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Postural Control in a Fall Risk Situation in the Elderly: Stepping Over an Obstacle Under Dual-Task Conditions

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Abstract: Avoiding and negotiating obstacles is a common cause of falling in the elderly. There is also evidence that walking under dual-task conditions, which requires a high level of attention, is associated with an elevated risk of falls in older adults. To better understand the role of dual-tasking in the disturbance of postural control when subjects are faced with obstacles, we used a simple quantification method to assess postural control after obstacle clearance. Sixty healthy elderly volunteers (aged 66-85 years) were tested for their postural stabilization on a force platform under the five following conditions: i) simple walking, ii) walking and stepping over an obstacle, and iii to v) walking and stepping over the obstacle under dual or triple-task conditions, the secondary task being either motor or cognitive for the dual-task and a combination of both for the triple-task. Postural control was assessed by determining both the distance covered by the center of pressure (COP) and the root-mean-square of the medio-lateral COP displacement. Only the latter differed significantly between walking conditions. In the "walking plus stepping" conditions, the motor and cognitive secondary tasks led to opposite effects, the motor task perturbed whereas the cognitive task improved postural control. These findings highlight the adverse effects of performing a secondary motor task while walking under challenging conditions, and confirm the appropriate prioritization of postural control over a cognitive task in cognitively unimpaired older subjects. These results also indicate that this near ecological approach may be useful for fall risk investigations in the elderly.

Keywords: Gait, posture, obstacle, dual-task, aging.

INTRODUCTION

A large proportion of falls in older adults occurs while walking, especially in dual-task situations such as talking while walking [1; see also 2 for review]. Despite conflicting early reports [3], several recent studies indicate that, in the aged population, changes in performance during dual-task walking conditions are associated with an increased risk of falling [4 for review].

Over the last decade, accumulating evidence has indicated that postural and gait control is highly attention-demanding, and that adding a concurrent secondary task to walking requires even more attention, especially in elderly subjects [2, 5]. This has mainly been demonstrated using dual-task paradigms during "static" or dynamic balance tests, by preferentially measuring the center of pressure (COP) displacement while the subject is standing on a fixed or moving force platform and is submitted to various additional tasks (eg, reaction-time tasks, counting backwards, or spatial memory tasks) [6-9] or by analyzing the gait parameters (gait speed and variability) when subjects are walking on a flat surface and simultaneously performing additional tasks [10, 11]. Decreased postural stability, gait speed and/or poor secondary task performance are frequently observed in older adults when the postural or walking task and the secondary tasks are performed concurrently. Although very useful for gaining knowledge about the relationship between postural control and attentional demand, these experimental conditions that focused on either stationary balance tests or walking on even ground do not reproduce challenging postural control situations occurring while walking in real life such as crossing obstacles.

Many falls are caused by stepping on or tripping over obstacles [12]. Unexpected and unnoticed obstacles are most likely to cause falls. Crossing over large obstacles while walking is another challenging situation that is more attentional demanding than walking on even ground [13, 14]. Negotiating the obstacle safely requires engagement of several cognitive processes (e.g. selective attention, attentional control, programming, decision making,..) together with postural adjustments. Tasks that mimic these real life walking situations under dual-task conditions should provide better understanding of the dual-task challenges during obstacle crossing. A few studies have examined the effects of per-

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forming a secondary task while avoiding or negotiating obstacles. It has been shown that elderly subjects walk more slowly when they have to walk and step over obstacles while simultaneously engaged in other activities [14-16]. Other studies have reported detrimental effects of a concurrent cognitive activity on the control of foot placement before and during obstacle crossing, especially in older adults [13, 17, 18]. However, to our knowledge, there is no report addressing postural control just after obstacle clearance under dual-task conditions, even though this initial phase towards complete stabilization could give new insights into the causes of balance loss.

Fall risk is known to be increased by low cognitive performance [19], a common occurrence in the older population with, however, great inter-individual variability. Increased attentional demand for obstacle crossing as compared to walking on even ground has been shown to be higher in healthy older subjects than in younger subjects whether the obstacle appears suddenly [13] or not [14]. It is thus likely that if older adults frequently fall when negotiating obstacles [12], the risk of falling may be higher in cognitively impaired older adults who have compromised availability of attentional resources. Adequate postural adjustments after obstacle clearance and effective strategy implementation should indeed be less common in the latter.

There is also evidence that the nature of the secondary task plays an important role in the disruptive effects on gait and posture and in the priority given to each task [2, 5]. However, discrepant findings have been reported, partly as a result of differences in the methodological procedures. Because postural control and gait may be associated with any type of secondary task in real life, this issue remains to be more fully elucidated.

In order to better understand the causes of balance loss during challenging walking conditions in the elderly, we investigated postural control after stepping over an obstacle under conditions of high attentional demand, a putative situation of fall risk in this population. As a first step, we developed an original method that we applied to unimpaired aged subjects to acquire knowledge about normal functioning before applying the method to subjects at higher risk for falls. Postural control was assessed with an ecological-like quantitative method using a force platform and measuring COP parameters including the medio-lateral COP displacement, a dynamic parameter shown to be the most representative of balance disorders and fall injuries [20], after crossing over an obstacle in simple and dual-task conditions. To test whether regaining balance after obstacle crossing differs depending on the nature of the secondary task, we used secondary tasks that predominantly involve cognitive and/or motor skills. According to the cognitive theory from Baddeley, the interference effect of a secondary task on a primary task is more marked when both tasks are in the same modality, thus sharing the same attentional resources [21]. We thus hypothesize that a secondary motor task would interfere with the postural stability to a greater extend than a cognitive task, thus leading to higher disturbance in postural control after stepping over an obstacle.

MATERIALS AND METHODOLOGY

Subjects

Sixty elderly volunteers (36 women, 24 men; range 66 to 85 years old; mean age: 72.2 ± 4.7 years), with no history of falls in the past year, no affection of the locomotor system and no cognitive impairment (Mini Mental Test Examination score > 24), participated in this study. Subjects were recruited through the French Mutuality of Calvados, a group of mutual health insurance companies, and the regional press. All subjects provided informed written consent prior to the experiment, which had previously been approved by the Regional Ethics Committee, CCPPRB of "Lower Normandy".

Experimental Procedure

The subject was required to walk at his or her own speed along a 5-m walkway, then stop for 3 seconds on a force platform (Bertec®, Columbus, USA; sampling frequency: 100 Hz) in simple and stepping conditions (see Fig. (**1**) for the experimental set-up). In the stepping conditions, an obstacle (cardboard log; diameter: 10 cm), designed to simulate a large object that can be encountered when wandering, was placed just before the force platform that thus recorded the

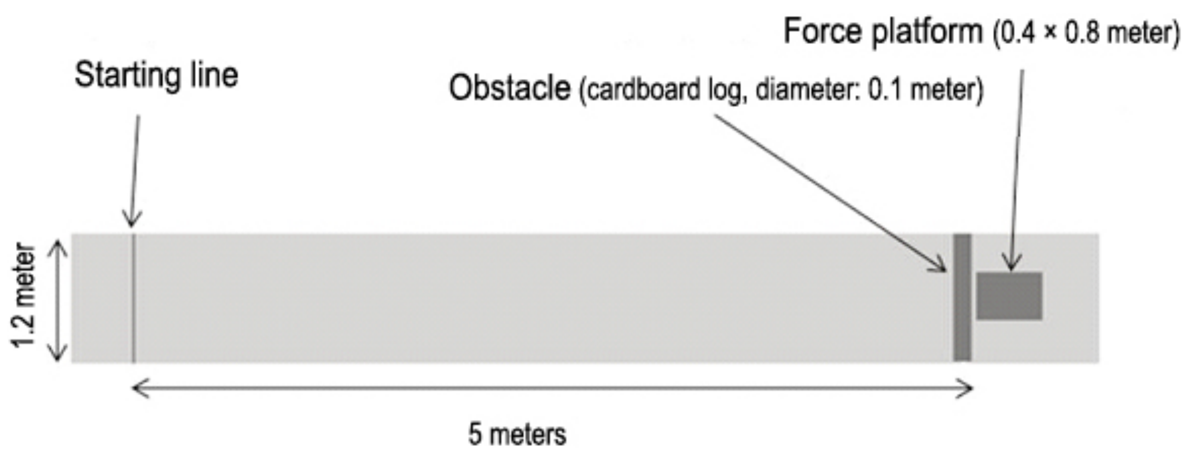

Fig. (1). Schematic representation of the experimental set-up (top view). The walkway was materialized with a large brown wood floor. A starting line was drawn 5 meters prior to the obstacle and the force platform was placed just behind it. Both the obstacle and force platform were clearly visible, each being displayed in a different colour (with red stripes for the obstacle and in dark grey for the platform).

ground reaction forces subsequent to stepping across the obstacle. Five conditions were tested in the following order: i) simple walking, ii) walking and stepping over the obstacle, and iii to v) walking and stepping over the obstacle under dual or triple-task conditions, the secondary task being either motor or cognitive for the dual-task and a combination of both for the triple-task. Before each condition, the walking and stopping procedure were shown to the subject by the experimenter who gave verbal descriptions at the same time including how to stand on the force platform ("Stand still and stable with both feet apart naturally").

The motor task consisted of carrying a rectangular tray made of plexiglass (30 cm in length, 20 cm in width, and with a 2-cm border) containing 2 balls (radius: 7 mm) and 2 cones (radius: 34 mm; height: 115 mm) with both hands. In the cognitive task, the subject was asked to count backwards from 100 at his or her own speed. We deliberately chose easy tasks that, nonetheless, mobilize the subject's attention to avoid falls that could occur with high attentional-demanding tasks and to test whether such simple secondary tasks were able to induce changes in postural control. The subject was required to continue performing the secondary or combined task during the 3-s stop on the force platform. To assess the ability of obstacle clearance and subsequent regaining of balance, we focused on the first seconds after obstacle crossing that are the most critical in the case of loss of balance. This period that influences the final stabilization includes two successive phases starting with the first foot contact on the floor and continuing with the very early phase of regaining balance on both feet. To have the subject behave as naturally as possible, thus reproducing as closely as possible real life situations, no instructions were given concerning the priority to be allotted to one or the other concurrent task (postural, cognitive, motor, ..) or to the take-off leg to be used for crossing. The number of balls and cones that fell and that of generated digits were recorded from the beginning of the walking task to the end of the 3-sec stop on the platform after stepping over the obstacle. Practice trials were given to the subject until full comprehension was achieved prior to each condition.

Data Analysis

Two measures were used to evaluate postural control on the force platform in the first two seconds after obstacle crossing from the first foot contact on the platform: 1) sway path of the center of pressure (COP), hereafter called "length of the COP path", thus allowing to follow the COP trajectory

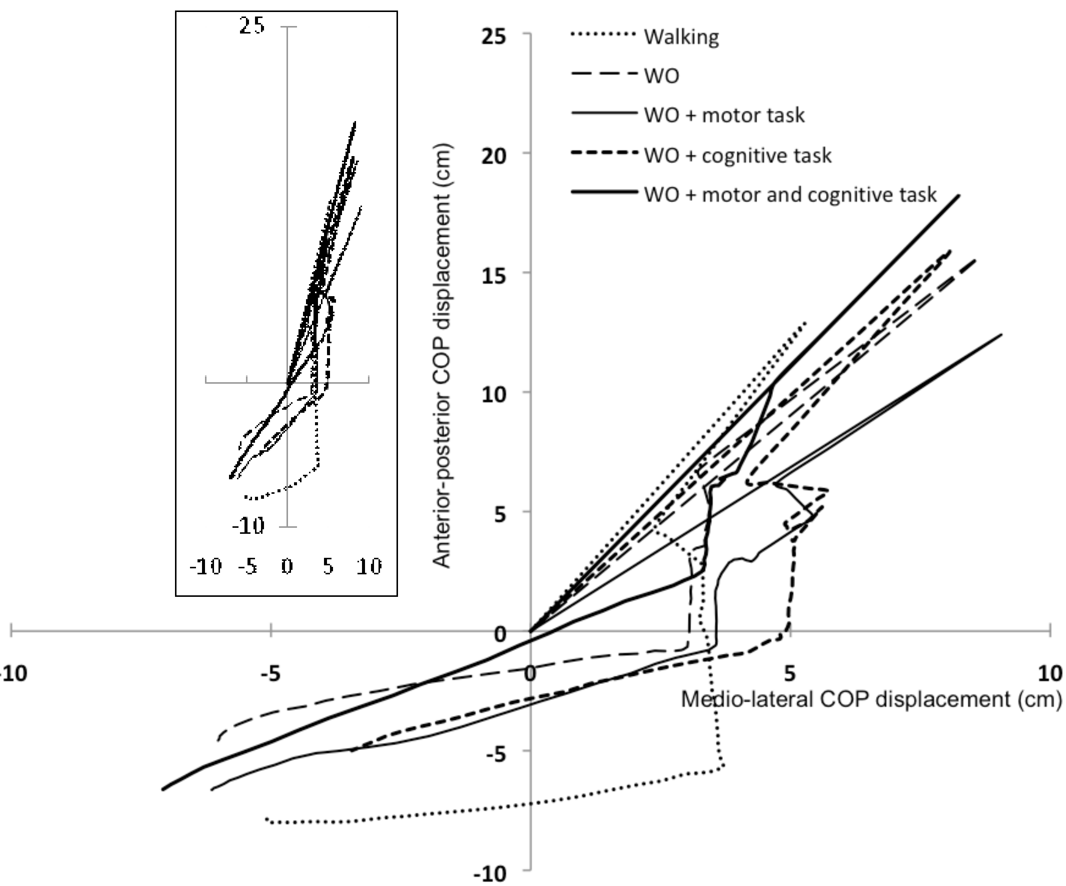

Fig. (2). Mean of the total path of the center of pressure (COP) over the course of the recording time in each walking condition. In insert, a second representation with the same scales for each axis as compared to enlarged x scale for the main figure. Starting position was arbitrarily affected to the zero position for each condition. For a better visualization and comparison of the COP path between the different walking conditions, the sign of the medio-lateral COP displacement was reversed in each subject showing negative values on the x axis for the initial first foot contact with the platform, so that the initial COP deviation is the same in all conditions regardless of the take-off leg used by the subject. Walking: walking without obstacle; WO: Walking and stepping over an obstacle; WO +: Walking and stepping over an obstacle while simultaneously performing one or two tasks as specified.

during the initial stabilization phase; and 2) fluctuations in the medio-lateral COP displacement, as quantified using the root-mean-square (RMS). Although COP displacement is usually examined in bipedal stance [e.g. 6, 7, 8, 9, 20] medio-lateral COP excursion has been previously used as an outcome measure during the unipedal contact on a force platform just before an obstacle crossing [17]. RMS values provide information about the amplitude variability of COP displacement relative to its mean. A higher RMS value indicates greater variability and is interpreted as greater postural instability. A one-way analysis of variance (ANOVA) with the 5 walking conditions as repeated measures was conducted to assess the stepping and dual- or triple-task effects on postural stabilization. Post hoc analyses were performed with the Fisher's protected least significant difference (PLSD) test. Comparisons of the motor or cognitive performance between dual- and triple-task conditions were computed with the non parametric Wilcoxon test due to the non-gaussian distribution of both performances. Statistical analyses were performed with the Statistica software (Statsoft, France) and statistical significance was set at $p < 0.05$.

RESULTS

There was no significant difference in the performance of the secondary task between dual- and triple-task conditions, neither for the cognitive performance (mean ± SD for the number of generated digits: 8.25 ± 1.45 and 8.34 ± 1.76, respectively) nor for the motor performance (zero fallen objects in each task condition), which confirms that both secondary tasks are rather low-attentional demanding.

Graphic representation of the total COP path in the two-dimensional plane over the course of the recording time can be found in Fig. (**2**). At first glance, the length of the COP path looks rather similar in all 5 conditions, with an anterior-posterior distance 5 to 10 times greater than that of the medio-lateral. As shown in Fig. (**3**), the distance covered by the COP was, indeed, quite similar and no significant "Walking condition" effect was found with ANOVA ($F_{4,\ 59} = 2.07$; $p = .09$).

Conversely, the RMS value of the medio-lateral component of the COP displacement differed significantly between walking conditions ($F_{4,\ 59} = 4.74$; $p = .001$). Post hoc analysis revealed that this balance parameter was significantly (i) smaller in the dual cognitive condition than in all other conditions except the simple walking condition; and (ii) higher in the dual-motor and the triple conditions than in the simple walking condition (Fig. **4**).

DISCUSSION

The present study shows that, when stepping over obstacles, the medio-lateral COP displacement, but not the length of the COP path, varied significantly between walking conditions in older adults. The strong ability of the RMS of the medio-lateral COP displacement for detecting changes in postural stability is in agreement with several studies. In particular, it has been shown that this index of lateral stability is highly predictive of the risk for falling [20]. The lack of change in the length of the COP path in dual- or triple-task conditions likely results from the fact that the COP path was highly conditioned by anteroposterior movements when "walking and stopping" so that a secondary task that only slightly disturbs the locomotor activity has relatively little effect on this parameter.

The observed changes in the RMS values of the medio-lateral COP displacement indicate that walking and negotiating obstacles while simultaneously engaged in other activities modify the attentional resources allocated to postural control. This is consistent with previous reports that recorded gait parameters or measured foot placement in similar conditions [13, 15-18]. Our data also extend the interest of this postural parameter in assessing the effects of dual-tasking on postural control [e.g. 13] subsequent to obstacle crossing.

Interestingly, motor and cognitive activities performed while walking and stepping over obstacles have opposite effects, as shown by their respective highest and lowest RMS values of the medio-lateral COP displacement. The greatest disturbance of postural stabilization, occurring while performing a predominantly motor secondary task, is in agree-

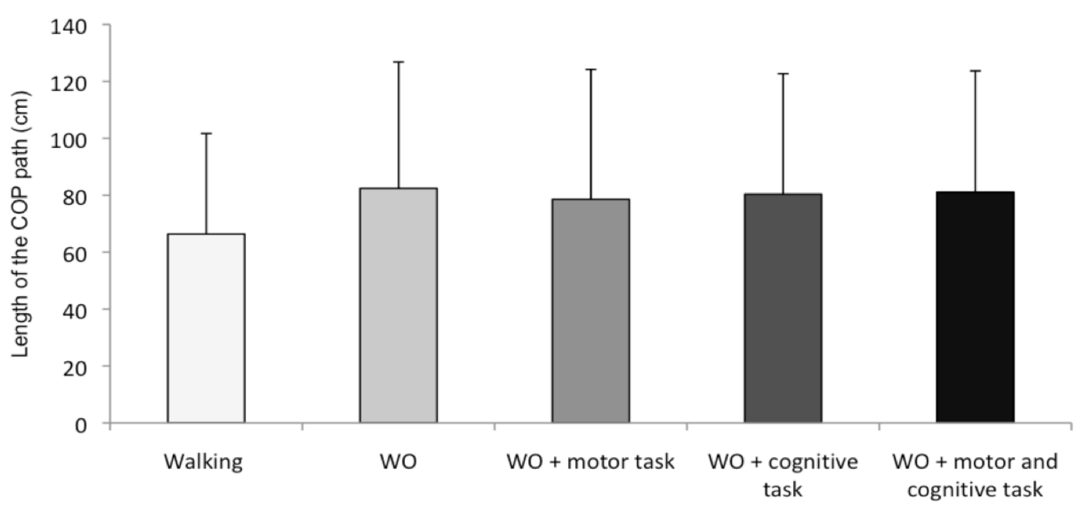

Fig. (3). Mean values and standard deviation for the total length of the center of pressure (COP) path in each walking condition. Walking: walking without obstacle; WO: Walking and stepping over an obstacle; WO +: Walking and stepping over an obstacle while simultaneously performing one or two tasks as specified.

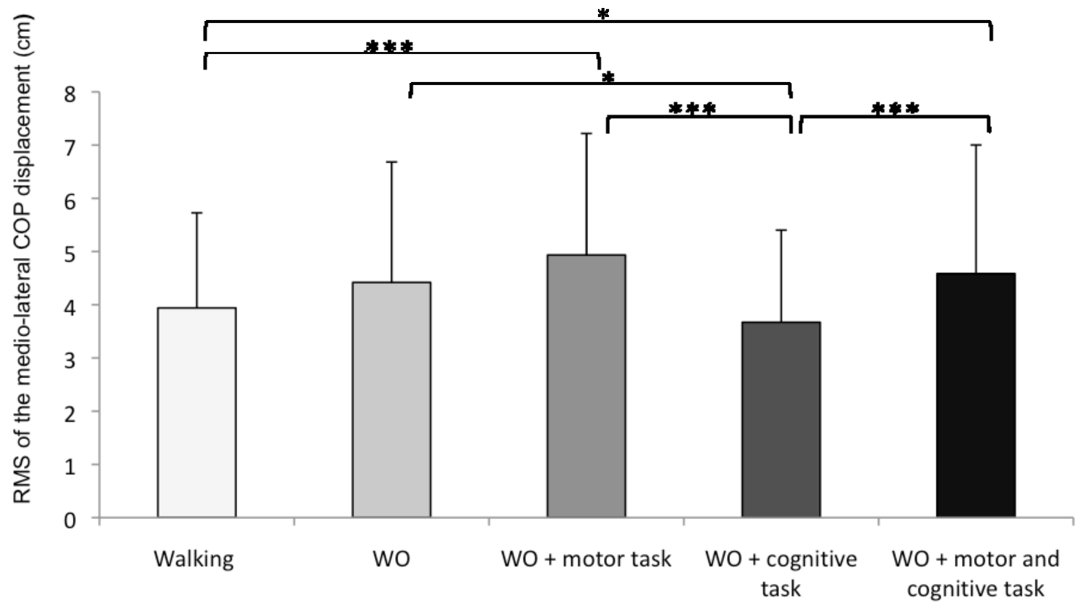

Fig. (4). Mean root-mean-square (RMS) values and standard deviation for the medio-lateral component of the center of pressure (COP) in each walking condition. Walking: walking without obstacle; WO: Walking and stepping over an obstacle; WO +: Walking and stepping over an obstacle while simultaneously performing one or two tasks as specified. * *p*<.05, *** *p*<.005.

ment with a previous postural study [22], and is consistent with most studies on deleterious interference effects under dual-tasking conditions when both tasks share the same input-output resources [21]. On the contrary, improved control of lateral stability was found when walking and negotiating the obstacle was performed in conjunction with a cognitive task. Because ceiling motor performance was observed in both the dual- and triple-task condition, it is unlikely that the disturbed postural control observed under the dual motor task condition only resulted from a higher level of difficulty of the motor task, as compared to the cognitive task. Although we cannot ensure a similar level of difficulty for the cognitive task, especially since cognitive performance in a neutral condition (e.g. in quiet stance) was not tested, the lack of significant difference in the cognitive performance between the dual- and triple-task condition is in favor of a rather easy cognitive task as initially intended. In any event, it is likely that better postural control following obstacle clearance while concurrently performing an easy cognitive task could result from adaptation processes reflecting prioritization of postural control over a cognitive secondary task, which adequately reduces the risk of falling. This prioritization of postural control under challenging postural conditions in near ecological dual-task situations strengthens previous observations reported in less complex situations using either stationary balance tests [22, 23] or walking on even ground [4,5]. We cannot exclude, however, that improved postural control while simultaneously performing the low-demanding cognitive task may result from shifting the focus of attention away from the postural task "walking and obstacle crossing" as reported with more automatized activities performed in experimental conditions in older adults [e.g. 24, 25] and demonstrated by the inverted U-shaped relation between postural control and cognitive demand [25]. As the five conditions were given in the same order for all participants, an effect of practice cannot be ruled out, especially for the dual cognitive condition. Yet, even if present, such a practice effect clearly could not overcome the disruption of postural stabilization under the dual-motor and triple task conditions. In future studies, varying the level of difficulty for each secondary task in the present protocol would be useful to better understand the interference effects of additional tasks with challenging postural control. Additional measures such as walking speed and time for regaining stability of bipedal stance would also afford valuable complementary data on the functional profile of the subjects and its relation to their ability to clear an obstacle in single- and dual-task conditions. Furthermore, analysis of the placement of the feet would be helpful to elucidate the role of increasing base of support as an adaptation mechanism that adequately improves balance after obstacle crossing.

As a whole, our data suggest that the risk of falling when stepping over obstacles would be higher when simultaneously performing a motor rather than a cognitive task. However, because the present data were observed in cognitively intact aged subjects, it does not predict whether this would also apply to those with cognitive impairment, who have less available attentional resources. Indeed, attentional competition between postural and cognitive tasks is likely to emerge at a lower level of cognitive demand and postural difficulty in cognitively impaired elderly subjects, as already demonstrated for older as compared to young adults [2, 23, 25] thereby further increasing the risk of falls during challenging postural condition in cognitively impaired than intact aged subjects.

CONCLUSION

The changes in postural control observed here using an easy secondary task, highlight the fact notion that a low cognitively demanding task can induce a shift of attention during a challenging postural task. Consequently, negotiating obstacles per se is highly attentional-demanding in older adults [14] and postural control may be easily compromised in elderly adults simultaneously faced with an additional task. Furthermore, the present study shows that measuring RMS values of the medio-lateral COP displacement after negotiating obstacles under dual-task conditions provides valuable information about the attentional requirement for postural control during challenging walking conditions, and may thus be a very useful near ecological approach for investigating balance loss in the elderly.

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