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ORIGINAL RESEARCH

The effect of a cognitive-motor intervention on voluntary step execution under single and dual task conditions in older adults: a randomized controlled pilot study

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Background: This randomized controlled pilot study aimed to explore whether a cognitive-motor exercise program that combines traditional physical exercise with dance video gaming can improve the voluntary stepping responses of older adults under attention demanding dual task conditions.

Methods: Elderly subjects received twice weekly cognitive-motor exercise that included progressive strength and balance training supplemented by dance video gaming for 12 weeks (intervention group). The control group received no specific intervention. Voluntary step execution under single and dual task conditions was recorded at baseline and post intervention (Week 12).

Results: After intervention between-group comparison revealed significant differences for initiation time of forward steps under dual task conditions ($U = 9$, $P = 0.034$, $r = 0.55$) and backward steps under dual task conditions ($U = 10$, $P = 0.045$, $r = 0.52$) in favor of the intervention group, showing altered stepping levels in the intervention group compared to the control group.

Conclusion: A cognitive-motor intervention based on strength and balance exercises with additional dance video gaming is able to improve voluntary step execution under both single and dual task conditions in older adults.

Keywords: fall prevention, exercise, dance, video game

Introduction

Appropriate timing and execution of stepping responses is needed for the effective avoidance of falls.[1] With age, the speed of these responses inevitably declines due to changes in the sensory and motor systems.[2,3] Consequently, individuals who require more time to initiate and execute a step to avoid a threat or to recover postural balance, either during walking or performing postural transitions,[4] may be at greater risk of falling.[5]

Considerable evidence has been accumulated showing that an additional secondary cognitive dual task causes postural instability in older adults, and thus, a delay in step execution.[6,7] Postural balance control requires, among other things, the integration of visual, somatosensory, and vestibular inputs, as well as the adaptation of these inputs to changes in tasks and environmental context.[6] Maintenance and regulation of postural balance require a high information processing capacity, and a more difficult motor task may demand an amount that exceeds the capacity of the available resources.[8]

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Reduced step execution capabilities can be mitigated by exercise, and improvements in voluntary step execution after exercise interventions have been reported in older adults[5,9–11] and patients after stroke.[12] However, these improvements have been tested without any additional cognitive distraction, which questions the ecological validity of the findings; that is, it can be questioned whether the action within the test condition is equivalent to the motor performance requirements within the physical environment. Physical exercise alone does not contribute to an improvement of voluntary stepping performance under attention demanding conditions.[10]

A recently published systematic review supports the recommendation that a cognitive element should be part of an exercise program for older adults since falls often occur under attention demanding circumstances.[13] A way to incorporate a cognitive element into an exercise program is the use of virtual reality techniques in the form of dance video gaming.[14] Games based on this technique require players to stand on a dance pad and make rapid step responses from either leg to a target location in response to a presented visual stimulus.[15] It involves controlled body weight transfer, which is similar to the step responses required to cope with external threats in everyday life; thus, we hypothesized that the game has the potential to improve voluntary step execution under attention demanding circumstances. Previous dance pad studies have shown the feasibility of this approach in the elderly and have reported positive contributions to self-reported balance confidence and mental health in older adults.[15,16] Furthermore, there are strong indications that the addition of dance video gaming has a positive effect on dual task walking in older adults.[17]

New treatments usually have to go through a series of pilot studies to test whether they are safe and effective.[18] The aim of this pilot study was to perform a phase II trial according the model for complex interventions, advocated by the British Medical Research Council[19] to test a traditional strength and balance training program that also includes dance video gaming in a group of elderly people in order to receive an estimation of the treatment effect and its variations. The study aimed to explore whether this cognitive-motor exercise program is able to improve the voluntary stepping responses of older adults under attention demanding dual task conditions.

Material and methods

Participants

The study was designed as a prospective, randomized, controlled pilot trial and was carried out from October 2010 to January 2011 with participants recruited from two care homes in Zurich, Switzerland. The study protocol was approved by the local ethics committee (KEK-ZH-NR 2010-0337/0). The exercise intervention was conducted in suitable locations at the care homes. The measurements of voluntary step execution were performed in the laboratory of the Institute for Biomechanics of the ETH Zurich, Switzerland.

All residents of the care homes were invited to attend an information session in which the intervention was explained. Thirty-four persons attended the information session, and 30 were interested in participating in the study. Participants were included if they were older than 65 years, had a score of at least 22 points on the Mini-Mental State Examination,[20] were able to stand upright for at least 5 minutes, and were free of rapidly progressive or terminal illness, acute illness, or unstable chronic illness. If unsure, subjects were asked to consult their primary care physician for medical clearance. Interested individuals were contacted by the investigator seven days later for an individual appointment to clarify any remaining questions and to sign an informed consent statement.

Three persons refused to participate due to insufficient motivation. Two interested persons who used wheelchairs were excluded because they did not fulfill the inclusion criteria. A total of 25 eligible residents signed informed consent statements and were randomly assigned to either the usual care control group (CG) or the intervention group (IG). Eleven participants were allocated to the CG and 14 participants to the IG using a random numbers table. Blinding of investigators was not possible because the investigators supervised and conducted the training sessions.

Intervention

The IG underwent a cognitive-motor intervention consisting of twice weekly progressive resistance training, progressive postural balance training, and progressive dance video gaming for twelve weeks. Intensity and duration of the program were chosen based on guidelines published by the American College of Sports Medicine[21,22] and on a review by Paterson et al describing exercise recommendations for older adults.[23] Training sessions were conducted in groups of three or four participants to form group cohesion and to encourage exercise class participation.[24] A training session lasted 60 minutes and consisted of a warm-up (5 minutes), resistance training (25 minutes), balance exercises (10 minutes), and the dance video gaming (20 minutes).

The progressive resistance training focused on the muscle groups of the core and lower extremities that are used in the functional activities of daily living, such as walking, standing up from a chair, sitting down, or stair climbing. The goal of each session was to perform two sets of ten to 15 repetitions of each exercise in a slow, controlled manner, with a one minute sitting break after each set and between the series. Training intensity was controlled by perceived exertion and intensity between "somewhat hard" and "hard (heavy)" on Borg's perceived exertion scale. This corresponds to a point of instantaneous muscular fatigue at the end of a certain exercise.[25] To maintain the intensity of the stimulus during the training period, the number of repetitions and the load were progressively increased with weight vests (Kettler GmbH & Co KG, D-59469 Ense-Parsit), as tolerated by the participants. The weight of the vests was adjusted with single sand-filled elements of 1.125 kg each.

The progressive postural balance program consisted of static and dynamic functional balance exercises.[26] Participants' balance skills were challenged through a variety of activities performed with the help of air-filled balance cushions (diameter 32 cm and 16 cm) and grip balls (diameter 12 cm) (Ledraplastic S.p.a, I-33010 Osoppo).

The dance video game was performed on metal dance pads (Figure 1A) (TX 6000 Metal DDR Platinum Pro, 93 × 14.7 × 109 cm, Mayflash Limited, Baoan Shenzhen, China) with a specially designed modification of the StepMania (Version 3.9) software.[17] The dance pad was connected to a desktop computer using USB. The video game was then projected on a white wall with a beamer. A scrolling display of arrows moving upwards across the screen cued each move, and the participants were asked to execute the indicated steps (forward, backward, right, or left) when the arrows reached the fixed raster graphic at the top of the screen (Figure 1B–D) and in time with different songs (32 to 137 beats per minute). In the first training session, a tutorial sequence was provided to ensure understanding of the task. As the levels increased, additional distracting visual cues, eg, "bombs," were presented (Figure 1C). Participants had to ignore these cues and keep their attention focused on the arrows. Occasionally, some arrows were drawn-out on the target locations, indicating that the trainees should remain for a while on the dance pad button on one leg (Figure 1D). The arrow sequences were generated using the Dancing Monkey MATLAB script.[27] Electronic sensors in the dance pad detected position and timing information that was then used to provide participants with real-time visual feedback. For each training session, the participants performed for four songs of 2 to 3 minutes length each, with a short break of 30 seconds after each song. Progression of performance was controlled through the beats per minute and the difficulty level.

When an exercise required the participants to stand, they were secured with ropes fixed on the ceiling, which they could hold on to (Redcord AS, Staubo, Norway).

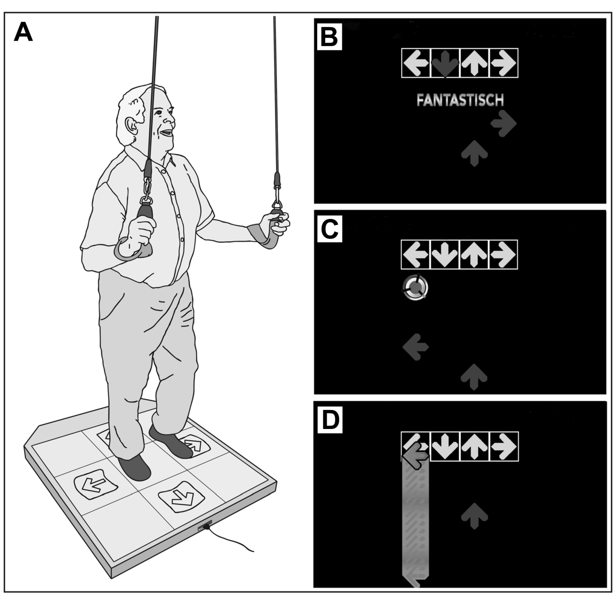

Figure 1 Dance video game: (**A**) participant on the dance pad secured by ropes fixed on the ceiling; (**B**–**D**) screenshots of the dance video game.

Usual care

The participants in the CG did not participate in the cognitive-motor program, but were able to participate in the leisure time programs offered at the care homes at their own will. These programs were non-specific, not targeted toward specific exercise goals, and were representative of what is usually offered in assisted-living facilities.[28] Table 1 provides information regarding the physical activities of the CG during the intervention period.

Voluntary step execution

To estimate the performance of voluntary step execution, a test protocol was adopted that is able to identify elderly individuals at risk for falls under attention demanding conditions.[29,32] The protocol assesses the change in the speed of voluntary step execution under the influence of a secondary distractive cognitive task and the time to initiate and complete a step.[7,8,24] The test was performed with all participants one week before and one week after the twelve-week training period.

For the test, subjects stood upright on a force platform with feet abducted 10°, barefoot, and heels separated mediolaterally by 6 cm. The stepping task required the execution

Table 1 Physical activities of the control group during intervention

Participant	Activity	Duration (minutes)/ frequency
1	Walking	30–60/daily
	Social dancing	120/weekly
2	Walking	60/daily
	Exercise program at care home*	45/irregularly
3	Walking	90/weekly
	Exercise program at care home*	45/irregularly
4	Walking	45/daily
	Aqua gym	45/weekly
5	Walking	90/daily
	Exercise program at care home*	45/weekly
6	No activities	–

Notes: *Exercise program at the care home: Exercise is conducted seated or/and in a standing position. Trained factors are flexibility, coordination of movements, strength, endurance, fine and gross motor skills, posture and memory.

of a step forward, backward, or to the side as quickly as possible after a tap cue on the heel, which was provided by the investigator with a cushioned hammer. The tap cue resembles the cutaneous stimulus experienced by the foot when hitting an object prior to stumbling or tripping.[29] Six trials for each step direction were recorded under single task and dual task conditions for a total of 36 trials. Step execution trials always occurred with the dominant leg, as chosen by the subject. Two target force platforms were used in front of (for forward steps) or behind (for backward steps) the main platform in order to register the data from the landing of the moving leg (Figure 2A). The force platforms (Kistler AG, Switzerland, 400 × 600 mm) collected the ground reaction force data at a frequency of 2000 Hz.

In the single task condition, subjects focused on a white cross displayed at eye-level on a black screen at a distance of 4.60 meters in front of them. Under dual task conditions, a Stroop Color-Word task was displayed.[30,31] Participants were instructed to read the ink color of the displayed words out loud. The performance of the participants was controlled and corrected by the investigator if needed, but was not recorded as the Stroop Color-Word task was used only for distractive purposes.

Data and statistical analysis

The criteria for success of this pilot was based on the primary feasibility objective (adherence to the exercise plan), and methodological standards for being adherent to training. A 75% attendance rate for the training sessions was set as the definition for being adherent to the training program.[34] A total of 24 training sessions was scheduled for each individual in the IG.

Force platform data was analyzed with a program written in MATLAB R2011a (Math Works Inc, Cambridge, MA) to identify the following time points for each trial: tap cue, response initiation (INI), foot off, and foot contact (Figure 2B). These time points relate to the definitions provided by Melzer et al.[32,35] Tap cue on the heel was detected as a spike greater than three standard deviations from the average baseline noise in the anteroposterior direction of the ground force data. INI was defined as the first mediolateral deviation of center of pressure toward the stance leg (greater than 4 mm away from the average baseline noise after the tap cue). Foot off was defined as a sudden change of the center of pressure slope toward the stance leg in the mediolateral direction. Foot contact corresponds to the time when loading of the vertical ground reaction force on the target force platform reaches more than 1% of a subject's body weight.

Statistical computations were carried out with SPSS 19 for a per-protocol strategy of analysis in which only those subjects who adhered to the training counted toward the final results. An average value for each temporal parameter in each stepping direction and for both task conditions (single task and dual task) was calculated. A comparison at baseline was undertaken using a Mann–Whitney *U* test and a chi-squared test for dichotomous variables. Due to non-normality of the data, a Mann–Whitney *U* test was used to estimate group interaction effects in the form of between-groups differences, ie, IG and CG after the twelve-week time period. For this purpose, the difference of the values pre and post intervention for each subject were calculated and then compared. The effects size, r, was calculated as $r = Z/\sqrt{N}$ (where Z is the approximation of the observed difference in terms of the standard normal distribution and N is the total number of samples; $r = 0.1$, small effect; $r = 0.3$ medium effect; and $r = 0.5$, large effect). A Wilcoxon signed rank test was used to compare inner-group pre/post data. The significance level was set at $P \leq 0.05$. A trend to significance was defined as $0.10 \leq P < 0.05$.

Results

A flow chart (Figure 3) provides detailed information on the subjects included in this study and on the subjects lost during the intervention phase. Demographic data is summarized in Table 2. The participants were willing to be randomized. Neither subjective nor objective side effects related to the used intervention were reported. There were no significant differences at baseline in either demographic data or temporal measurements of the voluntary step execution test between the groups.

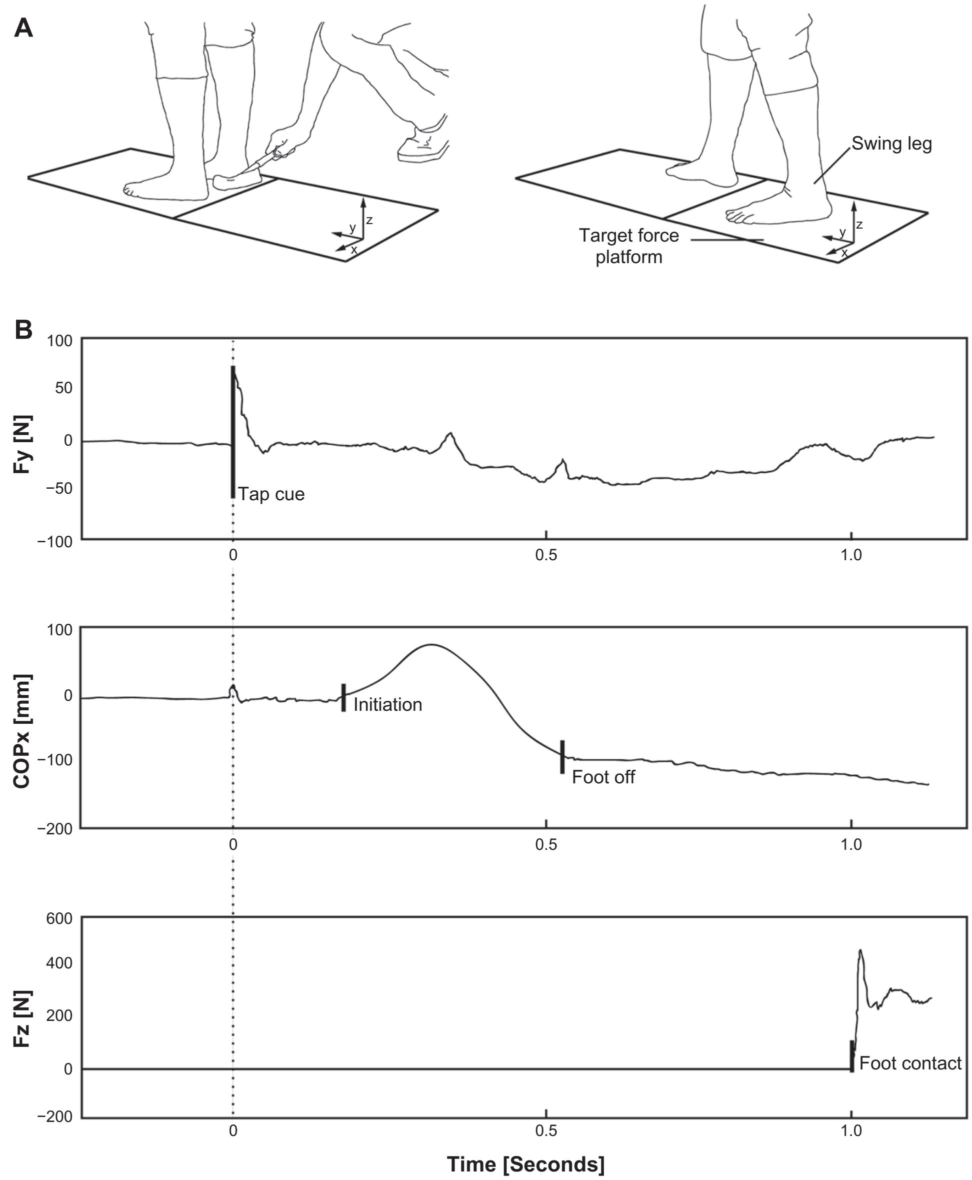

Figure 2 Voluntary step execution test: (**A**) participant standing on the force platform and executing a backward step after tap cue on the heel by the supervisor; (**B**) example of force platform data for a single step to determine the occurrence of the step parameters.

Abbreviations: COPx, mediolateral deviation of body's center of pressure in millimeters; Fy, anteroposterior ground force in Newton; Fz, vertical ground force in Newton.

The average exercise program compliance was 86.9% (20.8 out of 24 sessions). Two participants achieved a compliance of only 71% (17 out of 24) and 42% (10 out of 24), respectively. As we expected the participants to attend at least 75% of the exercise sessions, they were not considered for the analyses.

Temporal data of the voluntary step execution task is summarized in Table 3. Compared to the baseline data, the IG showed an overall time reduction of −17.9% in all assessed temporal parameters after the training program (single task condition: −15.7%; dual task condition: −20.1%). In comparison, the CG showed an increase in time of +1.3% in all assessed temporal parameters (single task condition: +1.5%; dual task condition: −4.1%). Data for the dual task condition showed longer times for each of the three examined temporal parameters under dual task conditions compared to single task conditions for all step directions in both groups (IG: +42.7%; CG: +30.0%).

Between-group comparison revealed significant differences for INI of forward steps under dual task conditions ($U = 9$, $P = 0.034$, $r = 0.55$) and for backward steps under dual task conditions ($U = 10$, $P = 0.045$, $r = 0.52$) in favor of the IG.

Inner-group comparisons resulted in step directions with significance and step directions with a trend to significance

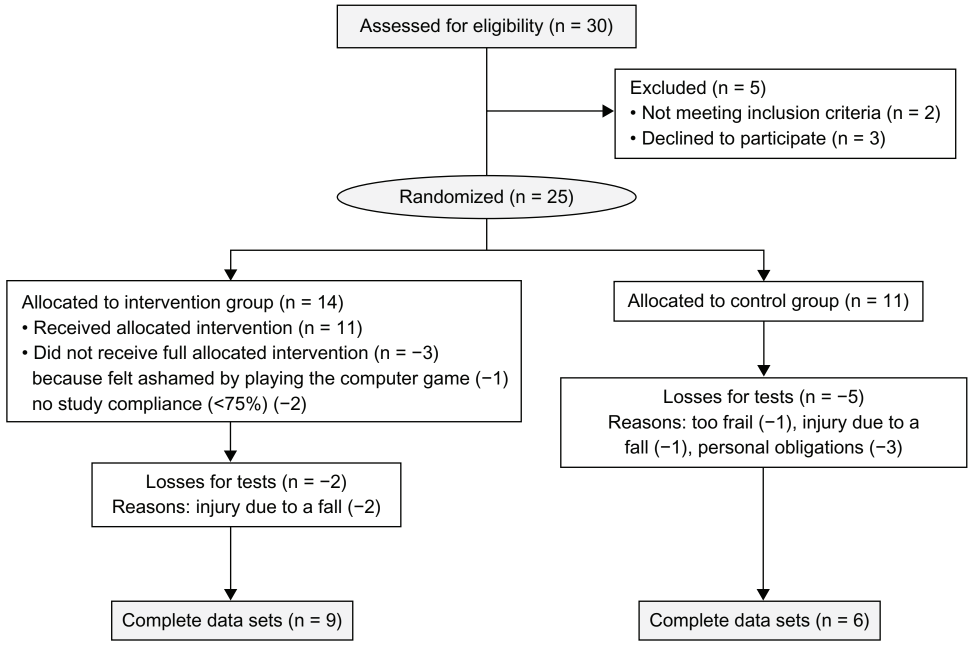

Figure 3 The study flow chart.

in pre/post-differences in the IG for INI, foot off, and foot contact (Table 3). There were no changes detectable for the CG for the inner-group comparisons.

Discussion

The present pilot study aimed to develop and test a multimodal exercise intervention and to deliver it to individuals living in care homes. The main focus was to evaluate the feasibility of the multimodal intervention as a whole and the ability to recruit and retain elderly subjects, as well as to assess the effects of the intervention. This study showed that a cognitive-motor training program containing strength, balance, and computerized cognitive training components is feasible and is able to improve voluntary step execution under single task and dual task test conditions in older adults living in care homes. We demonstrated the feasibility of acquiring acceptable compliance rates for care home dwelling older people randomized to control and experimental training groups. Our target of 75% compliance for this 12-week pilot project was attained. Two individuals had a less than 75% attendance rate and were considered non-compliant for the training. This non-compliance was mainly attributable to permanent sickness and low motivation that prevented program adherence. Thus, compliance with the exercise interventions and retesting was excellent. Adherence for group based exercises could be expected to be between 72%–88%.[34] Our intervention is in the higher range of adherence for group based exercise. However, where we report on values after three training months, Nyman and Victor[34] report values that may be expected by 12 months. In a future phase III trial, the follow-up period for the assessment of adherence and attrition should, therefore, preferably be extended to a similar time frame to facilitate comparability of this future study with reference values.

Table 2 Demographic baseline data of participants

Group	Intervention group	Control group
No of participants	9	6
Age (mean, SD)	83.6, 3.4	86.2, 4.8
Sex (female/male)	6/3	3/3
Height in cm (mean, SD)	160.3, 9.9	160.9, 9.4
Weight in kg (mean, SD)	68.0, 17.5	65.5, 9.4
Mini-mental status[a] (median, range)	28, 27–30	25.2, 22–29
Walking assistance		
None/cane or crutches	5/4	5/1
Number of falls in the last 6 months[b]		
None	7	4
One	1	1
>One	1	1
Diabetes	0	1
Hypertension	2	3
Cardiac insufficiency	3	1
Arthropathy	5	1
Osteoporosis	4	2

Notes: [a]Minimum score = 0, maximum score = 30 (higher scores indicate better functioning); [b]a fall was defined as an event, which results in a person coming to rest on the ground or other lower level.[33]
Abbreviation: SD, standard deviation.

Table 3 Temporal data in seconds and statistical evaluation of the voluntary step execution test

Temporal parameters	Intervention group (n = 9)			Control group (n = 6)				
	Pre	Post	P_{inner}	Pre	Post	P_{inner}	$P_{between}$	r
Initiation								
Forward ST	0.162 (0.144; 0.253)	0.163 (0.143; 0.186)	*0.260*	0.190 (0.174; 0.213)	0.180 (0.166; 0.194)	*0.249*	*0.906*	0.03
Forward DT	0.301 (0.269; 0.496)	0.265 (0.195; 0.404)	0.051°	0.259 (0.196; 0.335)	0.291 (0.247; 0.355)	*0.600*	0.034+	0.55”
Backward ST	0.197 (0.144; 0.208)	0.168 (0.138; 0.201)	0.066°	0.175 (0.174; 0.190)	0.170 (0.149; 0.185)	*0.345*	*0.637*	0.12
Backward DT	0.273 (0.219; 0.392)	0.265 (0.204; 0.323)	*0.110*	0.241 (0.214; 0.363)	0.248 (0.209; 0.359)	*0.600*	*0.289*	0.27
Sideway ST	0.179 (0.148; 0.197)	0.161 (0.147; 0.181)	*0.173*	0.187 (0.171; 0.198)	0.195 (0.173; 0.212)	*0.463*	*0.289*	0.27
Sideway DT	0.272 (0.192; 0.360)	0.261 (0.244; 0.282)	*0.374*	0.259 (0.205; 0.410)	0.278 (0.211; 0.413)	*0.753*	*0.480*	0.18
Foot off								
Forward ST	0.489 (0.438; 0.986)	0.437 (0.391; 0.618)	0.015*	0.602 (0.505; 0.777)	0.611 (0.483; 0.744)	*0.345*	*0.239*	0.30
Forward DT	0.716 (0.652; 0.879)	0.603 (0.530; 0.776)	0.028*	0.897 (0.586; 0.934)	0.709 (0.614; 0.890)	*0.345*	*0.346*	0.24
Backward ST	0.538 (0.409; 0.838)	0.445 (0.387; 0.605)	0.028*	0.629 (0.588; 0.661)	0.577 (0.487; 0.632)	*0.345*	*0.724*	0.09
Backward DT	0.723 (0.570; 1.155)	0.644 (0.556; 0.800)	0.066°	0.782 (0.583; 0.847)	0.683 (0.575; 0.830)	*0.917*	*0.157*	0.37’
Sideway ST	0.431 (0.298; 0.645)	0.338 (0.289; 0.541)	0.051°	0.461 (0.396; 0.545)	0.468 (0.406; 0.522)	*0.917*	*0.239*	0.30’
Sideway DT	0.615 (0.492; 0.879)	0.560 (0.506; 0.631)	*0.260*	0.733 (0.465; 0.852)	0.612 (0.504; 0.717)	*0.249*	*1.000*	0.00
Foot contact								
Forward ST	0.836 (0.674; 1.576)	0.676 (0.627; 1.057)	0.015*	0.906 (0.813; 1.122)	0.975 (0.717; 1.151)	*0.600*	*0.157*	0.37’
Forward DT	1.163 (0.890; 1.245)	0.799 (0.765; 1.256)	0.028*	1.231 (0.899; 1.296)	0.989 (0.906; 1.195)	*0.345*	*0.346*	0.24
Backward ST	0.782 (0.662; 1.246)	0.738 (0.641; 1.056)	0.066°	0.966 (0.727; 1.083)	0.894 (0.789; 1.110)	*0.917*	*0.480*	0.18
Backward DT	1.045 (0.925; 1.523)	0.918 (0.843; 1.158)	0.086°	1.096 (0.876; 1.307)	1.113 (0.984; 1.360)	*0.116*	0.045+	0.52”
Sideway ST	0.941 (0.510; 1.110)	0.619 (0.497; 0.911)	0.051°	0.820 (0.743; 0.901)	0.767 (0.588; 0.961)	*0.917*	*0.556*	0.15
Sideway DT	0.883 (0.685; 1.344)	0.989 (0.760; 1.058)	*0.859*	1.039 (0.786; 1.313)	0.991 (0.780; 1.101)	*0.463*	*0.906*	0.03

Notes: Values are in seconds and displayed as group medians with interquartile ranges (q1; q3) due to non-normal distribution of data. *Significant inner-group differences pre-post ($P_{inner} \leq 0.05$) calculated with Wilcoxon signed rank test; °trend to significance ($P_{inner} \leq 0.10$); +significant between-group differences after intervention phase ($P_{between} \leq 0.05$) calculated with Mann-Whitney *U*-test.
Abbreviations: $P_{between}$, *P*-value for between-groups comparison; P_{inner}, *P*-value for inner-group comparison; DT, dual task; r, effect size (*r* = 0.1: small effect, ’*r* = 0.3: medium effect, ”*r* = 0.5: large effect); ST, single task.

To our knowledge this is the first intervention study that demonstrates temporal improvements in voluntary step execution under dual task conditions in older adults. This study confirms previous findings that showed improvements in dual task motor performance after an exercise program that included additional dance video gaming.[17] Although in previous literature, the deficiency of older adults in making rapid voluntary steps under dual task conditions is well documented, there is still a lack of studies aiming to improve the performance of voluntary step execution of older adults, specifically under attention demanding circumstances. The deficiency of coping with attention demanding situations is well illustrated by the temporal delay of step execution in the dual task condition of the voluntary step execution test used in this study. In line with previous reports,[29] we observed a temporal delay in step responses for all participants, regardless of group allocation, under the influence of a concurrent cognitive task.

In the dance video game, subjects were expected to observe the virtual environment for drifting arrows and initiate dance steps at the same time. When using an outward step, participants needed to rapidly unload the leg they were falling toward to allow them to take a step. This may be challenging from a cognitive, reaction time, and/or muscle power generation perspective.[36] The crucial point is that dance video gaming not only requires well-coordinated leg movements, but also requires cognitive work, eg, sensing of stimuli, paying attention, and making quick decisions.[14]

The fact that this intervention had an impact on the initiation of the step response is important since step or gait initiation is frequently repeated during daily activities, leading to accidental falls during the step initiation phase in people with deficits in balance control.[37] Important mechanisms for step initiation are the anticipatory postural adjustments (APAs). The function of APAs is to prepare the body for the imminent movement and possible changes in balance as a direct result of the movement caused by moving the body center of mass toward the stance limb.[38] Falls during initiation of a step could occur when the APAs are not performed efficiently enough prior to the unloading of the swing leg, causing an unstable postural condition.[4] These mechanisms are complex and require efficient peripheral sensory detection and afferent nerve conduction, followed by central neural processing and efferent nerve conduction.[29,39] It is hypothesized that these mechanisms are repeatedly trained by the use of a dance video game. Every step on a dance pad has to be planned and executed with the proper timing while focusing attention on the arrows on the screen.

Since our dance video game was based on the correct timing of the steps and not on the maximal speed generation of the leg, we hypothesized that improvements in step execution would be accountable in large part to the more efficient intramuscular interplay, induced as well by the strength and balance training. The finding that a large part of the improvements in voluntary step execution seems to be attributable to the earlier execution of APA movements during the initiation phase was somewhat surprising. This leads to the question of whether the improvements we observed are attributable to peripheral or to central adaptations. It is known that the supplementary motor area contributes to the timing of the APAs during step initiation.[40] It would be interesting to examine whether our cognitive-motor intervention has an influence on the activity of the supplementary motor area in a future study to clarify this observation.

Related work

There are some reports on the use and effects of similar virtual reality training in various populations. Methods using immersive computer technologies resulted in improved motor functions of the upper extremities and a cortical activation after virtual reality intervention in patients with chronic stroke.[41] Older adults benefited from training in terms of improved functional abilities, postural control, and simple auditory reaction times under dual task conditions.[42] Functional balance and dual task reaction times in older adults are improved by virtual reality and biofeedback training. A virtual rehabilitation program with the help of a semi-immersive virtual reality workbench, in a non-hospital environment, resulted in qualitatively improved manual trajectories and increased movement velocity of the trained upper extremities for patients with stroke, but without any transfer to real-life activities.[43] A virtual reality based treadmill intervention conducted by Yang et al[44] showed improved walking speed and walking ability at post-training in patients with stroke. Preliminary evidence for clinical effectiveness of virtual reality obstacle training post stroke has been reported by Jaffe et al.[45]

Although it seems more intuitive that more immersive virtual environments are to be preferred for motor training, this may not actually be the case.[46] Less immersive desktop or wall screen displays can be used for this purpose as well[14] and have the advantage that no studies that used these two dimensional displays have been associated with incidence of cyber-sickness.[46]

Limitations

Several limitations of this work should be discussed. Surely the fact that step direction and the swing leg in the voluntary step execution test were known prior to the step execution could possibly have influenced the initiation of the step. An impact on the generation of APAs cannot be excluded since the subjects may try to lean on the supporting leg prior to the tap cue. However, the subjects of the CG had the same conditions and showed different reactions. Furthermore, we attempted to control for this potential disruptive factor through careful observation of the center of pressure on the verge of the tap cue. The point of application of the tap cue itself might be a limitation of the assessment protocol. A trip stimulus under real life conditions would be expected on the front of the foot and not the heel, and therefore, giving tap cues on the foot front might result in different reactions. Another limitation was the rather small sample size. This pilot study, therefore, only reveals first estimates for the measures of a consecutive Phase III study. This is an inherent property of a pilot study, and our findings warrant further research in a larger Phase III main study that includes a larger sample and clinically relevant outcome measures. Differences regarding training intensities between the groups were another limitation. Future studies with larger sample sizes are needed, which compare training groups that achieve similar amounts of strength and balance training and where one group receives additional game-like training. For a more substantial study, monitoring the occurrence of falls post intervention is also recommended.

Future directions

The IG trained 60 minutes twice weekly for 12 weeks and the CG received the usual care. It was thus expected that we would observe a difference in the development between the two groups since it seemed obvious that the difference in the amount of training would be the explanatory factor for the observed differences in the voluntary step execution test. We did not expect an effect for usual care because it did not comply with training recommendations to improve physical functions to prevent falls in the elderly.[47] Therefore, future studies should compare training groups that achieve similar amounts of strength and balance training, where the intervention group receives an additional computerized cognitive component and the control group a placebo. In this case, we expect, however, only marginal effects on voluntary step performance under dual task conditions from the control group. The results of previous studies with similar groups that performed progressive, machine-driven, resistance training complemented with functional balance exercises revealed no improvement of performance under attention demanding circumstances.[48,49]

In future studies, to clarify the additional influence of the dance video game on the subjects in the IG, we should consider a study design with a control group that would perform the strength and balance exercises without the additional dance video gaming. Currently, we are performing such a trial registered under ISRCTN05350123 (http://www.controlled-trials.com). In this study, however, we wanted to demonstrate the "proof of concept" of the effect of a cognitive-motor intervention compared to usual care in care homes in a pilot study.

Conclusion

We conclude that pilot studies with explicit feasibility objectives are important foundation steps in preparing for large trials. Ongoing formal review of the multifaceted issues inherent in the design and conduct of pilot studies can provide invaluable feasibility and scientific data for rehabilitation specialists, eg, physiotherapists, and may also be highly relevant for furthering the development of theory based rehabilitation. For older adults, the ability to take a quick step to prevent a fall is crucial, especially under attention demanding circumstances. We could demonstrate that a cognitive-motor intervention based on strength and balance exercises with the addition of dance video gaming is able to improve voluntary step execution under both single and dual task conditions in older adults. The trainees were able to quicken step initiation and total step completion time. This study may constitute a reference for further studies in the topic of fall prevention in older adults with the aim to improve physical performance under dual task conditions. This study encourages the further development of this intervention, preferably with a randomized control design and a larger sample. The application in a main study is deemed feasible with no need for protocol modifications.

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Authors' contributions

Conception and design: GP, EDdB, AC; manuscript drafting: GP, EDdB; critical revision of manuscript for its content and approval of final version: GP, EDdB, AC, SL, KM.

Disclosure

The authors report no conflicts of interest in this work.

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