

Does an attentional and physical program improve walking adaptability in moderate dementia participants?

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Abstract:

Problem Statement: Falls are a critical problem for older adults. Beyond the functional consequences, they often lead to a significant loss of independence, increasing morbidity rates. Physical activity programs have proven effective in this regard. Moreover, particularly for individuals with moderate dementia, attentional and cognitive activity can slow the decline in overall health and the increase in dependence. **Approach:** A comparison was made between two groups of elderly people suffering from moderate dementia. One group followed a simple physical activity program for six months while another group followed a physical activity program associated with attentional exercises. A control group allows us to compare both experimental groups with lack of activity. Tinetti index, Time Up-and-Go test, stabilometric measures and walking evaluation have been compared among the groups to evaluate the different effects at the beginning of the experiment, after one, three and six months. **Results:** The results show significant improvement in both physical activity and physical and attentional activity groups relative to the control group. The increase in the average speed after the training program and stabilometric measures improvement, particularly the sway area of the dispersion of CoP positions, contribute to reduce fall risk. Moreover, beyond physical improvement, Tinetti test which is an evaluation of the fall risk in elderly individuals highlights significant improvement in the group with physical and attentional activities (from high risk to moderate risk). **Conclusions:** The different results of this experiment confirm the relevance of a dual-task training program associating functional and attentional capabilities and the requirement of regularity in the follow-up with the training program, particularly for participants with moderate dementia. Improvements were observed, with high or moderate effect size.

Key Words: - Fall, Elderly, Gait, Dual Task, Attention

Introduction

Falls are a critical problem in the elderly (Montero-Odasso et al., 2021). According to Mellone et al. (2012), approximately one third of older adults fall unintentionally each year. Rubenstein has specified that most falls occur during daily behavior such as walking (Rubenstein, 2006). Moreover, Snijders et al. (2007) showed that nearly 80% of people over 85 have balance and walking disorders, thus indicating that both increased gait variability and short-term local dynamic stability are risk factors for falling in the elderly as stated by Toebe et al. (2012). Beyond immediate consequent injuries, the reduced mobility, the loss of self-confidence and the consequent loss of autonomy increase frailty (Axer et al., 2010). Taylor et al. (2004) highlighted a significant link between gait (specifically walking) and a faller status, based on spatiotemporal parameters (e.g., speed and cadence). Although a strong link between fall risk and gait disorders has been described (Toebe et al., 2012), physical activity, particularly walking, is a recognized component in the management of aging and it facilitates both physical and social activities (Acree et al., 2006; Franke et al., 2013). Although difficulty with walking is considered to be a factor contributing to falls, physical activity appears to be a solution for enhancing physical function among the elderly and, consequently, for reducing the risk of falls. Walking, strength, and balance retraining are the underlying basis for these physical activity programs (Liebherr et al., 2016). In keeping with the World Health Organization guidelines that recommend physical activity for older people to reduce the risk of falls and to maintain functional independence (2010), several studies have corroborated the benefit of these practices on health (Burton et al., 2013).

Whereas Taylor et al. (2003) noted that training programs can be opportunities for community health to provide preventive health care to frail elderly individuals, the potential of physical activity to improve walking performance and the perception of well-being has also been demonstrated in older adults with intellectual disabilities or who are suffering from Alzheimer's disease (Kamil-Rosenberg et al., 2018). While difficulty and slowness of gait are considered determinants of frailty in the elderly, thereby increasing the fall risk, they can also be a pertinent indicator of the development of dementia (Gill et al., 2010). Gait disturbances may occur in the early stages or even precede cognitive disorders in subjects with dementia (Yang et al., 2020).

Walking is an automatic activity without conscious control (Hamacher et al., 2015). Attention phenomena which underlie such automaticity contribute to improve coordination and balance stability while walking (Clark, 2015). In the elderly, the cortical control of walking appears to increase with greater mobilization of attentional resources as shown in dual-task conditions (Beauchet et al., 2005). In situations that require association of automatic and cognitive activities, gait performance decreases significantly in the elderly relative to younger people (Hegeman et al., 2012). Moreover, Inoue et al. (2018) pointed out that poor attention while walking is a critical factor contributing to falls. Taking environmental conditions into consideration is crucial for adapting motor behavior in evolving conditions. For example, training programs for older adults should be carried out in settings that closely resemble their everyday lives, rather than in specialized environments such as rehabilitation clinics or gyms. In addition to the material constraints posed by the environment (e.g. chairs and tables), older people who walk are faced with constant changes requiring their attention in a context where their senses may be impaired (Cavazzana et al., 2018).

A secondary task increases the negative effects on gait in the elderly with dementia even with only moderate cognitive impairment (Ijmker & Lamoth, 2012). Thus, assessing gait when stepping over obstacles in a dual-task (e.g., associating automatic and cognitive activities) has been suggested as a potential tool for fall risk screening (Beauchet et al., 2009). In elderly, the multi-sensorial integration, including conscious and unconscious proprioception, appears to be deficient (Sohn & Kim, 2015), particularly in terms of the involvement of intrinsic factors (such as loss of strength) (Andrade et al., 2017). In this way, multisensory conflicts occur, leading to postural instability. So, rehabilitation programs that focus on developing physical abilities, balance and posture are effective, transferring these skills to everyday activities appears to be more difficult. The physical and social conditions of the activity (e.g., a stable and secure environment and the presence of a therapist) boost self-confidence, but do not facilitate transfer to everyday living conditions (Yoshikawa et al., 2020). Fear of falling increases, leading to a reduction in activity and a significant loss of autonomy (Hawkins et al., 2024).

Although a secondary task appears to be detrimental, previous studies have suggested that dual-task training (i.e., obstacles encountered on a sidewalk) focuses the attention on another goal and develops the adaptation of new gait strategies (Zhang et al., 2011). Moreover, while the benefit of physical activity to improve locomotor performance and perception of well-being has been shown among older adults with intellectual disability or who are suffering from Alzheimer's disease (Doi et al., 2013), the relevance of dual-task training and improving gait adaptability does not yet appear to have been determined for this population.

In this context, the potential for developing walking adaptability during a dual-task training program combining physical and attentional tasks and to increase compensatory adjustments in participants with low cognitive and analysis capacities has remained unclear. Whereas motor skills are based on implicit procedural memory (Nishimoto et al., 2024) and the cortical control of walking appears to increase with greater mobilization of attentional resources as shown in dual-task conditions in the elderly (Beauchet et al., 2005), a lower cognitive capacity could decrease the emergence of new motor control solutions particularly when attention is recruited on a cognitive task (Araújo et al., 2004).

However, training program designed to maintain motor skills without considering the usual context does not facilitate adaptation. In the elderly, particularly in those suffering from moderate dementia, it is important to contextualize rehabilitation as closely as possible to real-life situations. A dual task involving both functional and cognitive aspects, such as counting for example, is not sufficiently linked to daily reality. Who counts down while walking? On the other hand, walking while holding a glass of water is a common activity. It could appear that a dual task combining a physical activity program with a cognitive activity unrelated to the surrounding environment is insufficient. In order to walk safely, it seems necessary to maintain the ability to pay attention to and process attentional information from the environment.

The present study sought to quantify the effects of a program of physical activity associated with attentional cognitive exercise on gait and its persistence relative to either a single training program or the lack of a gait and balance training program.

Material & methods

This study was carried out in accordance with the 2013 Helsinki Declaration regarding ethical principles for medical experimentation using human beings. At the date of the experimentation, as well as at present, ethics committee approval number was not mandatory for non-interventional experimentation on human participants.

Participants

Sixty adults participated in the study (age: 80.1 ± 5.9 years; weight: 66.4 ± 10.3 kg; height: 168.7 ± 5.4 cm; Body Mass Index: 23.2 ± 2.4). They were recruited based on their ability to understand instructions and to follow an adapted physical activity program. The participants had to have sufficient autonomy to move without assistance. They provided informed consent to take part in the study. When necessary, the legal guardian provided informed consent.

The Mini-Mental State Examination (MMSE) (Tombaugh & Mc Intyre, 1992) score was measured for each participant. The mean score was 21.8 (SD: 1.9) (min. score: 19, max. score: 23.8). A score in this range indicates that the participants had a moderate degree of cognitive impairment.

Procedure

Participants were divided randomly into two groups (G1 and G2). A control group (G3) was formed with 20 participants who did not want to take part in the experiment, but who volunteered to take part in the control evaluations. No differences were noted in the composition of the groups (Table 1).

	G1	G2	G3
n	19	18	20
Age (years)	81.4 (4.4)	82.4 (4.3)	82.2 (4.6)
Weight (kg)	55.9 (5.4)	54.9 (6.7)	59.9 (8.3)
Height (cm)	166.5 (4.7)	164.8 (8.3)	163.5 (8.7)
BMI	22.3 (1.9)	20.3 (1.9)	20.4 (2.6)
MMSE	20.9 (2.0)	21 (2.2)	21.3 (1.5)

Table 1: Mean and SD of the individual characteristics of the participants.

An initial clinical evaluation (T0) based on the Tinetti balance assessment tool (Tinetti et al., 1986), the Timed Up and Go test (TUG) (Podsiadlo & Richardson, 1991; Shumway-Cook et al., 2000), and stabilometric measures in a quiet stance with the arms resting alongside the body while standing on a stabilometric platform (WinPosturo, Medicauteurs[®]) were performed. Participants were barefoot while they stood on the platform. One trial was performed at 5 Hz for a duration of 51 s in accordance with Nardone et al. (2009).

Moreover, as done by Beauchet et al. (Beauchet et al., 2002), a clinical test of gait including cognitive task was performed. It consisted of walking alone for a distance of 10 meters without instruction and walking for a distance of 10 meters while performing randomly one or the other of cognitive tasks (counting backward out loud starting from 50 or a verbal fluency task that involves enumerating as many animal names as possible aloud). Tasks were performed in randomized order. Participants were told to maintain their usual walking speed while counting backward or enumerating animal names. They wore their own footwear. The elapsed time (in seconds) and the number of steps were recorded in both walking alone and dual-task walking conditions.

These evaluations were also performed after one (T1), three (T3), and six months (T6).

After the initial evaluations, participants in G1 (n = 20) undertook a training program three times per week based on walking, and balance tasks associated with tasks requiring proprioceptive and attentional capabilities (e.g., walking with a glass of water, crossing low barriers, catching and throwing a foam ball while walking...). Participants in G2 (n = 20) undertook a training program three times per week based on walking, and balance tasks.

The training programs were led by the same physiotherapists during their internship in elderly care homes. Their duration was 30 minutes.

Participants in G3 (n = 20) did not undertake any training program.

Three participants had to end their participation in the experiment due to medical reasons (not relative to the experiment) at T1 (one participant from G1 and one participant from G2) and T3 (one participant from G2), respectively. These changes did not alter the inter-group consistency.

Data collection

The Tinetti balance assessment tool (Tinetti et al., 1986) is an easy to perform and reproducible test for evaluation of the fall risk in elderly individuals. It consists of evaluation of balance and gait parameters. The resulting scores can range from 0 to 28. When the score is less than 18, the fall risk is considered to be high. When the score is between 18 and 24, the fall risk is considered to be moderate, and when the score is 24 or higher the fall risk is considered to be low.

The Timed Up and Go test (Podsiadlo & Richardson, 1991; Shumway-Cook et al., 2000) consists of measuring the time that a person takes to rise from a chair, walk three meters, turn around, walk back to the chair, and sit down. Frail elderly and disabled patients generally take between 11 and 20 seconds to perform this task (Bischoff et al., 2003).

Stabilometric measures such as those used by Tallon et al. (2013) consist of the measuring the CoP displacement that is its length L (mm) and its surface area S (mm²), taken as the surface of the confidence ellipse enclosing 90% of the CoP sway.

The Beauchet clinical test of gait (Beauchet et al., 2002) consists of walking for a distance of 10 meters under two different experimental conditions: walking with and without an explicit cognitive task (counting backward out loud starting from 50 or a verbal fluency task that involves enumerating as many animal names as possible aloud). The elapsed time (in seconds) and the gait frequency, from the number of steps, are recorded. The difference between the experimental conditions is expressed as a percentage of the walking without an explicit cognitive task condition. Pairwise comparison between conditions was calculated for each participant.

Statistical analysis

The data were averaged and analyzed pairwise using a *t*-test.

Effect sizes were calculated using Cohen's *d*, with .8 indicating a large effect size, .5 a medium effect size and .2 a small effect size (Cohen, 2013).

The significance level was set at $p < 0.05$.

Results

Tinetti balance assessment tool

Inter-group comparison (Figure 1a)

At T0, the Tinetti index was not different for G1 versus G2, for G1 versus G3 and for G2 versus G3.

At T1, it was significantly higher for G1 versus G3 ($p = 0.03$; $d = 0.48$) and for G2 versus G3 ($p = 0.03$; $d = 0.23$).

At T3 and T6, the Tinetti index was significantly higher for G1 versus G2 (resp. $p = 0.01$; $d = 0.58$ and $p = 0.002$; $d = 0.58$), for G1 versus G3 (resp. $p = 0.001$; $d = 1.73$ and $p = 0.002$; $d = 1.86$) and for G2 versus G3 (resp. $p = 0.003$; $d = 1.06$ and $p = 0.02$; $d = 1.21$).

Intra-group comparison (Figure 1b)

For the participants who undertook a training program based on walking, and balance tasks associated with tasks requiring proprioceptive and attentional capabilities (G1), the Tinetti index increased significantly between T0 and T1 ($p = 0.001$; $d = 0.4$), between T0 and T3 ($p = 0.01$; $d = 1.07$), between T0 and T6 ($p = 0.02$; $d = 0.61$), between T1 and T3 ($p = 0.01$; $d = 0.6$) and between T1 and T6 ($p = 0.03$; $d = 0.21$). There was no significant difference between T3 and T6 ($p = 0.1$).

For the participants who undertook a training program based only on walking, and balance tasks (G2), the Tinetti index also increased significantly between T0 and T1 ($p = 0.003$; $d = 0.28$) and between T0 and T3 ($p = 0.01$; $d = 0.61$). There was no significant difference between T0 and T6 ($p = 0.07$), between T1 and T3 ($p = 0.09$), between T1 and T6 ($p = 0.1$) and between T3 and T6 ($p = 0.2$).

No changes were observed in the control group (G3).

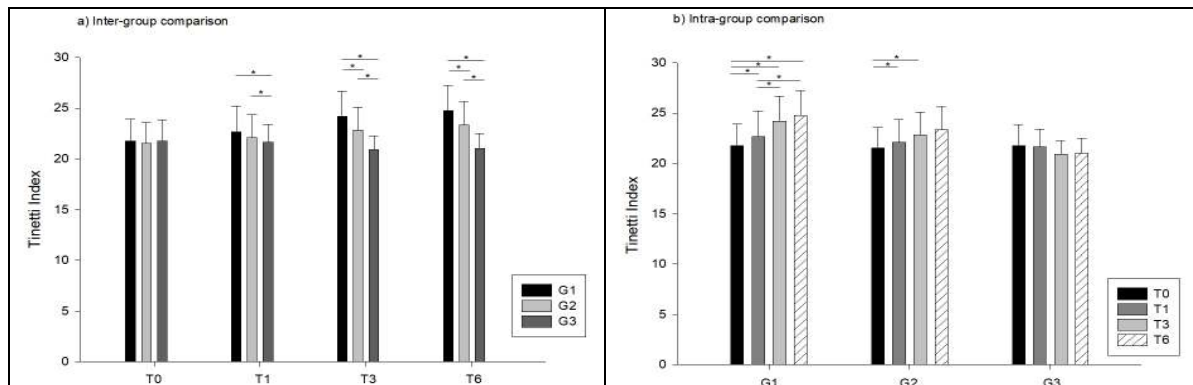


Fig. 1: Inter-group (a) and Intra-group (b) comparisons of Tinetti Index (* denotes significant differences)

Stabilometric measures (Figure 2)

Inter-group comparison

L, which is the measure of CoP displacement, was not significantly different between G1, G2, and G3, irrespective of the evaluation sessions.

S, which is the sway area of the dispersion of CoP positions, had significantly lower values at T3 and T6 between the participants who undertook a training program based on walking, and balance tasks associated with tasks requiring proprioceptive and attentional capabilities (G1) and the participants who undertook a training program based only on walking, and balance tasks (G2) compared to the control group (G3) ($p = 0.02$; $d = 1.03$ and $p = 0.04$; $d = 0.74$, respectively at T3 and $p = 0.01$; $d = 1.36$ and $p = 0.02$; $d = 0.73$, respectively at T6) (Figure 2a).

S had significantly lower values at T6 between the participants who undertook a training program based on walking, and balance tasks associated with tasks requiring proprioceptive and attentional capabilities (G1) compared to the participants who undertook a training program based only on walking, and balance tasks (G2) ($p = 0.04$; $d = 0.59$).

Intra-group comparison

L, which is the measure of the CoP displacement, was not significantly different between the different evaluation sessions, irrespective of the group.

S decreased significantly between T0 and T3 ($p = 0.01$; $d = 0.73$), T0 and T6 ($p = 0.01$; $d = 0.58$), T1 and T3 ($p = 0.04$; $d = 0.6$) and between T1 and T6 ($p = 0.02$; $d = 0.38$) for the participants who undertook a training

program based on walking, and balance tasks associated with tasks requiring proprioceptive and attentional capabilities (G1) (Figure 2b).

S decreased significantly between T0 and T3 ($p = 0.02$; $d = 0.59$) and T0 and T6 ($p = 0.04$; $d = 0.32$) for the participants who undertook a training program based only on walking, and balance tasks (G2) (Figure 2b).

No changes were observed in the control group (G3) (Figure 2b).

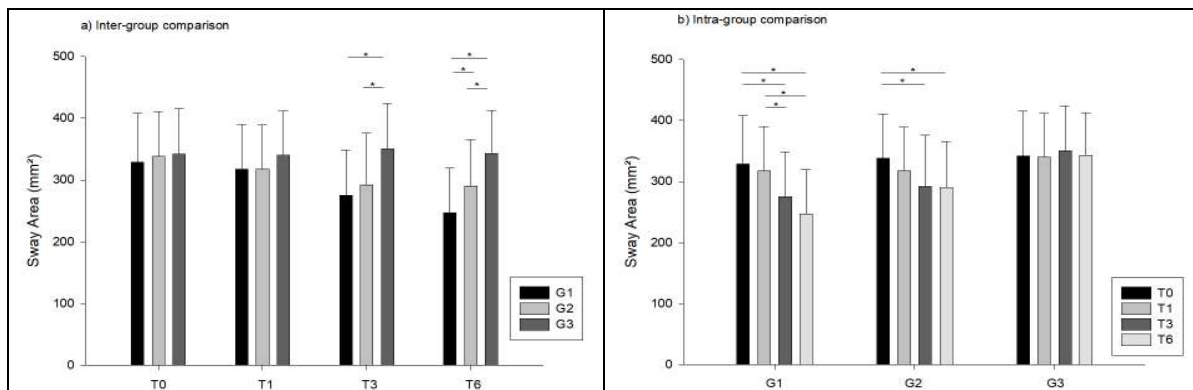


Figure 2: Inter-group (a) and Intra-group (b) comparisons of the sway area of the dispersion of CoP positions (S) (* denotes significant differences)

Beauchet clinical test of gait

The duration of the 10 m walk with an explicit cognitive task (irrespective of the cognitive task) is always higher than walking without an explicit cognitive task.

Inter-group comparison (Figure 3a)

At T3 and T6, the relative difference duration 10 m walk was significantly lower between G1 and G2 ($p = 0.04$; $d = 0.58$, and $p = 0.04$; $d = 0.57$, respectively), G1 and G3 ($p = 0.001$; $d = 1.45$ and $p = 0.002$; $d = 1.18$, respectively) and, at T3 between G2 and G3 ($p = 0.004$; $d = 0.83$).

Intra-group comparison (Figure 3b)

For the participants who undertook a training program based on walking, coordination, and balance tasks associated with tasks requiring proprioceptive and attentional capabilities (G1), the relative difference duration between experimental conditions (i.e. walking with and without an explicit cognitive task) decreased between T0 and T3 and T0 and T6 ($p = 0.001$; $d = 1.45$ and $p = 0.001$; $d = 0.76$, respectively). It decreased also between T1 and T3 and T1 and T6 ($p = 0.03$; $d = 0.76$ and $p = 0.02$; $d = 0.1$, respectively).

For the participants who undertook a training program based only on walking, coordination, and balance tasks (G2), the relative difference duration between experimental conditions (i.e. walking with and without an explicit cognitive task) decreased significantly between T0 and T6 ($p = 0.04$; $d = 0.5$).

No changes were noted in the control group (G3).

No significant changes in the cadence parameter were observed between the different evaluation sessions, irrespective of the group.

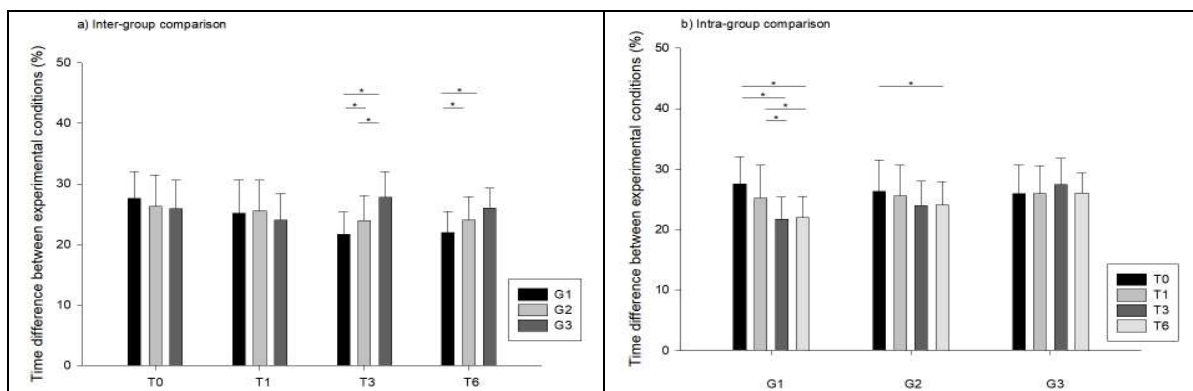


Fig. 3: Inter-group (a) and Intra-group (b) comparisons of the time difference between experimental conditions in the Beauchet clinical test (%). (* denotes significant differences)

Timed Up and Go

No changes were observed between the different evaluation sessions, irrespective of the group.

Discussion

The present study aimed to determine the possible effects of a physical activity program associated with attentional exercises on gait in participants with moderate dementia and its persistence to prevent falls.

The increase in the average speed after the training program supports the fact that the participants improved their ease with locomotor activity. This was confirmed particularly between T3 and T6, irrespective of the training program. The results even indicate that the participants who underwent a training program based only on walking, coordination, and balance tasks improved their gait speed, but slower than the participants who undertook a training program based on walking, coordination, and balance tasks associated with tasks requiring attentional capabilities. Functional implementation alone is not enough, and enhancing (and/or maintaining) attentional capacities enhances functional capacity. It appears to confirm an improved gait ease in accordance with the findings of Barak et al. (2006). On the other hand, the results of the control group are in accordance with what has often been described in the literature (Prince et al., 1997). While it appears to make walking safer and less unbalanced for elderly subjects (Blanke & Hageman, 1989), it is characterized in the control group by an increase in the stop-time in dual-task situations that might place the elderly subjects at a greater risk of falling (Barrett et al., 2010).

The gain in strength and motricity ease obtained by participation in the training program allows muscle strength to be improved (Kubo et al., 2008; Rodacki et al., 2009) and it contributes to make walking easier and more adaptable, although the mechanisms involved remain unclear (El Hadouchi et al., 2022). The newly acquired muscle strength and power increase leg support in stance phase. It provides the energy for the push-off and drives the limb into swing. These improvements are in accordance with Taylor et al. (2004) indicating that an action on postural muscle groups contributes to enhanced posture and equilibration, thereby leading to higher Tinetti test scores. With balance exercises, muscle strengthening and coordination derived from the training program help to counteract the loss of muscle strength in the lower limbs responsible for balance disorders and walking as well as the postural instability (Sohn & Kim, 2015).

These generalized effects of a training program may be related to the notion that functional improvements increase maximal voluntary force and power to increase gait speed rather than isolated intrinsic strength of muscle (Mian et al., 2007). Beyond these functional improvements, the contribution of a training program with tasks requiring proprioceptive and attentional capabilities increases compensatory adjustments and gait adaptability in the elderly (da Rocha et al., 2013). These training conditions closely resemble ecological conditions and appear to maintain autonomy, thereby reducing the risk of falls, as Job et al. point out (2020). In accordance with previous works (e.g., Moore et al., 2005), the average score on the Tinetti test confirms the potential benefit of a specific training program, particularly of a dual-task training program. The significant improvement for participants in group G1 led to a decreased risk of a fall relative to the other groups, going from 'High risk' to 'Moderate risk' of a fall.

However, our results indicate that the different explanatory variables do not have the same sensitivity to the training program, particularly the TUG test, which did not reveal inter- and intra-group differences. These results are in accordance with Hiyamizu et al. (2011). These authors indicate that adding a cognitive task to standard balance training does not significantly affect improvement in balance. Likewise, while stabilometric measures, particularly the sway area of the dispersion of CoP positions, offer a pertinent follow-up of balance (Tallon et al., 2013), their improvements in postural stability are not directly expressed in gait speed gain.

Beyond these analytical results, the changes were largely indiscernible after a small number of training sessions but were significantly more pronounced after 3 months of participation in a training program. While the elderly tend to spontaneously execute movement sequences as a series of individual movements (Verwey, 2010) intrinsic coordination is freed (Elble, 2007; Giladi et al., 2007). Gait fluency, characterized by a limb's relative independence, requires profound changes in the whole neuromuscular system and it takes a long time to learn to crossover from a 'freezy' gait to a 'freely' gait (Kubo et al., 2008). Whereas a training program has an effect on the neural control of locomotion and acts on mobility, particularly on the spatiotemporal organization of body segments (Hausdorff, 2007), a dual-task program improves fluency of gait after many sessions. While a dual-task program offers various environmental constraints that facilitates the emergence of new motor control solutions and motor learning and adaptive strategies (Davids et al., 2012) in populations with moderate dementia, the results for the G2 group show that the resulting gain is temporary. As long as coordination between the trunk and the legs of elderly individuals tends to be constrained, the dual-task training program allows better adaptation, and it consequently decreases the risk of a fall. However, consequently, the allowed dynamic stability, particularly the inter-girdle independence that facilitates coordination between the lower and the upper body (Pascaud et al., 2025), remains tenuous.

Conclusions

The different results of this experiment confirm the relevance of a dual-task training program associating functional and attentional capabilities and the requirement of regularity in the follow-up with the training program, particularly for participants with moderate dementia. Improvements were observed, which were often high or moderate in effect.

This experiment allowed us to study changes in the variables of interest over several months and with a large number of participants. This enables us to observe changes in each variable individually and consider how they interact. For example, the increased gait speed demonstrated in the *Beauchet clinical test of gait* contributes to an improvement in *Tinetti balance assessment tool*.

Similarly, the large number of participants enabled the sustainability of the observed changes to be assessed over a long period. This confirms the need to provide this training regularly throughout the year for older people. It also highlights the importance of support in ecological settings (i.e. not requiring any special equipment) to improve patients' daily lives and prevent falls.

Conflicts of interest

Every author does not have commercial relationships which may lead to a conflict of interests.

Use of Generative AI

The authors did not use Generative AI in the writing process.

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