall program or user-friendliness as poor or very poor.

3.4.2. Adverse events

There were 7 adverse events potentially or definitely due to the program. This included one non-injurious fall using the box (which was then turned off for this participant) and 6 complaints of new, or aggravation of existing, musculoskeletal pain (three definitely and two potentially related to the exercise program). Two musculoskeletal events (hip and knee pain) occurred in the same participant and one further event in a separate participant (knee pain). It was determined that the box exercises were the contributing factor and were subsequently turned off for these participants.

3.4.3. User experience questionnaire open-ended questions

Improving balance and memory, preventing falls and dementia, and supporting research were given as the main reasons for participating in the trial. Participants *liked* the commitment, discipline and flexibility to do the exercise at home, and the mental and physical challenges the program offered. Participants reported subjective improvement in balance, confidence, memory and processing speed. Some participants noted that the program was somewhat repetitive and boring, others expressed that certain exercises were too difficult. Competing work or

Table 2
Outcomes at baseline, 6-months and differences between groups.

	Control group						Intervention group									
	Baseline (n = 44)*		6-month (n = 33)*		Change		Baseline (n = 49)*		6-months (n = 44)*		Change		Between group difference		Adjusted, age, sex, pain, past falls and diabetes	
	Mean	SE	Mean	SE	Mean	95%CI	Mean	SE	Mean	SE	Mean	95%CI	Mean	95%CI	Mean	95%CI
Gait speed (m/s)	1.22	0.03	1.21.4	0.03	-0.01	−0.04, 0.02	1.27	0.03	1.30	0.03	0.03	−0.00, 0.01	0.04	−0.01, 0.08	0.04	−0.01, 0.08
Gait speed numbers(m/s)	0.98	0.04	0.95	0.04	−0.04	−0.10, 0.02	1.05	0.04	102.4	0.05	−0.03	−0.08, 0.03	0.02	−0.07, 0.10	0.02	−0.07, 0.10
Gait speed alpha (m/s)	0.98	0.04	0.99	0.05	0.01	−0.05, 0.06	1.03	0.04	1.02	0.04	−0.01	−0.06, 0.04	−0.02	−0.10, 0.06	−0.02	−0.10, 0.06
5 sit to stand (*sec*)	9.9	0.6	9.7	1.01	−0.2	−0.8, 2.2	11.2	0.6	11.9	0.97	0.7	−0.8, 2.2	0.9	−1.4, 3.1	0.8	−1.4, 3.1
Step test (number)	16.4	0.6	15.8	0.8	−0.6	−1.8, 0.6	17.7	0.6	17.5	0.8	−0.2	−1.2, 0.87	0.4	−1.1, 2.0	0.5	−1.1, 2.1
FISCIT-4	21.1	0.8	22.6	1.0	1.4	−0.04, 2.9	22.5	0.8	25.1	1.03	2.6	1.3, 3.8	1.1	−0.8, 3.1	1.1	−0.7, 3.1
Simple reaction time (sec)	235.8	7.5	247.7	11.1	11.9	−4.2, 28.1	249.8	7.9	266.0	10.6	16.3	2.3, 30.3	4.4	−17.0, 25.7	4.3	−17.2, 25.7
Mood (GDS)	2.2	0.3	2.8	0.5	0.6	0.01, 1.2	1.4	0.4	1.6	0.4	0.2	−0.3, 0.7	−0.4	−1.2, 0.4	−0.4	−1.2, 0.4
HVLT recall	23.4	0.7	21.2	1.0	−2.1	−3.5, −0.7	23.5	0.8	22.8	1.0	−0.7	−1.9, 0.5	1.5	−0.4, 3.3	1.5	−0.4, 3.4
HVLT delay	7.7	0.4	7.4	0.6	−0.3	−1.1, 0.5	7.5	0.5	7.8	0.6	−0.3	−0.4, 1.02	0.7	−0.4, 1.7	0.7	−0.41, 1.7
HVLT recognition	9.9	0.2	10.1	0.4	0.2	−0.5, 0.8	9.7	0.3	10.1	0.4	0.4	−0.2, 1.0	0.2	−0.6, 1.1	0.2	−0.6, 1.1
Digit symbol coding	56.0	1.9	57.4	2.1	1.4	−0.5, 3.4	55.5	2.0	58.8	2.1	3.3	1.6, 5.0	1.9	−0.7, 4.4	1.9	−0.7, 4.4
COWAT	20.8	0.7	21.5	1.0	0.7	−0.6, 2.0	21.4	0.7	21.7	0.9	0.3	−0.9, 1.4	−0.4	−2.1, 1.3	−0.4	−2.1, 1.3
Stroop time	15.2	0.5	14.9	0.7	−0.2	−1.1, 0.7	14.1	0.5	13.2	0.7	−0.9	−1.7, −0.1	−0.6	−1.9, 0.6	−0.7	−1.9, 0.6
Stroop word	19.3	0.9	18.7	1.1	−0.6	−1.6, 0.4	19.3	1.0	19.0	1.1	−0.3	−1.2, 0.6	0.3	−1.1, 1.7	0.3	−1.1, 1.7
Stroop colour	34.0	2.1	35.5	3.1	1.6	−2.9, 6,1	31.7	2.3	31.2	3.0	−0.5	−4.5, 3.6	−2.1	−8.1, 4.0	−2.5	−8.5, 3.6
Trails A	35.8	1.7	33.3	2.4	−0.5	−3.7, 2.7	34.9	1.8	31.9	2.3	−3.0	−5.8, −0.2	−2.5	−6.7, 1.8	−2.5	−6.8, 1.7
Trails B	90.3	5.9	92.2	7.9	1.9	−8.4, 12.2	78.3	6.2	76.9	7.7	−1.3	−10.4, 7.7	−3.2	−16.9, 10.5	−3.4	−17.2, 10.5
ABC	85.6	2.3	86.4	2.8	0.8	−2.4, 4.0	87.9	2.4	89.4	2.8	1.5	−1.3, 4.3	0.7	−3.5, 4.9	0.8	−3.4, 5.0

FISCIT-4: Frailty and Injuries Cooperative Studies of Intervention Techniques test; GDS: Geriatric depression scale; HVLT: Hopkins verbal learning test; COWAT: controlled oral word test; ABC- activities balance confidence scale; *Missing data: HVLT recall, delay and recognition in intervention group at baseline n = 43; gait speed under all conditions, 5 sit to stand, step test, FISCIT-4 and reaction time in intervention group at 6-months n = 32; step test in control group at 6-months n = 43.

social commitments, other exercise programs, sickness, fatigue and injury, other life events or travel were noted as barriers. Examples of responses are included in Supplementary Table 2.

4. Discussion

This randomised controlled trial examined the efficacy of an innovative app that delivered a tailored and progressive physical and cognitive exercise program to older people with subjective and objective cognitive impairment. The *StandingTall* program resulted in a non-significant difference in the primary outcome of gait speed of 0.04 m/s (95% CI -0.01, 0.08) in a group of older people with subjective and objective cognitive impairment.

The *StandingTall* program targets balance, strength and cognition, factors associated with poor mobility and risk of falls in older people. Prior meta-analyses have found cognitive training alone (Marusic et al., 2018) or physical interventions such as combined resistance, balance and endurance exercises can improve mobility (Van Abbema et al., 2015). Further systematic reviews also support combined cognitive-motor training to improve mobility (Zhang et al., 2019; Gavelin et al., 2020), with simultaneous better than sequential exercise (Tait et al., 2017). The mean difference between groups of 0.04 m/s is clinically small (Perera et al., 2006), but similar to findings of a meta-analysis examining the effect of progressive resistance and balance training or multi-modal training on gait speed (Van Abbema et al., 2015).

In many previous studies exercise was performed in groups or outside participants' home (Zhang et al., 2019), which may not suit all older people (Yardley et al., 2008). Reported barriers to exercise include time, self-efficacy, motivation and access to classes (Ziebart et al., 2018). Technology provides a feasible way for older people to exercise in their own home (Taylor et al., 2020; Daly et al., 2021; Simpson et al., 2020; Geraedts et al., 2017; van Het Reve et al., 2014), which has the potential to increase long-term adherence (Valenzuela et al., 2018). Adherence (obtained by the program itself rather than self-reported by the participant) was excellent, and similar or better than prior studies that used technology to deliver exercise over similar (Geraedts et al., 2017) or shorter periods (Daly et al., 2021). Participants knew that they were being monitored, and so this may have provided additional motivation/discipline. However, adherence was lower in those who eventually withdrew from the program early. Motivation and self-efficacy are important factors to consider when starting an exercise program and some older people may require greater assistance in staying motivated

and choosing programs that meet their needs and preferences (Ziebart et al., 2018).

Participants reported subjective benefits in terms of balance and memory, and liked the discipline and flexibility of doing the program at home. The majority of participants also expressed that they wanted exercises to improve mobility and prevent falls and dementia, suggesting a need for such programs. There is potential for the *StandingTall* program to be offered to all older people with subjective cognitive impairment at a population-wide level. Alternatively, *StandingTall* could be prescribed by health professionals as a stand-alone intervention or in conjunction with face-to-face or group classes. Experience from this study suggests that an initial home visit is essential in people with subjective or objective cognitive impairment to ensure safety of the home set up and additional tailoring of the exercises. Follow-up visits were useful to reinforce safety, and also to assist those participants who were unfamiliar with using technology. Furthermore, engaging partners/family to supervise exercises and six-monthly reviews may be useful to check on safety, especially if a decline in cognitive function is expected.

An unexpected aspect of the program was that for some people it highlighted their strengths and weaknesses with some perceptively reporting differences in left and right leg balance or in visual versus verbal recall ability. However, some participants found the time needed to commit to the program difficult, with five people withdrawing due to being too busy. Some reported the exercises often took them longer than the time chosen, and this was reported as a frustration. Others thought that the exercises were repetitive, although this was also recognised as important for improvement. Subsequent versions of the app may need to look at reducing the time between exercises. Feedback provided on the program will assist in developing the app for future widespread scale-up.

4.1. Limitations

In addition to the impact of COVID-19 on recruitment, six participants did not return to the final clinic due to COVID-19 concerns, two participants dropped out of the intervention due to medical conditions (stroke and total hip replacement), and five reported they were too busy to complete the program. In addition, musculoskeletal events were reported by 5 participants. The box exercise aggravated some participants pre-existing hip and knee pain and therefore this exercise may need to be modified by starting with a smaller step or strengthening provided using alternative exercises. Older people are likely to have medical problems, and it is a balance between excluding those with chronic conditions and generalisability. The majority of participants already had Wi-Fi at home, and it is possible technology naive older people may require greater training than provided in this study. Finally, feedback on the program was obtained via a questionnaire. Qualitative interviews may have resulted in richer information about the intervention and its delivery method.

In conclusion, although we did not find significant differences between groups, participants found the *StandingTall* app easy to use and reported subjective benefits from the program including improved functioning. The program appears feasible in terms of recruitment and adherence for people with subjective and objective cognitive impairment and warrants a larger definitive trial to determine efficacy.

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CRediT authorship contribution statement

Michele Callisaya – conceptualisation, formal analysis, funding acquisition, methodology, project administration writing original draft, Oshadi Jayakody data curation, project administration writing- review and editing, Anagha Vaidya- formal analysis, writing – review and editing, Velandai Srikanth – writing – review and editing, Maree Farrow – conceptualization, writing- review and editing, Kim Delbaere – conceptualisation, funding acquisition, methodology, writing – review and editing

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.exger.2021.111434.

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