Negative effect of task complexity on the balance and mobility of healthy older adults

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Abstract

Objective: to analyze the impact of task complexity on the mobility and balance of healthy older adults. *Methods:* ninety older adults were enrolled in the study. The participants performed tasks that simulated problems common to aging, such as low visual acuity, changes in the base of support and difficulties in carrying out activities simultaneously. Mobility was evaluated with the Timed Get Up and Go test during dual cognitive and motor tasks. Balance was assessed using a force plate with different bases of support and visual information. Cognitive tests were applied to characterize the sample and to analyze the association between the motor and cognitive variables. For statistical analysis, the Friedman test was used to verify the impact of task complexity on the older adults and the Spearman correlation coefficient was used to verify the association between the motor and cognitive variables. Significance was set at 5%. *Results:* task complexity impacted the mobility of participants, with a greater number of steps and time required to complete the test (p=0.001). Similarly, small bases of support and restricted visual information resulted in greater insecurity among the participants in terms of balance reactions (p=0.001). Correlation tests identified significant associations between executive functions and complex motor tasks (p<0.05). *Conclusion:* healthy older adults exhibited motor instability when performing complex tasks, potentiating aging-related changes. The association between the cognitive and motor variables suggests the need of multi-professional care to prepare older adults for their daily challenges.

Keywords: Health of the Elderly. Postural Balance. Mobility Limitation. Accidental Falls. Cognition.

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INTRODUCTION

The aging process is associated with a series of bodily transformations which often deprive individuals of the independence required to carry out their routine activities[1]. In such cases, older adults perceive they no longer have the same dexterity and motor skills they had in the past and that their cognitive processing cannot keep up with the growing demand for information and decision-making that is a feature of today's society[2]. Thus, older adults often find themselves in conflicting situations and, without realizing it, are subjected to conditions that cause risks to their health[3].

Several studies have sought to analyze the impact of aging on people's health, and problems of frailty, balance, motor coordination and muscle strength have been extensively reported in literature[4-6]. However, although the influence of cognition on daily tasks has been investigated in recent years, a significant number of studies have focused their analysis on older adults with dementia – a situation where cognitive decline is prominent and pathological[7,8].

Task complexity is an important aspect of the analysis of the routines of older adults. Healthy older adults are subjected to cognitive demands during their daily activities which cause the focus of their attention to become divided[9]. The cognitive apparatus of such adults needs to be preserved as complex situations require attention, concentration and cognitive processing for their execution. These aspects tend to be influenced by aging and affect the health of older adults[10].

Understanding the changes that occur in the body is important when analyzing the impact of aging on the routine of older adults, and can prevent complications and risks. In the present study, healthy older adults performed complex tasks that potentiated changes common to aging, such as low visual acuity, changes in the base of support and difficulties in performing simultaneous tasks. With such a premise, the intention was to evaluate the impact that task complexity has on the motor apparatus (mobility and balance) of healthy older adults.

The researchers' hypothesis was that the performance of complex activities that potentiate changes common to aging would affect the mobility and balance of older adults, generating risks to their health. Such information may be useful for health professionals focusing on the field of geriatrics and gerontology, as it promotes fresh discussions on the relationship between aging and the complex daily activities of older adults.

METHODS

A cross-sectional research with quantitative data was undertaken. The selection of participants was carried out through a stratified probabilistic approach, with age and sex as selection criteria. Participants were recruited in the city of Campo Grande, Mato Grosso, Brazil, and all subjects provided written consent prior to assessment. The study was carried out in accordance with the Declaration of Helsinki and its protocols were approved by the institutional ethics committee (protocol number 2.305.644; CAAE: 73163817.2.0000.0021).

The inclusion criteria involved participants of both sexes, aged 60 years or over, with no history of neurological or psychiatric diseases, and with higher cognitive scores in the Mini-Mental State Examination (MMSE)[11] than the cut-off points stipulated by Brucki et al.[12]. The normal MMSE parameters for the Brazilian population are: a minimum of 20 points for illiterate people; a minimum of 25 points for people with one to four years of schooling; a minimum of 26.5 points for people with five to eight years of schooling; a minimum of 28 points for people with nine to 11 years of schooling; and a minimum of 29 points for people with more than 11 years of schooling.

The exclusion criteria involved cases of vertigo, participants who used lower limb orthoses or prostheses, wheelchair users, bedridden patients and those who were unable to remain in an orthostatic position for 60 seconds. In addition, those who had been hospitalized or had had surgery in the previous six months were excluded, as were residents of long-term care facilities.

The sample size was calculated assuming a statistical power of 80%, with a type I error of 5% and an effect size of 0.27[13]. The final analysis revealed the need for a minimum of 83 participants, and 110 older adults were originally recruited. Of these, nine were excluded as they did not wish to participate in the study, four were removed due to having lower limb prostheses, and seven were excluded for having cognitive scores below the cut-off point stipulated by Brucki et al.[12]. Thus, 90 older adults made up the final sample of the research, a figure 8.4% above the minimum required sample size.

All the methodological procedures are described in accordance with the STROBE[14] initiative. The participants underwent a two stage evaluation at the Biomechanics Laboratory of the Health Institute of the Universidade Federal de Mato Grosso do Sul (the Federal University of Mato Grosso do Sul). The first stage involved an anamnesis with questions about general aspects such as age, education, marital status, professional occupation, body mass index and physical activity practices, while in the second stage, the researchers used specific tests to assess the cognition, mobility, risk of falls and balance of the participants. All tests were applied randomly in accordance with Latin Square distribution[15].

Cognitive functions were analyzed using the MMSE[11.12] and the Frontal Assessment Battery (FAB)[16]. The MMSE was used to assess the general cognition of the participants. This instrument consists of seven specific categories: temporal orientation, spatial orientation, registration of three words, attention and calculation, immediate and delayed recall of the three words, language and visual-constructive practice. MMSE score ranges from 0 to 30 points and the cutoff points adopted were those defined by Brucki et al.[12] (specifications as previously described).

The FAB was included to assess the executive functions of the participants. This instrument addresses the following cognitive skills: concept recognition, lexical flexibility, motor programming, conflicting instructions, inhibitory control and environmental autonomy. The FAB score ranges from 0 to 18 points and the cutoff points adopted in this study were those established by Beato et al.[17]: a minimum of ten points for people with one to three years of schooling, a minimum of 12 points for people with four to seven years of schooling, a minimum of 13 points for people with eight to 11 years of schooling, and a minimum of 15 points for people with more than 11 years of schooling.

Mobility assessment was performed using the Timed Up and Go (TUG)[18] test, which consists of an individual's ability to get up from a chair, walk three meters, come back and sit in the chair. A greater number of steps and time needed to complete the task indicates an increased risk of falls[19]. In this study, the TUG was applied in three different ways: 1st) normal test, as developed by Podsiadlo & Richardson[18]; 2nd) dual motor task test, where the participant performed the test holding a glass with 100 ml of water in their dominant hand; and 3rd) dual cognitive task test, where the participant performed the test concomitantly with the random naming of animals. These different approaches were applied to analyze the mobility of older adults when performing single and simultaneous tasks. The order of application of the tests was randomized, to minimize the learning effect on the results.

In addition to the mobility analysis, the researchers assessed the risk of falls of the participants, measured herein by the Falls Efficacy Scale International (FES-I)[20] and the number of falls suffered in the previous twelve months. Falling was defined for the participants as any marked imbalance that culminated in unintentional contact between the body and the ground. The FES-I is a quick and easy test to apply, which measures an individual's level of concern about falling during social and physical activities inside and outside their home. In this instrument, higher scores indicate a greater concern about falls.

Postural balance was assessed using a force plate (BIOMEC 400_V4, EMG System®), composed of a 500 mm plate^2, four load cells and a 100 Hz calibration system. This plate was chosen due to its ability to analyze the center of gravity of older adults. Participants performed all tests in their bare feet and were instructed to remain on the plate for 60 seconds, the standardized period in classic tests that assess the body balance of older adults[21].

Balance assessment was based on the variables body displacement (cm), area (cm^2) and postural displacement speed (cm/s). The force plate data were processed using the MATLAB® program (The Mathworks, Natick, MA). The data routine was defined for a sampling of 100 frames per second, with a 2nd order digital low-pass Butterworth filter at 35 Hz. On the force plate, negative values in the anteroposterior and mediolateral planes represented body displacement backwards and to the left, respectively.

The force plate assessments involved four tasks, differing in terms of visual information (eyes open and eyes closed) and base of support (bases of support of 30 and 10 cm). The use of these conditions aimed to simulate changes common to age, such as low visual acuity and an unstable base of support. Like the TUG, the conditions were applied to the force plate in random order, with the objective of minimizing the learning effect on the results. For safety reasons, two researchers remained on each side of the participants during the assessments, in order to prevent falls.

The Shapiro-Wilk and Levenne tests were applied to all data to analyze the normality and homogeneity of variance patterns. Data that exhibited normality and homogeneity in their variance parameters were analyzed by parametric statistics, while those that did not were analyzed by non-parametric statistics.

The independent Student-t, Mann-Whitney U and Fisher tests were therefore used when the aim was to compare the variables of the present study (parametric and non-parametric) in relation to men and women. The Friedman test was applied to verify the effect of task complexity on mobility and the balance variables, and the Wilcoxon post-test was used to perform paired comparisons. Spearman's correlation coefficient (rho) was applied with the sex variable as a covariant factor. The purpose of such an analysis was to investigate the association between the cognitive and motor variables, with the difference between sex controlled in an inferential analysis.

For a better visualization of the findings, the variables are described as number of events, percentage and mean ± standard deviation. In all analyses, the significance level was set at 5%. Outliers were identified as values greater than 3 interquartile ranges, and were excluded from the descriptive and inferential analyzes[22].

RESULTS

Table 1 shows the sex, age, education, marital status, professional occupation, body mass index, physical activity practices, cognition and risk of falls of the participants.

Table 2 details the mobility of the participants during single and simultaneous activities. The results show that women took the same time as men to perform the activity, but required a greater number of steps. The analysis of the impact of task complexity on mobility indicated the effect of the dual cognitive and motor tasks on the participants, with more time and a greater number of steps required to perform the dual cognitive task activity, followed by the dual motor task activity.

Table 3 details the participants' static balance during activities that simulated low visual acuity and a restricted base of support. The results indicated similar responses among men and women for the various activities performed, other than for the base of support area, which was larger among men than women. Complementary analyzes confirmed the impact of visual acuity and base of support on the balance of older adults.

Table 4 shows the Spearman's correlation coefficient between the cognitive and motor variables. The results revealed a significant association between the executive functions and the mobility tests, but weaker associations with the balance tests.

Table 1. General characteristics of the participants (n=90). Campo Grande, Mato Grosso do Sul, 2019.

Variables	Men	Women	*p*
Sample size, %	27.8	72.2	0.001
Age (years)	68.1±7.0	68.6±7.3	0.797
Schooling, %			0.297
Complete higher education	28.0	6.2	
Incomplete high school education	8.0	7.7	
Complete high school education	36.0	23.1	
Incomplete high school education	0.0	0.0	
Complete primary education	16.0	36.8	
Incomplete primary education	12.0	6.2	
Marital status, %			0.001
Single	4.0	15.4	
Married	72.0	41.5	
Divorced	4.0	13.8	
Widow/widower	12.0	27.7	
Civil union	8.0	1.6	
Body Mass Index Kg/m^2	27.1±4.2	27.1±4.3	0.981
Physical activity			0.465
Yes	56.0	66.2	
No	44.0	33.8	
MMSE, pts	27.5±2.1	26.7±2.3	0.134
FAB, pts	15.3±2.1	14.2±2.4	0.030
FES-I, pts	25.0±5.3	25.8±7.8	0.993
Falls			0.064
Yes, %	12.0	32.3	
No, %	88.0	67.3	

Data are expressed in number of events (%) and mean ± standard deviation. *P* values from the Fisher's exact test for sample size, education, marital status, professional occupation, physical activity and falls in the last twelve months. *P* values from the independent Student-t test for age and body mass index. *P* values from the Mann Whitney U test for the MMSE, FAB and FES-I.

Table 2. Impact of task complexity on mobility of participants (n=90). Campo Grande, Mato Grosso do Sul, 2019.

Variables	Single task	Dual motor task	Dual cognitive task	$p_{(task)}$
Time				
Men	10.2±2.2	10.8±2.5	13.8 ± 5.4^{a,b}	0.001
Women	10.8±2.2	11.1±2.7	13.5±4.3^{a,b}	0.001
$p_{(sex)}$	0.248	0.623	0.810	---
Number of steps				
Men	13.4±2.6	13.9±2.3	14.0 ± 3.3^{a}	0.011
Women	15.2±2.2	15.7 ± 2.5^{a}	15.7±3.2	0.001
$p_{(sex)}$	0.004	0.007	0.016	---

The data are expressed in number of events (%) and mean ± standard deviation. *P* values from the U-Mann Whitney test when comparing sex. *P* values from the Friedman test when analyzing the impact of task complexity. Complementary analyzes were performed using the Wilcoxon post-test. ^{a} = means difference in the same group compared to the single task. ^{b} = means differences in the same group compared to the dual motor task.

Table 3. Impact of task complexity on balance of participants (n=90). Campo Grande, Mato Grosso do Sul, 2019.

Variables	BS30-EO	BS30-EC	BS10-EO	BS10-EO	$p_{(task)}$
AP Position (cm)					
Men	-1.0±3.0	-1.1±2.4	-2.9±2.8[a]	-2.0±2.8[b]	0.001
Women	-1.4±2.5	-2.2±2.9[a]	-2.4±2.5[a]	-2.3±3.2	0.001
$p_{(sex)}$	0.311	0.060	0.405	0.452	---
ML Position (cm)					
Men	-0.8±1.5	-0.8±1.6	-0.6±1.0	-0.4±1.0	0.299
Women	-1.2±1.3	-1.3±1.4	-0.9±0.9[a, b]	-0.9±1.1[b]	0.001
$p_{(sex)}$	0.153	0.152	0.193	0.077	---
Area (cm^2)					
Men	2.9±1.4	3.7±2.1	5.4±2.8[a,b]	9.8±6.9[a, b, c]	0.001
Women	2.2±1.8	2.3±1.4[£]	3.7 ± 1.5[a, b]	5.6±3.3[a, b, c]	0.001
$p_{(sex)}$	0.013	0.006	0.006	0.003	---
AP Speed (cm/s)					
Men	1.5±0.6	1.7±0.6[a]	1.4±0.4[b]	2.0±0.8[a, c]	0.001
Women	1.3±0.3	1.5±0.3	1.4±0.3	1.7±0.4[a]	0.001
$p_{(sex)}$	0.431	0.364	0.777	0.051	---
ML Speed (cm/s)					
Men	1.0±0.2	1.0±0.3	1.4±0.4[a,b]	2.0±0.8[a, c]	0.001
Women	1.0±0.3	1.0±0.2	1.3±0.3[a,b]	1.6±0.4[a, b]	0.001
$p_{(sex)}$	0.788	0.555	0.651	0.035	---

BS30-EO: Base of support of 30 cm, eyes open. BS30-EC: Base of support of 30 cm, eyes closed. BS10-EO: Base of support of 10 cm, eyes open. BS10-EC: Base of support of 10 cm, eyes closed. AP: anteroposterior. ML: mediolateral. The data are expressed in mean ± standard deviation. *P* values of U-Mann Whitney test when comparing sex. *P* values of the Friedman test in analysis of the impact of task complexity. Complementary analyzes were performed using the Wilcoxon post-test. [a] = difference in the same group compared to BS30-EO; [b] = difference in the same group compared to BS30-EC; [c] = difference in the same group compared to BS10-EO.

Table 4. Spearman correlation index (rho) between motor and cognitive variables (n=90). Campo Grande, Mato Grosso do Sul, 2019.

Motor variables	Cognitive variables	
	MMSE	FAB
FES-I	-0.247*	-0.153
Simple TUG		
Time	-0.031	-0.468*
Number of steps	-0.044	-0.394*
TUG with dual motor task		
Time	-0.012	-0.475*
Number of steps	0.036	-0.460*
TUG with dual cognitive task		
Time	-0.019	-0.376*
Number of steps	0.029	-0.361*

to be continued

Continuation of Table 4

Motor variables	Cognitive variables	
	MMSE	FAB
30 cm base eyes open		
AP Position	0.027	0.212
ML Position	0.108	-0.240*
Area	-0.081	-0.273*
AP Speed	-0.166	-0.212
ML Speed	-0.093	-0.205
30 cm base eyes closed		
AP Position	0.193	0.097
ML Position	0.085	0.130
Area	0.117	-0.070
AP Speed	0.096	-0.100
ML Speed	0.027	-0.170
10 cm base eyes open		
AP Position	0.108	-0.231*
ML Position	0.004	0.035
Area	-0.189	-0.131
AP Speed	-0.161	-0.154
ML Speed	-0.213	-0.143
10 cm base eyes closed		
AP Position	-0.042	0.050
ML Position	-0.074	-0.257*
Area	-0.102	0.036
AP Speed	-0.083	0.001
ML Speed	-0.160	0.043

MMSE: Mini Mental State Exam FAB: Frontal Assessment Battery. FES-I: Falls Efficacy Scale International. TUG: Timed Up and Go. AP: Antero-posterior. ML: Mediolateral. Significant correlations are highlighted with asterisks.

DISCUSSION

The present study investigated the impact of task complexity on the mobility and balance of older adults. The results showed that, in healthy older adults with a low risk of falls, task complexity impacted mobility, with individuals requiring a greater number of steps and a longer period of time to perform the activity. Similarly, a restricted base of support and reduced visual information caused greater insecurity in participants when remaining in an orthostatic position. Understanding these results is important for the development of therapies capable of reducing health risks for older adults.

The initial aim of the study was to include a similar number of men and women in order to investigate the impact of task complexity on both groups. The reality observed, however, included considerably more women than men. Factors that explain this scenario are related to the higher life expectancy of women and their tendency to be more proactive in research projects than men[23].

Regarding cognitive functioning, the groups were similar for overall cognition, but diverged in relation to executive functions. The FAB differs from the MMSE in that it focuses its analysis on the executive functions of subjects, which are mainly associated with the prefrontal cortex[24]. The MMSE, in contrast, is responsible for an overall analysis of cognition and is used to track cases of dementia in combination with a clinical evaluation of the patient[25]. The difference in executive functioning between groups, while statistically significant, is not clinically relevant, as it describes normal FAB scores according to the reference values identified by Beato et al.[17]. In addition, this divergence of scores between men and women may have been influenced by the level of schooling of women (slightly lower than that of men) and the routines of women (linked in this study to household activities). As the FAB scale is influenced by both factors[26,27], it is likely that these aspects impacted the final score of women, without identifying signs of cognitive decline.

Most participants reported that they had not suffered falls in the previous twelve months. On the FES-I scale, the subjects had scores corresponding to a sporadic risk of falling[28]. Even with these parameters, health professionals should not neglect older adults with a low risk of falls, as the participants in the present study, despite falling infrequently, suffered the impact of complexity of task on their mobility and balance.

The researchers' initial hypothesis was confirmed when the impact of task complexity on the time and number of steps required to complete the TUG test was observed, a result that corroborates the findings of previous studies[29,30]. Interestingly, both men and women had greater difficulty performing the dual cognitive task activity than the dual motor task activity. This proves the impact of challenging cognitive situations on the daily lives of older adults, especially when the focus of attention is divided between more than one activity performed simultaneously.

Women were found to require more steps to perform mobility tasks than men, although this difference was not observed in relation to the time variable. Several factors may be associated with this finding, such as stride length, fear of suffering falls and cognitive functions. Further studies should be carried out to address this theme and investigate the topic in greater depth.

In relation to stabilometric measures, the participants presented oscillations in balance when subjected to a restricted base of support and imprecise visual information. Both factors impacted the balance of healthy older adults, corroborating previous studies[31,32]. As poor vision and an unstable base of support are common in aging, the results suggest the use of different bases of support and visual aids during rehabilitation procedures as a way of encouraging older adults to deal with daily motor challenges.

Regarding the association between the cognitive and motor variables (Table 4), the MMSE, which assesses overall cognitive aspects, was not associated with measures of mobility and balance. The FAB, in contrast, revealed a significant association, especially with mobility tests. These results reinforce the interference of the prefrontal executive functions in the daily motor activities of older adults. The authors attribute the few, weak associations between executive functions and stabilometric tests to the fact that the activities performed on a force plate involve physical restrictions (a restricted base of support and imprecise visual information), but present low cognitive demands.

Although the correlations were significant between executive functions and mobility, the analyzes identified weak ($0.10<|r_s|<0.39$) and moderate ($0.40<|r_s|<0.69$) intensities[33]. This reveals that factors other than executive functions are associated with the mobility of older adults. Further studies should address this issue and seek to identify other factors that are associated with mobility in the population in question.

Certain limitations should be considered when assessing the results of the present study. Firstly, the sample was composed predominantly of "younger older adults". Difficulties in including older seniors are related to mobility problems, high rates of hospitalization, the inability to attend the assessment center and a higher prevalence of cognitive decline[34]. Secondly, the number of men was significantly lower than the number of women. Finally, the correlations between cognitive and motor tests, although significant, were weak and moderate in scale – which indicates that there may be other factors, not included in the present study, associated with mobility and balance.

CONCLUSION

Healthy older adults experienced mobility and balance difficulties when performing complex tasks. The association of cognitive and motor variables reinforces the impact of prefrontal executive functions on the mobility of older adults, and suggests the importance of multiprofessional rehabilitation in stimulating such individuals to face daily challenges. Further research must be carried out to analyze whether other factors impact the mobility and balance of older adults, in addition to the variables analyzed in the present study.

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