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Postural control performance of active and inactive older adults during manipulation of sensory information tests: a cross-sectional study

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HIGHLIGHTS

- This study compared the postural balance of active and inactive elderly women in situations involving manipulation of sensory systems.
- This study corroborates the literature on the importance of physical exercise practice as a preventive strategy to reduce the occurrence of falls.
- Active elderly present reduced dependence of visual inputs and improved somatosensory afferences when compared to inactive elderly.
- Active elderly present higher COP average displacement speed than inactive elderly.

ABBREVIATIONS

ADL	Activities of daily living
ap	Anteroposterior
CNS	Central nervous system
COP	Center of pressure
COPap	COP displacement in the ap direction
COPml	COP displacement in the ml direction
COPvel	COP avarage displacement speed
Fap	Ground reaction force ap component
FLP	Foam-laser Dynamic Posturography method
Fml	Ground reaction force ml component
Fv	Ground reaction force vertical component
h	Distance from the surface to the geometric center of the platform
Map	Moment about the anteroposterior axis
ml	Mediolateral
Mml	Moment about the mediolateral axis
MMSE	Mini Mental State Examination
TOS	Sensory Organization Test

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BACKGROUND: Inactivity during the aging process negatively influences postural control.
AIM: The aim of the present study is to evaluate the postural balance of active and inactive elderly women in situations involving manipulation of sensory systems.
METHOD: The study included 20 elderly women (10 active and 10 inactive) with a mean age of 63.45 ± 2.37 years, who underwent postural balance assessment using a force platform in the six conditions of the Sensory Organization Test. For comparison between groups, the Student's t-test and Mann-Witney test were used. Statistically significant differences were observed between the groups for the three balance variables analyzed: Center of pressure displacement in the anteroposterior direction (COPap), in the mediolateral direction (COPml) and average speed (COPvel).
RESULTS: In situations in which the somatosensory system was not disturbed, as Sensory Organization Test (TOS) I, II and III, it was observed that active elderly women presented smaller COPap and COPml than inactive, however, in tests in which the somatosensory system was disturbed, due to the addition of a cushion between the platform and the individual's feet (TOS IV, V and VI), this difference was not observed. Furthermore, active elderly present higher COP displacement average speed than inactive elderly in almost all sensory tests (TOS I, III IV, V and VI).
CONCLUSION: It can be concluded that active elderly presented reduced dependence of visual inputs and improved somatosensory afferences when compared to inactive elderly and that active elderly presented higher COP average displacement speed than inactive elderly.

KEYWORDS: Postural balance | Elderly | Physical exercise

INTRODUCTION

Aging is characterized as a progressive and natural process with constant changes, biologically, functionally and structurally [1]. It is a process that can alter the neuromuscular, somatosensory, vestibular and visual systems [2], which can influence postural stability, generating deficits in the postural control system [3].

In this context, it is known that balance is a complex function that requires the integration of the somatosensory, visual and vestibular systems, and the organization of this information by the central nervous system (CNS), which will generate neuromuscular responses [4,5]. In this way, it can directly impact the activities of daily living (ADL) of the elderly [3,6,7]. In the literature, there are studies that emphasize that these progressive changes delay the feedback of information, affecting postural control and consequently increasing the risk of falls [8,9].

Falls occur when the individual loses control of their center of gravity and there is insufficient recovery of balance [10]. In this way, they are characterized as any type of unintentional displacement to a level lower than the level before, with the inability to correct in a timely manner, even if a fall to the ground does not occur [11].

The causes of the increased risk of falls in the elderly can be multifactorial and subdivided into intrinsic, extrinsic and behavioral factors [12]. Thus, it becomes a serious public health issue related to the age of individuals over 60 years old, as it has consequences such as increased risk of subsequent falls, hospital readmission, functional decline, mortality, fear of falling again and social isolation [8,13].

The practice of physical activity acts as an essential factor in maintaining functional fitness and postural balance, reducing the negative effects caused by the aging process, even delaying some restrictions regarding the performance of ADLs, prolonging the active life span of this population as well as reducing the rate of falls in the elderly population [14,15,16].

Studies have shown that physical inactivity harms the systems that act in postural control [17,18] as well as that with the practice of physical activity there is an improvement in functional, coordinative and neuromotor capacity [19]. Furthermore, there are indicators that show that exercises improves postural and neuromotor stability, such as a decrease in the total speed of the trajectory and area of sway in the anteroposterior direction with eyes open and closed and bipedal support [17,20]. However, it is still necessary to investigate which sensory systems physical exercise influences the most, so strategies and interventions can be proposed in order to focus on the system in question.

The amplitude and speed of body sway in the mediolateral and anteroposterior directions are frequently investigated COP variables [9,21-23] and are used to predict the risk of falls in the elderly [24-26] in addition to the sensory organization test, through assessment by Foam- laser Dynamic Posturography (FLP) method, which analyzes the relative contribution of the somatosensory, visual and vestibular systems to the individual's body stability, indicating the system responsible for instability, it is possible to infer that the use of the aforementioned tests can concomitantly bring interesting information about the means these systems contribute to postural control.

In this context, the aim of the present study was to evaluate the postural balance of active and inactive elderly women in situations involving manipulation sensorial to analyzes the relative contribution of sensory systems. Assessments of the visual, somatosensory and vestibular systems were carried out with eyes open and closed, with an unstable and stable surfaces and with and without a mobile cabin.

METHODS

This is a cross-sectional study, approved by the Ethics and Research Committee of the Federal University of Santa Maria (CAAE – 010.0.243.000-08), in accordance with the standards established in Resolution 466/12 of the National Health Council on research involving human beings.

Participants

The study included 20 elderly women who met the inclusion criteria: aged between 60 and 80 years, scoring above 26 points on the Mini Mental State Examination (MMSE), complying with the Informed Consent Form. The sample selection was for convenience, and for the group of active elderly women, elderly women who practice water aerobics at the Federal University of Santa Maria (UFSM) were invited, and those who performed physical exercises at a frequency equal to or greater than 150 minutes per week in the last three months [27] were included. For the group of inactive elderly women, elderly women were invited from a long-term care institution for elderly people living in Santa Maria-RS who had not performed physical exercise for 150 minutes per week in the last three months28. Individuals who had known neurological disease, acute orthopedic trauma, severe visual impairment and/or used medications capable of influencing the tests were excluded from the study.

To calculate the sample size, G*Power software version 3.1.9.2 was used, in which an $\alpha = 0.05$ was adopted, a power of 90%. Of the variables to be investigated in the present study, the results found in the study by Meereis et al. [16], referring to the amplitude of COP displacement in the mediolateral direction during the Sensory Organization Test (TOS 1) were used to support the sample calculation. Thus, the effect size was 1.42, therefore the minimum "n" of 10 individuals in each group was adopted.

Procedures

The research was carried out in the biomechanics laboratory of the Center for Physical Education and Sports (CEFD) at UFSM. First, an anamnesis and assessment of the level of physical activity [27] and MMSE were carried out to identify cognitive function. Soon after, anthropometric data such as body mass and height were collected using a scale and a Welmy stadiometer, respectively.

The group was composed of 10 active elderly women and 10 inactive elderly women, with similar anthropometric characteristics, illustrated in table 1.

Table 1. Anthropometric Characteristics.

	Active Elderly n= 10 Mean ± SD	Inactive Elderly n=10 Mean ± SD	T-Test	Mann-Whitney Test
Age (years)	61,35 ± 2,80	62,95 ± 2,87	0,183	
Height (m)	1,53 ± 0,12	1,54 ± 0,05		0,932
Mass (kg)	73,42 ± 7,03	75,34 ± 7,55	0,516	
BMI (kg/cm^2)	29,56 ± 5,67	31,50 ± 3,63	0,585	

n= number of individuals in the group; BMI = body mass index; p-value = probability value in Student's t test, indicates a statistically significant difference if $p < 0.05$.

The assessment of postural control was carried out using a force platform (OR6-6, Advanced Mechanical Technology Incorporation, USA), during sensory manipulation, which was carried out through the sensory organization test (TOS), using posturography dynamics validated by Castagno [28]. For the evaluation, each participant was positioned the force platform in a one m^2 cabin, two meters high.

Individuals were asked to remain standing barefoot on the platform during the six conditions following sensory organization test (TOS), with feet positioned hip-width apart for 30 seconds after the individual was stabilized. The support base was marked on each individual's first attempt on graph paper so that the positioning of the lower limbs could be repeated in all conditions. For unstable support surface conditions, an AIREX® Balance Pad (Airex AG, Inc.) flexible foam cushion was added on the platform with dimensions of 50 cm long, 50 cm wide and 10 cm thick and density, calculated by indications Patel [29], of 80 kg/m^3.

Hereinafter the six conditions of the sensory organization test are presented:

- TOS I) Individual with eyes open and fixed horizontally, stable support surface (feet supported on the force platform), fixed visual cabin. This test evaluates the visual, somatosensory and vestibular systems.
- TOS II) Individual with eyes closed, stable support surface. Assessment of the somatosensory and vestibular systems.
- TOS III) Eyes open, stable foot support surface, oscillating visual cabin, 10 seconds manually tilted forward and 10 seconds to return to the starting position. It evaluates the somatosensory, vestibular and, above all, visual systems.
- TOS IV) Eyes open, fixed visual cabin, unstable support surface (with the addition of a foam cushion between the person's feet and the platform). It mainly evaluates the somatosensory system.
- TOS V) Eyes closed, fixed visual cabin, unstable support surface. This test evaluates the somatosensory and vestibular systems under overload conditions.
- TOS VI) Eyes open, unstable support surface with oscillating visual cabin. Assessment of the somatosensory, visual and vestibular systems.

Three attempts were made in each condition, with a 1-min interval between them, totaling 18 attempts. The order of tests was randomized for each participant. The displacement of the center of force overtime results in a trajectory which is related to the movement of the center of mass [21] and, therefore, related with postural control. The COP position is calculated each time:

$$COPap = (Mml - h \cdot Fap) / Fv$$

$$COPml = (Map - h \cdot Fml) / Fv$$

Where COPap denotes center of pressure displacement in the anteroposterior direction; COPml denotes center of pressure displacement in the mediolateral direction; Map denotes moment about the anteroposterior axis; Mml denotes moment about the mediolateral axis; Fap: ground reaction force anteroposterior component; Fml denotes ground reaction force mediolateral component; Fv denotes ground reaction force vertical component, h denotes distance from the surface to the geometric center of the platform.

The variables analyzed were center of pressure displacement in the anteroposterior direction (COPap), in the mediolateral direction (COPml) and center of pressure average displacement speed (COPvel). The frequency used to acquire data from the force platform (forces and moments) was 100 Hz. The raw data from the platform were filtered by a 4th order Butterworth low-pass filter at a frequency of 10 Hz, thus eliminating possible interference from the environment.

Statistical Analyses

For statistical analysis, SPSS Software (Statistical Package for the Social Science) version 13.0 for Windows was used. To analyze the distribution of data, the Shapiro-Wilk test was performed. Then, the Student's t test was performed for data with normal distribution and the Mann-Witney test for data with non-normal distribution for comparison between groups. For all tests, a significance level of 5% was used.

RESULTS

The results of the study are described below. Table 2 illustrates the behavior of COPap, COPml and COPvel during the execution of the six sensory organization tests.

Table 2. Balance test statistical data

		Active Elderly n= 10	Inactive Elderly n=10		
		Mean ± SD	Mean ± SD	T-Test	Mann-Whitney Test
TOS I	COPap (cm)	1,27 ± 0,69	2,74 ± 0,94		< 0,01*
	COPml (cm)	0,59 ± 0,30	1,70 ± 0,69	< 0,01*	
	COPvel (cm/s)	3,22 ± 1,70	1,26 ± 0,28		< 0,01*
TOS II	COPap (cm)	1,78 ± 0,74	2,59 ± 0,83	0,02*	
	COPml (cm)	1,00 ± 0,60	1,31 ± 0,51		< 0,01*
	COPvel (cm/s)	3,58 ± 1,44	1,40 ± 0,42		0,11
TOS III	COPap (cm)	2,38 ± 1,26	3,74 ± 1,21		0,03*
	COPml (cm)	0,94 ± 0,57	2,22 ± 1,04	< 0,01*	
	COPvel (cm/s)	3,43 ± 1,09	1,76 ± 0,64	< 0,01*	
TOS IV	COPap (cm)	2,14 ± 0,61	3,32 ± 1,77		0,03*
	COPml (cm)	1,24 ± 0,37	2,60 ± 2,49		0,10
	COPvel (cm/s)	3,64 ± 1,47	1,70 ± 0,72		< 0,01*
TOS V	COPap (cm)	3,54 ± 1,16	4,70 ± 1,69	0,05	
	COPml (cm)	1,97 ± 1,00	2,20 ± 0,86		0,35
	COPvel (cm/s)	4,19 ± 1,30	2,23 ± 0,67		< 0,01*
TOS VI	COPap (cm)	6,83 ± 5,75	6,41 ± 1,83		0,37
	COPml (cm)	3,37 ± 4,75	3,13 ± 1,11		0,26
	COPvel (cm/s)	5,38 ± 2,56	2,69 ± 0,96		< 0,01*

COPap = displacement of the center of pressure in the anteroposterior direction; COPml = displacement of the center of pressure in the medio-lateral direction, VM = Average velocity of COP displacement. * < 0.05.

DISCUSSION

Active elderly women demonstrated less postural sway, which infers better postural control and a lower risk of falls then inactive elderly women. By specifically analyzing the COP sway amplitude in different TOS conditions on a stable support surface, that is, TOS I, II and III, statistically significant differences were found for all postural balance variables analyzed. Indicating the contribution of the sensory systems responsible for postural balance without manipulating the somatosensory system.,

In relation to TOS I, a situation in which information from the visual, vestibular and somatosensory systems were present, the COP displacement amplitude was significantly smaller in the group of active elderly women for both COPap and COPml, inferring that exercise promotes better postural control, corroborating other studies [16,22]. Similarly, in TOS II and TOS III, when visual information is suppressed and respectively manipulated, the COPap and COPml displacement values from active elderly were lower than inactive. Elderly people generally depend more on visual inputs, and the results of this study indicated that active subjects presented better postural performance and managed sensory conflicting situations in a better way when compared to inactive subjects. Given this, it can be inferred that exercise can mitigate the risk of falls in situations where vision is compromised, such as, in situations of low vision or low light, circumstances which generate greater postural instability for the elderly [31].

In situations of TOS IV, V and VI when an unstable support surface is added, hindering the action of the somatosensory system, the active elderly women obtained statistically significant lower values only in one of six variables (COPap on TOS IV). From this result, it can be observed that when somatosensory inputs were distorted, the sway amplitude of the two groups was similar. This finding corroborates other studys [32] meaning that physical exercise improves somatosensory afferences, since it indicates that the active elderly group depend of undisturbed somatosensory inputs to present better balance control than inactive group.

Regarding COPvel, it can be observed that active elderly women presented statistically significant higher COP displacement speed in most tests (TOS I, TOS III, TOS IV, TOS V, TOS VI), differently from other studies that compared active and inactive elderly women [22,36]. However, the present study suggests that active elderly women are able to make postural adjustments more quickly, ensuring the maintenance of postural control, demonstrating that the central nervous system was able to change the trajectory of sway quickly in order to ensure that balance was not threatened. This is important, since the ability to make postural adjustments necessary for adequate postural control is reduced with aging, especially in complex tasks [9,37].

Several authors have found a relationship between better postural control and physical exercise [16,33,34], showing that losses related to postural control are related not only to the aging process, but also to physical inactivity, thus, the practice of physical exercises is capable to improve the balance of inactive elderly women. In relation to this, Patti and collaborators [35], state that the practice of physical exercises favors the improvement of the conditions for receiving sensory information from the vestibular, visual and somatosensory systems and also activates the antigravity muscles, in addition to limiting the loss of muscle mass and strength, which is reinforced by the results of the present study.

This study as any cross-sectional analysis has certain limitation. The group of inactive elderly woman was institutionalized, so some characteristics arising from institutionalization can provide to these elderly more inactivity than living in community. However, the influence of institutionalization on elderly physical activity wasn't the aim of this study.

Despite the limitations, the present study reinforces that postural control is influenced by the practice of physical exercise and active elderly women have a smaller COP displacement compared to inactive elderly women [9,38,39]. This reinforces the idea that the lower postural control and consequent higher risk of falls among inactive elderly women may not only be due to the aging process, but also to factors related to physical inactivity [18,40].

CONCLUSION

This study corroborates the literature on the importance of practicing physical exercise as a preventive strategy to reduce the occurrence of falls because (a) it demonstrates that active elderly present reduced dependence of visual inputs when compared to inactive elderly; (b) somatosensory afferences were improved and (c) higher COP average displacement speed can reflect the ability to make postural adjustments more quickly in order to maintain a postural control.

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