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The complexity of the handgrip task modulates postural performance in older adults

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HIGHLIGHTS
• Aging influences the performance of the combined task of posture and prehension.
• Older had worse postural control on the unstable surface when compared to younger.
• Postural control is modulated to the difficulty of the grasping tasks and the bases.

ABBREVIATIONS

COP	Center of pressure
OA	Older adults
YA	Young adults

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BACKGROUND: The acts of reaching and grasping objects are involved in the performance of daily activities. There is a gap in the understanding of how the complexity of the grasping task associated with changes in the base of support influences postural control performance in the older population.
AIM: To investigate the postural control performance of older people as they performed the grasping movement, with different levels of task difficulty and complexities of the base of support.
METHOD: 15 young and 15 older adults participated. The participants stood on a force platform and performed: 1) Reaching a heavy object; 2) Reaching a light object in rigid and unstable base conditions. The variables analyzed were: area, mean velocity, and mean displacement amplitude of the center of pressure (COP).
RESULTS: Older had higher COP velocity in the anteroposterior and mediolateral directions, as well as in the rigid and unstable bases. They also had a larger COP area in the rigid and unstable base of support, and for all gripping tasks. In both groups, the mean amplitude of COP displacement in the rigid base was higher while gripping a heavy object than while gripping a light object or performing a non-gripping task.
CONCLUSION: Postural control in the older adults is mainly influenced by the difficulty of grasping tasks. It is possible to identify the postural control performance of the older while they grasp objects during daily activities and to assess how these activities disturb balance, which makes it possible to draw up guidelines to improve postural performance.

KEYWORDS: Postural control | Dual task | Grasping | Older adults

INTRODUCTION

Postural instability is defined as the inability to integrate sensory information and determine body oscillations in the upright position while maintaining balance [1]. With aging, the sensory systems (visual, somatosensory, and vestitubular) responsible for postural control become unable to maintain the center of pressure (COP) over the base of support, which causes physical decline and, consequently, impairs the performance of daily activities [2]. The worsening in the performance of activities is especially evident when older people perform associated tasks, such as reaching and holding a water bottle [3], because when a secondary task is performed concurrently with a postural one, attentional resources are divided [4] and influenced by the complexity and type of the task.

As a result, when older people are subjected to a dual-task condition, they have worse postural control performance [5]. Greater amplitude of oscillation [6], anteroposterior and lateral median velocity [7], and area of oscillation of the COP [8] were identified when older adults were subjected to cognitive tasks involving counting and calculations. The worse postural performance becomes even more evident when older people are subjected to sensory disturbances [9] such as an unstable support base. This behavior shows that additional tasks impact postural control performance and lead to greater difficulty in allocating attention to it, which causes balance impairment and affects the performance of daily activities [9].

The acts of reaching and grasping objects are involved in the performance of daily activities and are essential in interactions with the environment, such as reaching when drinking water from a bottle and grasping objects of different weights, sizes, and shapes. It has been identified that, when performing the reaching movement, older people have a greater amplitude of COP displacement than young adults [10,11], which reflects an adaptation to the decline of movement control systems due to the aging process [11].

Although postural control performance has been investigated under different base conditions [9,12,13] or associated with the movement of grasping the same object without manipulation of characteristics [3,10,11], there is a gap in the literature on how the complexity of tasks, adjusted in this study by changing the weight of objects, along with changes in the base of support (rigid or unstable), influences postural control performance in the older population. Thus, the objective of this study was to investigate the postural control performance of older people as they performed the grasping movement, with different levels of task difficulty and complexities of the base of support. It is expected that 1) older adults will have worse postural control performance than young adults and 2) poorer performance will be seen when individuals – especially the older people – are subjected to more complex tasks, such as grasping heavier objects, and while the unstable base is used.

METHOD

Participants

This study was carried out at the Laboratory of Biomechanical Analysis of Movement (Bio.Mov) at the Center for Physical Education and Sports of the Federal University of Espírito Santo (CEFD/UFES). The participants were 15 younger adults and 15 older adults. All the participants were right-handed, able to stand without support and had normal or corrected vision, preserved cognitive functions to understand the tasks, and no neurological alterations, self-reported musculoskeletal disorders or dizziness preventing them from performing the experimental tasks. After agreeing to participate in the study, all individuals signed an informed consent form approved by the Research Ethics Committee of UFES (CAAE: 62459922.2.0000.5542).

Initially, anthropometric measurements of weight and height, as well as upper limb length, were taken. To verify the inclusion criteria, anamnesis was conducted. The Baecke Questionnaire for young adults [14] and the modified version for the older [15] were used to assess participants' physical activity levels. The cognitive function of older people was assessed using the Mini Mental State Examination [16], and their static and dynamic balance was assessed with the MiniBESTest[17].

Task and equipment

The participants were asked to stand barefoot on a force platform, keep an upright posture, and remain as stable as possible for 30 seconds, keeping their arms at their sides, their head still, and their gaze fixed on a target one meter away. When requested, participants performed the following movements: 1) reaching a heavy object; 2) reaching a light object, and 3) standing still. The reaching movements were performed with the right upper limb, and participants stood both on a rigid support base, on the force platform, and on an unstable base, on the foam. The foam was 0.47m length, 0.38m width and 0.055m thick. The mass of the foam used was 0.491 kg and the volume was 0.009 m3. The density of the foam was 50 kg/m^3. The light object was always positioned to the left of the participant, and the heavy object was positioned to the right. The weight of the objects was not initially informed, which made the manual task unpredictable and prevented any compensations anticipating the movement. The commands given were to "pick up the object to the right/left". Thus, the difficulty level of the grasping task was manipulated by using objects that differed in weight, and the postural task was manipulated by changing the type of support base. Three randomized trials were carried out for each baseline and object condition, which resulted in a total of 18 trials per participant.

The objects (two black wooden cylinders weighing 0.5 and 1.5 kg, with a diameter of 15 cm and a height of 10 cm) were positioned on a wooden stand in front of the participants, at a height adjusted in relation to the greater trochanter of their femur and a distance corresponding to 50% of the length of their right upper limbs (Figure 1). For subsequent kinematic analysis of the grasping movement, a reflective marker was positioned on top of each object. The participants wore a black glove in which reflective markers were also placed, specifically on the wrist joint, on the distal phalanx of the first finger, and on the distal phalanx of the second finger of the right hand.

For data collection, a force platform (Biomec 400, EMGSystem do Brasil, SP, LTDA) with a collection frequency of 100 Hz was used.

Dependent variables

- Mean total velocity: time domain variable, expressed in centimeters per second, was calculated from the displacement of the total oscillation of the center of pressure in the anteroposterior and mediolateral directions for the total time of each trial;

- Mean amplitude of center of pressure displacement: time domain variable, expressed in centimeters, was calculated between the maximum and minimum distance from the center of pressure for the anteroposterior and mediolateral directions;

- Area: spatial variable, expressed in centimeters squared, estimates the dispersion of the CP data through the calculus of the statokinesigram area. It was calculated using an ellipse that contains 95% of the center of pressure data, being the two axes of the ellipse calculated through the measures of the center pressure signals dispersion.

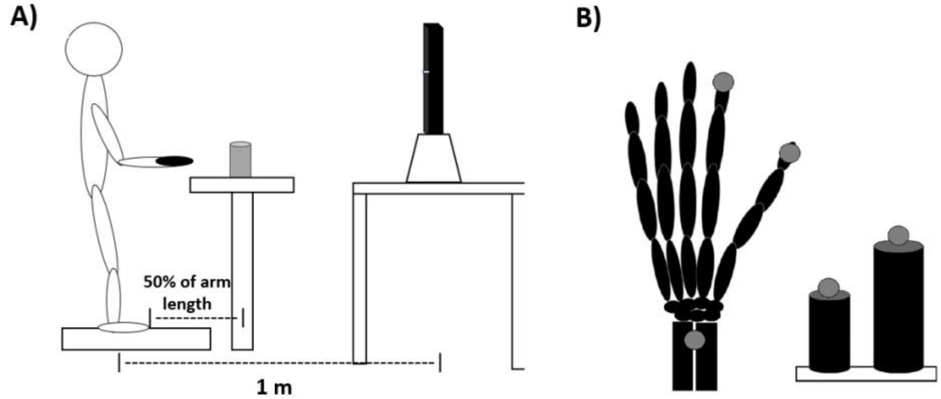

Figure 1. (A) Side view of the experimental setup, with the participant positioned on the force platform, in relation to the object and the screen, (B) Anterior view of the markers on the wrist joint, the distal phalanx of the thumb and of the second finger of the right hand, and on top of the light and heavy objects. Legend: m (meters).

Statistical analysis

The Shapiro Wilk test and Levene's test were used to verify the normality and homogeneity of the data, respectively. If the data differed from a normal distribution, z-score standardization was used for subsequent parametric analysis. One-way ANOVA was carried out to compare age, anthropometric characteristics (height, body mass), and clinical characteristics (age, Baecke assessment scores) between the two groups (young and older adults). To analyze postural control, 2 MANOVAs (groups [young and older adults] X object [none, light and heavy] X surface [rigid and unstable]) with repeated measures were carried out for the following sets of dependent variables: (1) mean velocity in the anteroposterior and mediolateral directions and (2) mean amplitude of displacement in the anteroposterior and mediolateral directions. In addition, an ANOVA with the same factors (group x object x surface) was carried out for area. When necessary, Bonferroni Post Hoc tests were conducted, and a significance level of $p \leq 0.05$ was adopted for all analyses.

RESULTS

Sample characterization

A total of 15 older people, nine women and six men, and 15 young adults, five women and ten men, participated in this study. Table 1 shows the clinical characteristics of the older and young people in this study, the respective statistical tests, and the mean and standard deviation values for the clinical tests (Baecke, MiniBestest, MiniMental).

Table 1. Mean and standard deviation of age, anthropometric characteristics, and clinical characteristics of the young and older adults groups, with the respective statistical analyses (one-way ANOVA).

Clinical Variables	Older adults (n=15)	Young adults (n=15)	ANOVA *(one way)*
Age (years)	65.6 (4.1)	26.4 (5.16)	$F_{1\text{-}28}$ = -526.06, $p \leq 0.001$*
Height (m)	1.62 (0.08)	1.74 (0.075)	$F_{1\text{-}28}$ = 15.93, $p \leq 0.001$*
Body Mass (kg)	65.11 (7.70)	70.36 (12.58)	$F_{1\text{-}28}$ = 1.90, p=0.179
Baecke Questionnaire (points)	14.25 (3.80)	9.42 (1.49)	$F_{1\text{-}28}$ = 20.94 p=0.179
Mini-Mental (points)	27.93 (0.85)	-	-
MiniBESTest (points)	30.0 (1.32)	-	-

Legend: n (number of participants); m (meters); kg (kilogram). *Difference between older adults and young adults ($p \leq 0.05$).

Control postural analysis

The group and interaction effects for the postural control variables will be described below.

COP velocity

MANOVA revealed a group effect (Wilks' Lambda=0.447; $F_{2,24}$= 14.832, $p \leq 0.001$) and a base*group interaction (Wilks' Lambda=0.560, $F_{2,24}$=9.436, p=0.001). ANOVA revealed a group effect for COP velocity in the anteroposterior ($F_{1,25}$=25.132, $p \leq 0.001$) and mediolateral ($F_{1,25}$=28.517, $p \leq 0.001$) directions, and a base*group interaction effect for COP velocity in the anteroposterior ($F_{1,25}$=16.292, $p \leq 0.001$) and mediolateral ($F_{1,25}$=10.363, p=0.004) directions.

Post-hoc tests showed that older adults had higher COP velocity in the anteroposterior direction than young adults (0.740 cm/s | 0.486 cm/s, respectively; $p \leq 0.001$) (Figure 2A). The same happened for the mediolateral direction (1.018 cm/s | 0.685 cm/s, respectively; $p \leq 0.001$) (Figure 2B).

In addition, the post-hoc tests showed that older people, when compared to young adults, had a higher COP velocity in the anteroposterior direction on both the rigid support base (0.612 cm/s | 0.438 cm/s; p=0.002) and the unstable base (0.867 cm/s | 0.534, respectively; $p \leq 0.001$). (Figure 3A). The same pattern was identified for the mediolateral direction on the rigid support base (0.875 cm/s | 0.609 cm/s, respectively; p=0.001) and on the unstable base (1.160 cm/s | 0.760 cm/s $p \leq 0.001$) (Figure 3B).

COP area

ANOVA revealed a base*group ($F_{1,25}$= 6.831, p=0.015) and object*group ($F_{2,50}$=4.290, p=0.002) interaction effect. Post-hoc tests showed that the older adults, when compared to young adults, had a larger COP area on the rigid support base (2.298 cm^2 | 1.052 cm^2, respectively; p=0.002) and on the unstable base (4.058 cm | 1.896 cm, respectively; $p \leq 0.001$) (Figure 3C). The older population, when compared to the young adults, had a larger COP area for the conditions of no object grasping (1.785 cm^2 | 0.693 cm^2, respectively; p=0.001), light object grasping (3.382 cm^2 | 1.479 cm^2, respectively; $p \leq 0.001$), and heavy object (4.368 cm^2 | 2.250 cm^2, respectively; p=0.001) (Figure 3D).

COP displacement amplitude

MANOVA revealed a group effect (Wilks' Lambda=0.411, $F_{2,24}$=17.173, $p \leq 0.001$) and a base*object interaction (Wilks' Lambda=0.473, $F_{4,22}$=6.119, P=0.002). ANOVA revealed a group effect for the anteroposterior ($F_{1,25}$=32.458, $p \leq 0.001$) and mediolateral ($F_{1,25}$=10.774, p=0.003) directions. For the interaction, ANOVA revealed an effect for the mediolateral direction ($F_{2,50}$= 11.011; $p \leq 0.001$).

Post-hoc tests revealed that older adults, when compared to young adults, had a higher mean amplitude of COP displacement in the anteroposterior (1.235 cm | 1.194 cm, respectively; $p \leq 0.001$) (Figure 2C) and mediolateral (2.873 cm | 1.179 cm, respectively; p=0.003) (Figure 2D) directions.

In addition, both groups had a higher mean COP displacement amplitude on the rigid base when grasping a heavy object (3.055 cm) than when grasping a light object (2.690 cm) (p=0.007) or performing the non-grasping task (1.259 cm) ($p \leq 0.001$). There was also a higher mean amplitude of displacement in the light object grasping task than in the non-grasping task ($p \leq 0.001$). Similar results were found for the unstable base: there was a higher mean amplitude of COP displacement in the heavy object grasping task (3.189 cm) and light object grasping task (2.876 cm) than in the non-grasping task (2.086 cm) ($p \leq 0.001$) (Figure 3E).

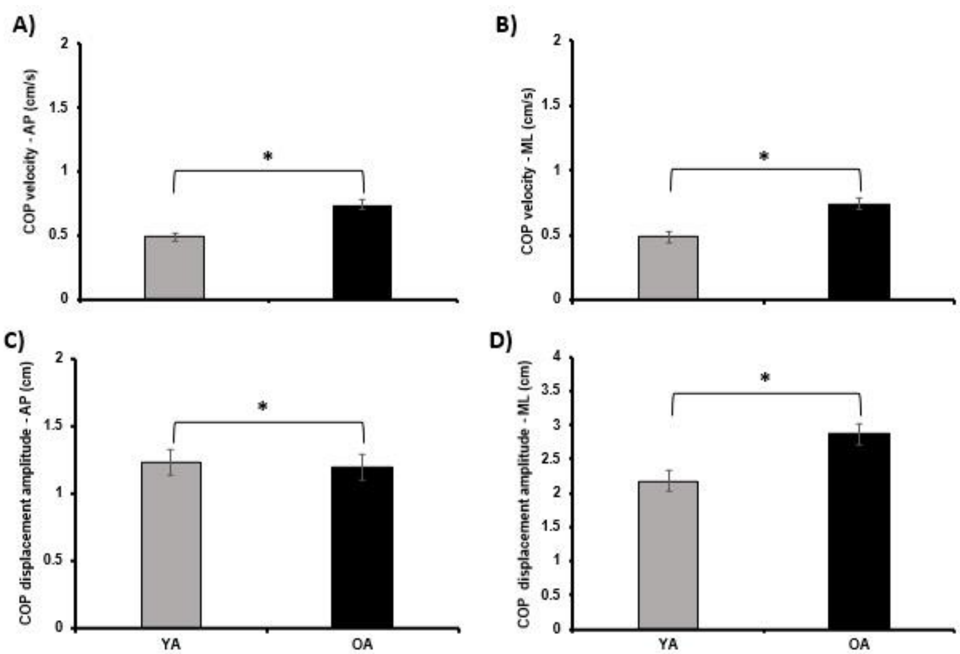

Figure 2. Mean and standard deviation of the group effect between young adults and older adults for the variables (A) COP velocity in the anteroposterior direction, (B) COP velocity in the mediolateral direction, (C) COP displacement amplitude in the anteroposterior direction, and (D) COP displacement amplitude in the mediolateral direction. Legend: YA (young adults); OA (older adults); COP (center of pressure); cm/s (centimeter per second) and cm (centimeter). *Difference between older adults and young adults ($p \leq 0.05$).

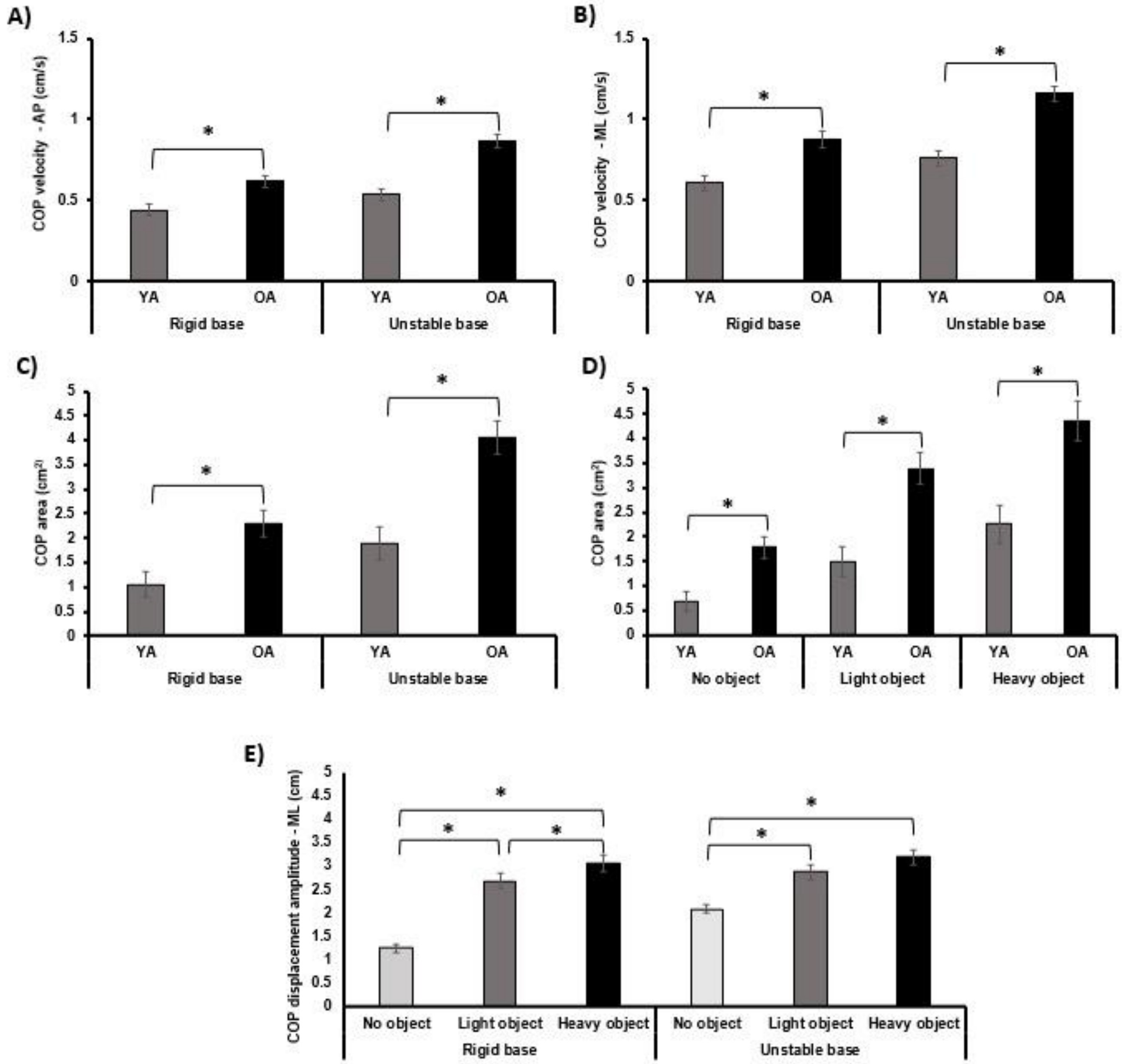

Figure 3. Mean and standard deviation of the group*base effect for the variables (A) COP velocity in the anteroposterior direction, (B) COP velocity in the mediolateral direction, and (C) COP area, of the group*object effect for the variable (D) COP area, and of the object*base effect for the variable (E) COP displacement amplitude in the mediolateral direction. Legend: YA (young adults); OA (older adults); COP (center of pressure); cm/s (centimeter per second), cm (centimeter) and cm2 (centimeter squared). *Difference between older adults and young adults or types of objects ($p \leq 0.05$).

DISCUSSION

The objective of this study was to investigate the postural control performance of older people as they performed the grasping movement, with different levels of task difficulty and complexities of the base of support. The hypotheses of this study were confirmed. Older people had worse postural control performance than young adults. This became even more evident when participants stood on the unstable surface and had to perform more difficult gripping tasks. In addition, for both groups, postural control performance was modulated according to the difficulty of the grasping tasks and the complexity of the bases.

Older adults had a higher velocity and mean amplitude of COP displacement in both directions when compared to young adults. These results demonstrate that older adults have greater COP oscillation, regardless of the task, and that the aging process influences the ability of older adults to maintain postural control. This is because aging causes neurodegenerative changes and acts directly on the performance of postural control, promoting a decline in functional capacity and lowering the efficiency of the systems responsible for postural adjustments [13].

The older population also had a higher velocity in both directions and a larger COP area, especially when standing on the unstable base. This demonstrates that older people have worse postural control performance when in more challenging conditions, such as standing on unstable surfaces. Similar results corroborate this finding, in which older people had worse postural control both in the rigid base and in the unstable base [13], being more evident when submitted to the unstable base [9,12,13]. It is also believed that the motor control of older adults is more affected by the stability of the support surface [18], which makes postural control on unstable surfaces even more difficult.

This happens because the central nervous system of older adults has a reduced capacity to efficiently integrate proprioceptive commands in order to maintain postural control, and because somatosensory deficiencies increase with aging [19]. This becomes even more evident when older people are subjected to more complex tasks, such as standing on unstable support surfaces [13].

Older people also had a larger COP area when performing grasping tasks. This area became larger according to the level of tasks. In other words, the performance of a dual task influences the postural control of older adults, and this is modulated by the level of task difficulty. If a secondary task is performed concurrently with a postural task, attentional resources are divided – this causes older people to have worse postural control performance under a dual-task condition [5], in this case, grasping an object.

Older adults were found to have deteriorated grip strength stability and object holding capacity when performing the reaching movement [3]. This is due to factors caused by aging: the degeneration of the nervous system and the deficits in feedback and movement perception receptors [3]. Older adults also have difficulty dividing their attention between two concurrent tasks, due to neuromuscular alterations [4]. These factors make postural control inefficient in the older people when associated with an object grasping task. This control becomes even worse when the difficulty of the task is intensified, which was done in this study by increasing object weight.

Previous studies [7,8] investigated the influence of dual tasks (calculations and countdowns) on postural control. It was found that the older adults showed an increase in the COP area, which became more evident as they performed increasingly challenging tasks, with the removal of visual information [8]. In addition, older people had a higher mean amplitude of COP displacement when grasping an object [10]. These results corroborate the findings of this study, but the results presented here are unprecedented due to the manipulation of the weight of objects. In summary, older adults showed worse postural control associated with the grasping task. Heavy objects increased the complexity of this task, induced greater COP oscillation, and, consequently, increased the risk of imbalance in this population.

For both groups, the associated grasping and base manipulation tasks influenced postural control. On both bases, participants had a higher mean amplitude of COP displacement in the mediolateral direction when grasping light and heavy objects than when performing the non-grasping task. On the rigid base, this amplitude was higher when participants grasped heavy objects than when they grasped light ones. These results demonstrate that the grasping task influences postural control and that the level of complexity of the task can increase COP oscillation. This is because the recruitment of sensory systems to maintain body stability did not differ between groups, but rather according to the demands of the task and the additional costs to the balance control systems.

When analyzing the motor performance of participants simultaneously walking and grasping objects with different difficulty levels, Rinaldi and Moraes (2015) [20] identified that grasping was superimposed on the walking task, especially when the difficulty level of the grasping task was higher. Thus, the performance of simultaneous tasks can cause a reduction or poor distribution of attentional resources [21] and impair postural control, since attention is divided between maintaining postural control and performing the task [22].

In this study, due to the established experimental protocol, the positions of the light and heavy objects were not manipulated, which may have been a limiting factor and influenced the results. So, it was found that the grasping task with different complexity levels influences postural control, especially in older adults. Future studies should aim to analyze postural control performance in older people grasping objects with different weights and in different positions in an even more unpredictable environment, so that participants are unaware of which object they will grasp and when they will do so. This will enable to investigate how older adults combine neural and sensory mechanisms to achieve better postural control performance in more complex conditions, such as when they need to quickly and accurately reach unknown or different objects in their daily lives.

CONCLUSION

Postural control in older adults is influenced by the base of support and, above all, by the difficulty of the grasping task. This is due to the neuromotor changes caused by aging, which prompt a decline in functional capacity and difficulty in dividing attention between two concurrent tasks. These results are unprecedented, as this was the first study to analyze postural control associated with different difficulty levels in the grasping task, which was manipulated by adding unpredictability to the difficulty level offered by the weight of the objects. These outcomes permits to identify the postural control performance of the older people as they grasp objects under different circumstances in daily activities, as well as how these activities disturb balance. This allows professionals to draw up guidelines for activity training in older adults, improving postural performance during tasks associated with reaching and grasping objects, and preventing falls.

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