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Original Article

The effect of cognitive-motor dual task training with the biorescue force platform on cognition, balance and dual task performance in institutionalized older adults: a randomized controlled trial

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Abstract. [Purpose] This study investigates whether cognition, balance and dual task performance in institutionalized older adults improves by a virtual reality dual task training. [Subjects and Methods] Randomized controlled trial; Twenty institutionalized older adults with mild cognitive impairment (13 female, 7 male; average age, 87.2 ± 5.96 years) were randomized to the intervention (i.e. Virtual reality dual-task training using the BioRescue) or control group (no additional training). The intervention group took part in a 6-week training program while the elderly in the control group maintained their daily activities. Balance was measured with the Instrumented Timed Up-and-Go Test with and without a cognitive task. The Observed Emotion Rating Scale and Intrinsic Motivation Inventory were administered to evaluate the emotions and motivation regarding the exergaming program. [Results] The intervention group improved significantly on the total Timed Up-and-Go duration and the turn-to-sit duration during single-task walking in comparison to the control group who received no additional training. Participants found the virtual reality dual task training pleasant and useful for their concentration, memory and balance. Pleasure and alertness were the two emotions which were mostly seen during the intervention. [Conclusion] The BioRescue is a pleasant and interesting treatment method, well suited for institutionalized older adults in need of lifelong physical therapy.

Key words: Mild cognitive impairment, Balance, Dual task training

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INTRODUCTION

Ageing is characterized by deterioration of vision, gait, muscle strength, balance and cognition[1)], which often results in a decrease of physical activity. This reduced physical activity leads to a vicious circle of further deconditioning[2)] including the emerge of balance disorders[3)]. The risk of falling in community-dwelling older adults increases with balance disorders[4)]. A fall is one of the most common accidents in older adults. Twenty-eight to 35% over the age of 65 fall at least once a year[5)]. The number of falls in institutionalized older adults (rate: 0.6–3.6 per bed annually, mean 1.7) is higher than observed in community-dwelling healthy older adults (rate: 0.3–1.6 per person annually, mean 0.65). In addition, injuries are much more severe[6)].

Cognitive decline is also associated with ageing. Forty-five percent of the institutionalized older adults have dementia[7)].

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Dementia and mild cognitive impairment (MCI) are due to atrophy of the hippocampus, located in medial temporal lobes (MTL), and degradation of connections between the brain regions MTL and prefrontal cortex[8)]. Mild cognitive impairment is defined as a state of cognition and functional ability between normal aging and very mild Alzheimer's disease characterized by a decline in one or more cognitive domains, including working memory, central executive function and attentional resources[9, 10)] with still intact ADL-oriented actions[11)]. Research suggests that during the MCI stage strengthening of executive function and reversing cognitive deficit is still largely possible[12)].

Balance and cognition impairments are related and both contribute to an increased fall risk[13)]. The cognitive input required for postural control depends on the task complexity and the abilities of the subject's postural control system[13)]. Postural control combined with a cognitive task, is called a cognitive-motor dual task. Specific brain regions related to dual tasking include the precentral, postcentral, and lingual gyri[14)]. To complete the secondary task, the older adult uses cognitive resources. This in turn leads to a weaker performance of the primary task and increases the fall risk in elderly with MCI.

General training programs have a positive effect on balance in institutionalized older adults[15)]. Last decade, the role of virtual reality in the domain of the physical therapy increased. Goble et al. showed that the 'Wii Balance Board' has a positive effect on balance in older adults[16)]. Further, virtual reality interventions might be more attractive for older adults who need lifelong physical therapy.

The BioRescue is a comparable form of virtual reality for cognitive-motor dual task training. It includes a platform (610 × 580 × 10 mm^3) equipped with 1,600 pressure sensors that measure vertical pressure fluctuations in both feet. It can be used as an assessment and intervention tool. The BioRescue might be more patient friendly and safer than the 'Wii Fit', as the surface of the BioRescue is bigger, more stable and lower to the ground, consequently decreasing the fall risk. During the exercises, the BioRescue gives the patients real-time feedback on the movement of the centre of pressure. Despite a good integration in clinical practice, there is only limited evidence on assessment and training with the BioRescue. Until now, the BioRescue has been reported in only 18 studies as an evaluation tool and in only one study as an intervention tool for stroke patients[17)]. In this study, significant improvements in balance and cognition were found in comparison to baseline measurements in a group of sub-acute stroke patients.

This study will examine the effect of dual task training with the BioRescue on cognition, balance and dual task performance in institutionalized older adults with MCI. In addition, the motivation and emotions experienced during the program will be monitored as this population needs lifelong physical therapy to reduce the risk of further motor and cognitive decline. We hypothesize that virtual reality dual task training with the BioRescue improves cognition, balance and dual task performance and is a pleasant alternative for traditional physical therapy resulting in positive emotions (i.e. pleasure and alertness) and more motivation towards the program.

SUBJECTS AND METHODS

Twenty older adults, aged 75 and over, were recruited from the residential care center St. Elisabeth in Hasselt, Belgium after signing a written informed consent. The study received ethical approval by the local ethical committee of Hasselt University and the regional ethical committee of medical research, UZ KU Leuven on 23/09/2015. The register number is B322201525648. Participants were able to walk 10 meters repeatedly with walking aid, lived for at least 3 months at the residential care center and suffered from mild cognitive impairment (MoCa<26)[18)] Participants who were still rehabilitating from a hospitalization (e.g., after a neurological disease or orthopedic surgery), had a diagnosis of dementia or major sensory or motor impairments of the upper or lower extremities which could interfere with the program were excluded. The participants were randomly assigned to an intervention group (n=10) and control group (n=10). The subjects in the control group continued their standard of usual care in the nursing home if applicable.

The subjects assigned to the intervention group, followed a training program with the BioRescue (RM Ingenierie, France) combined with their standard of usual care. Training sessions were planned two times a week for six weeks. The duration of each session was gradually increased from 18 minutes in week 1 to 30 minutes in week 5.

The BioRescue training was offered by a physical therapist. Participants were asked to stand on the platform located 1.0–1.5 m away from a 55 inch TV-flat screen. A training session consisted of a number of 3 minute exercises. Table 1 describes the nine exercises which were used to train balance, weight bearing, memory, attention and dual tasking. The degree of difficulty of each exercise was adjusted to the perceived skill level of each participant separately. If needed, the subjects could take a 90-second break for up to twice per session.

Balance and gait performance was evaluated using the Tinetti-POMA scale (Performance-oriented Mobility Assessment)[19)] and the instrumented Timed Up and Go test (iTUG). Participants wore inertial measurement units (Opal™, APDM's Mobility Lab™, APDM Inc, http://apdm.com) on the ankles, wrists and sternum while they were asked to stand up from a chair, walk 3 meters, turn 180°, walk 3 meters and sit down on the chair. Recorded data from total duration, step time before the turn, duration for sit-to-stand transition, turning and stand-to-sit transition were measured. Two measurements for every participant were averaged. This method is validated[20)] and has a high inter-rater reliability with video analysis for turning characteristics[21)].

To evaluate the effect of the program on cognitive-motor dual tasking, the iTUG was combined with an extra visual task (iTUG+DT). A visual task was chosen for its similarity to the dual task training and for the high impact on gait performance

Table 1. Exercises using BioRescue

Dual tasking	
Memory exercise	The participant is required to memorize the 4 cards during 8 seconds where after the cards are turned back over. A fifth card, matching one of the other 4, is presented at the center of the monitor. The participant has to perform weight shifts on the BioRescue to move the cursor to the matching card.
Avoidance whilst walking	The participant is required to walk through a street without touching barriers by performing weight shifts to the right and left side at a specific moment.
Weight-bearing transfer	
Hot air balloon	The participant must avoid the birds, hang-gliders, and other hot air balloons with the hot air balloon that he is flying by performing weight shifts.
Blackboard	The participant must guide the movements of a sponge to wipe a blackboard clean.
Spaceshuttle	The participant controls a space shuttle and avoids the obstacles he encounters by performing weight shifts.
Simple Maze	The patient moves a dot (by performing weight shifts) in a maze viewed from above to search for the exit.
Tortoise	Identical to the spaceshuttle.
Rally	The participant must avoid the obstacles and the other cars with the rally car that he is driving (by performing weight shifts to the left and right side).
Weight-bearing transfer and stabilization	
Downhill ski	The participant must avoid the various obstacles placed in his way. This exercise differs as participants have to retain the weight shift during a few seconds.

in comparison to tasks which involve external interfering factors (e.g., reaction time tasks)[22]. For this dual task, six different images (e.g., glasses, a key and traffic lights) were displayed on a screen in a specific color in front of the participant. The six colors were then spoken in a random order at three-second intervals. Participants were instructed to name the matching image without further instructions regarding task prioritization. One practice session while sitting was allowed before implementation during the iTUG. During every trial different images were used to avoid habituation effects. Dual task performance was measured as a percentage of wrong answers during the test. Two trials for each participant were averaged.

The Dutch version of the Montreal Cognitive Assessment (MoCA) is a 30-point test which assesses memory function, visuospatial abilities, executive function, orientation and verbal fluency[18].

The Dutch version of the Intrinsic Motivation Inventory (IMI) was used to evaluate the motivation during the exercise program[23]. The IMI consists of 37 questions, divided over six subscales (i.e., interest/enjoyment, perceived choice, perceived competence, pressure/ tension, value/usefulness, effort). It was filled out after the last training session by the intervention group.

To evaluate the participants' emotions during the intervention, the Observed Emotion Rating Scale (OERS) was used[24]. The intervention group was recorded on videotape during a session in the fifth week of the program. The first 10 minutes of these recordings were screened for presence and duration of 5 affects (Pleasure, anger, anxiety/fear, sadness, general alertness). Additionally, participants of the intervention group were recorded during a standard physical therapy treatment (if applicable) to compare the two treatments.

To standardize the protocol, identical footwear and walking aids were used during both pre- and post-testing. The assessor administrating the tinetti-POMA scale and MOCA was blinded to the treatment. For safety reasons, the blinded assessor was accompanied by the physical therapist during the iTUG with and without dual task.

As the data were not normally distributed, non-parametric statistics was chosen for the data-analysis. Group differences at baseline were determined with the Mann-Whitney U test using JMP Pro 12.1.0. The Wilcoxon signed-rank test two-sided was used to compare each variable within-group before and after the program. The level of significance was set at $p<0.05$ for all statistical analyses.

RESULTS

The clinical characteristics of the two groups are presented in Table 2. The groups did not differ significantly at baseline for age, gender, height, cognition, Tinetti-POMA, the use of a walking aid and additional physical therapy at the nursing home. However, the control group tended to get more standard physical therapy than the intervention group ($p=0.07$).

Two participants in the intervention group had to discontinue their training due to medical conditions not related to the program. The eight remaining participants were able to finish the six week intervention program without injuries or other inconvenience. Due to serious illness and hospitalization, one participant of the control group could not be retested, resulting in 17 subjects included for the analysis.

Table 2. Clinical characteristics at baseline

	Intervention (n=10)	Control (n=10)
Age (years)	86.9 ± 5.6	87.5 ± 6.6
Gender (M/F)	2/8	5/5
Height (cm)	161.0 ± 7.0	164.0 ± 11.0
MoCA (/30)	17.7 ± 5.3	16.8 ± 5.8
Tinetti (/28)	24.3 ± 4.7	21.6 ± 5.3
TUG (sec)	17.2 ± 9.0	22.1 ± 13.8
Walking Aids (Y/N)	4/6	6/4
Additional PT (Y/N)	2/8	6/4

Values are presented as mean ± SD.
After drop-out, differences remained non-significant.
MoCA: Montreal Cognitive Assessment; M: male; F: female; Y: yes; N: no; PT: physical therapy

Table 3. Changes in cognition, balance and dual tasking after intervention

Parameters	Experimental Group (n=8)		Control Group (n=9)	
	Pre	Post	Pre	Post
Moca (/30)	17.5 ± 6.0	18.6 ± 7.0	16.3 ± 5.9	15.8 ± 6.6
Tinetti (/28)	24.3 ± 5.2	24.8 ± 5.2	21.9 ± 5.5	21.2 ± 7.2
iTUG				
total duration (s)	17.2 ± 9.0	15.8 ± 9.2*	22.1 ± 13.8	20.1 ± 9.8
turn: duration (s)	3.2 ± 1.9	4.2 ± 3.9	3.7 ± 1.3	3.7 ± 1.7
sit to stand: duration (s)	2.7 ± 1.0	2.6 ± 0.7	2.5 ± 0.7	2.6 ± 0.6
turn to sit: duration (s)	5.3 ± 2.5	4.6 ± 2.0*	6.4 ± 3.8	6.4 ± 3.3
turn: step-time before turn (s)	0.7 ± 0.2	0.5 ± 0.2*	0.6 ± 0.1	0.6 ± 0.1
iTUG DT				
turn: duration (s)	4.3 ± 3.3	4.9 ± 3.1	3.6 ± 1.3	4.5 ± 3.3
sit to stand: duration (s)	2.7 ± 0.4	2.7 ± 1.4	2.6 ± 1.0	2.7 ± 1.0
turn: step-time before turn (s)	0.7 ± 0.3	0.6 ± 0.1	0.7 ± 0.3	0.6 ± 0.1
error rate (%)	10.1 ± 15.0	14.0 ± 15.2	26.5 ± 21.9	31.4 ± 21.7

Values are presented as mean ± SD. Moca: Montreal Cognitive Assessment; iTUG: instrumented Timed Up and Go; DT: dual task, *p<0.05

No changes were detected over time for either group with regards to the Tinetti-POMA or the MoCA (Table 3).

The total time of the iTUG improved significantly after 6 weeks training in the intervention group (17.2 sec versus 15.8 sec, p=0.02). The turn-to-sit transition improved in the intervention group by almost a second (p=0.02), whereas the sit-to-stand transition or turn duration did not improve. However, the step-time before the turn decreased significantly in the intervention group (0.7 sec versus 0.5 sec, p=0.02).

All older adults were able to perform the visual task while sitting. However, difficulties were experienced when it was combined with the iTUG. The iTUG + DT proved to be very challenging, as only 41.2% of participants remembered to sit at the chair at the end of the TUG in combination with the dual task. As a result, the total duration and the parameters from turn to sit of the iTUG + DT were not analyzed. Instead, supplemental analysis showed that only 37.5% of participants in the intervention group remembered to sit down at the end of the TUG + DT at baseline in comparison to 75% after the intervention. No changes were seen in the control group. Further, the BioRescue training did not seem to have any effect on gait or dual task performance during the TUG + DT as the percentage of errors nor gait parameters improved.

Interviews with participants from the intervention group showed that they found the program useful for their concentration, memory and balance, according to the results of the IMI, which resulted in a high compliance. They scored the program as very interesting and pleasant to do and perceived their performance of the different exercises as good to very good (Table 4).

The emotions during the program are rated with the OERS and presented in Table 5A. Overall, sadness, anger and anxiety were almost never experienced during the training with the BioRescue. These emotions appeared only as a small reaction to the failure of an exercise. Especially alertness and pleasure were seen during the training. In comparison to the standard physical therapy in the residential care center, BioRescue exercises were associated with more pleasure in the two participants who received both therapies (Table 5B and 5C).

DISCUSSION

The present study was conducted to investigate the influence of cognitive-motor dual task training with the BioRescue on balance, cognition and dual tasks during walking in institutionalized older adults.

Table 4. Descriptive statistics for the Intrinsic Motivation Inventory

Subscale (items)	Score
Interest-enjoyment (7)	6.2 ± 0.4
Perceived competence (6)	5.5 ± 0.5
Effort (5)	6.2 ± 0.4
Pressure-tension (5)	2.2 ± 1.1
Perceived choice (7)	6.6 ± 0.3
Value-usefulness (4)	6.4 ± 0.8

Values are presented as mean ± SD. The mean represents a score on a 7-point Likert scale, ranking from strongly disagree (=0) to strongly agree (=7).

Table 5. Observed Emotions Rating Scale (OERS)

	Never	<16"	16–59"	1–5'	>5'
A					
Pleasure		1	4	3	
Anger	5	3			
Anxiety/ Fear	5	3			
Sadness	8				
General alertness			1	6	
B					
Pleasure		O	X		
Anger	O	X			
Anxiety/ Fear	OX				
Sadness	OX				
General alertness				OX	
C					
Pleasure	O			X	
Anger	OX				
Anxiety/ Fear	OX				
Sadness	OX				
General alertness					OX

5A: all 8 participants who trained with the BioRescue; 5B and 5C: 2 participants who trained with the BioRescue (=X) and received additional physical therapy (=O)

This virtual reality training has a significant effect on dynamic balance during single task walking, as the total duration, turn-to-sit duration and step-time before the turn during the iTUG without dual task, improved only in the intervention group. This result shows that the intervention group improved functionality during transfers (i.e., turning and sitting down), in contrast to the control group. The fact that the iTUG improved after training with the BioRescue, is in line with the results of Rendon et al.[25)] who showed that the eight feet up and go improved significantly after six weeks of training with the Wii Fit. Further, Karaha et al. demonstrated a significant effect on balance, functional walking and quality of life after 6 weeks of virtual reality gaming using the Xbox KinectTM[26)]. Results on the tinetti-POMA test did not improve in contrast to earlier published research on cognitive-motor dual task training using the Wii Fit. These studies however included significantly younger participants (average aged 75 to 80 years)[27, 28)] or had a significant higher training frequency[28)]. In the present study, a training dosage of 2 days a week for 6 weeks with an increasing exercise duration up to 30 minutes was used, as suggested by the review of Goble et al[16)]. Only turn-to-sit and total duration of the TUG improved. This can be explained by the fact that these parameters are specifically correlated to executive functions[29)] and virtual reality training can have a positive effect on executive function in elderly[30)].

Cognition measured by the MoCA did not improve after 6 weeks of dual task training in contrast to the Biorescue training in the study of Choi et al[17)]. However, Choi et al. included subacute stroke patients, while the present study included a more than 20 years older group of institutionalized older adults. The cognitive improvement was also seen in the control group, suggesting that the target group in the study of Choi et al. was more sensitive for cognitive improvements. However, previous study has shown that turn duration and turn-to-sit are correlated to executive functions[29)]. In the present study, especially turn-to-sit and turn preparation improved after dual-task training. This is in line with previous study suggesting that executive functions improve with exergaming in institutionalized older adults[31)]. Future studies on BioRescue training in elderly should therefore include a more extensive test battery for executive functions.

The performance of the dual task did not improve in comparison to a control group who received no additional training. Improvements should be expected at the end of the TUG, which could not be analyzed due to missing data as almost 60% forgot to sit down on the chair. However, after the training only 25% of the intervention group still forgot to sit down on the chair while dual tasking in contrast to almost 60% in the control group. As a result, we can carefully suggest that dual-tasking seems to improve in the intervention group after the dual-task Biorescue training and secondary that the TUG with dual-tasking is a challenging test for elderly with MCI. In the present study, we have shown that the BioRescue training ensures enjoyment in a population of older adults living in a residential care center who are in need of lifelong physical therapy. Moreover, the participants felt that their performance of the different exercises was good to very good, proving that the BioRescue is also suited for this population and might improve patient compliance as a similar exergame training program has shown to do so in patients with multiple sclerosis[32)].

The following strengths should be recognized in this study. The participants were allocated in random order to the intervention or control group. The two non-computerized tests (i.e., MoCa and Tinetti-POMA) were administered by a blinded assessor. Further, for every participant, the same footwear and walking aids were used during pre- and post-testing. There are some limitations in this RCT. Although, physical abilities, mental abilities and fatigue of institutionalized older adults can vary between and within days[33)], the timing during the day for pre- and post-assessment was not standardized. Even though, groups were randomized, the control group tended to receive more standard physical therapy than the intervention group as it was unethical to withhold the standard of usual care in this old population. Therefore, we can cautiously conclude that even though both groups had equal access to physical therapy, the BioRescue training was more effective in improving dynamic balance than the everyday physical therapy in a nursing home setting. Future studies should include a larger number of participants and a longer training duration to see if balance, cognition and dual task performance during walking effectively improve by training with the BioRescue. Further, a follow-up period is recommended to determine the extent to which improvements are retained over time.

The results of this study suggest that the dynamic balance of institutionalized elderly improves by training with the BioRescue. It is a fun alternative exercise tool, well-suited for this population. More long-term studies are needed to see if cognition and dual task performance improve as well.

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