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Acute and Chronic Effects of Exercise in Health

Postural control and kinematics of lower limbs in older adult practitioners of strength exercises

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Abstract - Background: One of the main problems faced by older adults for a good quality of life are falls, which are related to aging and reductions in visual acuity, strength and postural control capacity. **Objectives:** To investigate postural control of strength exercise practitioners and non exercise practitioners in a postural control task with visual disturbance, in order to verify the collaboration of different sensory systems. **Methods:** Sixteen older women participated in this study (strength exercise: GM = 7; non exercise practiotioners: GNP = 9). For the evaluation of postural control, a force plate and an optoelectronic capture system were used, both at 120 Hz. The task performed by the participants consisted to observe three different images related with the participation of the visual system and stay as stable as possible. The data of amplitude, mean velocity, area, DOT, mid-lateral intensity and anteroposterior intensity were processed in three wavebands. Is study was approved by the Ethics Committee on Re-search Involving Humans (CAAE 53867816.5.0000.5231). **Results:** The results indicated significant differences in mid-lateral intensity variable percentages in the different conditions when compared GM to GNP. For the amplitude of knee and ankle relative angle and the standard deviation in the sagittal plane, there were no significant differences between groups. **Conclusion:** Thus, it is concluded that strength exercise practice seems to allow older women to be more susceptible to changes in postural control variables among different wavebands related to sensory systems.

Keywords: aging, exercise, postural balance, resistance training, vision.

Introduction

In the last decades, there was an increase in the number of older people in Brazil[1,2], from 8.6% to 11% of the country's total population, representing, in absolute numbers, from 15 to 20 million older people, from the beginning of the century until 2010[3]. With this increase, concerns about quality of life arise, which is directly related to older independence and autonomy. One of the factors related to life quality are falls, being one of the main factors of mortality and morbidity in this population range[4]. The increase in the incidence of falls with older adults is related to decrease at postural control and also a decrease in other systems, mainly due to aging[5].

For a good postural control it is necessary the integration and functioning of the visual, vestibular, somatosensory, proprioceptive, neural and muscular systems. The visual system has great importance for control in the upright posture tasks, being responsible for approximately 50% of the control of the body oscillation in static situations[6].

Reductions in the systems related to postural control performance also may occur as consequence of limitations in muscle strength[7], while the strength is affected directly by quantity of muscle mass[8]. Strength exercises practice is appointed as an efficient way of providing older adults functional capacities and contraction muscle capacity maintenance or improvement[9]. As the same way, it is important for majority of older population to have some of their capacities classified as "regular"[10].

Other systems have specific functions at postural control. Vestibular system sends information to central nervous system about the guidance of the head, detecting the temporal variations of velocity[6]. The somatosensory system, which has receptors spreaded throughout the body, sends information about different stimuli, such as touch, pain, temperature, and body position[11]. The proprioceptive system is responsible for continuously notify central nervous system about the position of one limb in relation to the other[6].

The frequency band analysis has been investigated to clarify how much are sensory systems contributed to postural control in the different groups analyzed. Different frequency bands were analyzed by Bernard-Demanze et al.[12] in adults and older adults, with cognitive and sensory demands in a postural task. The visual system was related to lower frequencies (0.05-0.5 Hz), vestibular/somatosensory system to median frequencies (0.5-1.5 Hz) and proprioceptive system to the highest frequencies (1.5-10 Hz). The latter is related to the aging process or pathological postural control and under dynamic conditions[13,14]. In addition, Kleiner et al.[11] (2011) have demonstrated the functioning of each of these systems, as well as the sensory receptors that comprise them, thus it is possible to relate the frequencies of each system with receivers types which collaborate to operation with them. So, the higher frequency values of a system can be attributed to aggregation of this receptor with muscle activation.

Due to these aspects, one of the questions raised is: how the practice of strength exercises would relate to the postural control and what would be the demands of other sensorial systems for this control?

In this sense, the purpose of this study was to investigate strength exercise practitioners and non-practitioners postural behavior during a visual disturbance postural control task, in order to verify the collaboration of different sensory systems to postural control.

Methods

Participants

This is a study accomplished in Londrina, located in the state of Paraná, Brazil. Seven older women practitioners of strength training (GM = 67.2 ± 4.6 years, 68.6 ± 11.9 kg, 155.5 ± 5.1 cm) and nine non-practitioners older women (GNP = 65.8 ± 6.4 years, 70.6 ± 19.1 kg, 153.5 ± 3.9 cm) who were not involved with any physical activities regularly in the last six months.

Due to retrospective cross-sectional character of the study, the GM provided information about mean time of practice (5.34 ± 5.01 years), mean week frequency (4 ± 1.2 sessions per week) and each session mean duration (71 ± 24.2 min).

Protocol

All participants were invited to read and sign a free and informed consent form, in order to be aware of all procedures adopted in the study, which was approved by the Ethics Committee on Research Involving Humans under protocol number #1.480.603 (CAAE 53867816.5.0000.5231). The tests were performed in a single experimental session, with duration of approximately 30 min.

Tasks and materials

For evaluate the participants body oscillation, force plate was used (AMTI, AccuGait, Watertown, MA, USA), in which three experimental conditions were performed.: In the control condition (condition 1), the participant stood barefoot, feet shoulder-width apart and looked at a fixed point (orange circle 15 cm in diameter) located 3 m away from the force plate and positioned in relation to the Frankfurt plane[15].

In experimental condition 2, the participant performed the same task of experimental condition 1, but the participant visually followed a two-dimensional (2D) sphere that moved counterclockwise in a circular manner in a projection in front of her (consider moment 1). In the experimental condition 3, the participant performed the same task as in condition 2, but now the sphere moved in the same direction with a change of its radius, simulating depth displacement (three-dimensionality, 3D). In all experimental conditions, the researcher remained with the participant to assure him protection and assistance during the data collection. Each experimental condition had duration of 60 s (considering only the 30 s central for analysis) and the frequency of acquisition adopted by force plate was maintained at 120 Hz. Three trials were performed for each experimental condition, resulting at nine trials throughout the experimental session. The inter-test interval was one minute.

The figures used in the tasks were projected by a projector (Sony, model VLP-EX3) in three different conditions: Condition 1 was composed by the projection of an orange circle with 15 cm in diameter, which remained unmovable in the center of projection screen; its height was adjusted in relation to the Frankfurt plane and 2 m away from the wall. In condition 2 the circle has traveled in a circular path in the counterclockwise direction. The center of the orange circle traveled a path over a radius of 22 cm completed a lap in 2 s. In condition 3, the parameters used remained the same as the previous condition, except that in this condition there was a change in the radius of the circle divided in two moments. At moment 1 the radius of the circle remained in its integral size (11 cm) and in moment 2 the radius decreased until approximately 55% of the size (6 cm) of the initial radius, and the moment transition period was 2.6 s (the same time required for the circle to travel twice over the complete path). The radius change occurred gradually, always alternating between the two moments (Figure 1).

To evaluate the amplitude of the angular range of lower limbs during the tasks, an optoelectronic capture system (Optitrack® - Optical Motion Capture Solutions) was used, with six Prime 13 cameras with frequency of acquisition of 120 Hz, integrated with real-time image capture.

During all tests, participants wore shorts or tight pants to the body, for movement component of the suit (which does not represent the actual movement of the segment) did not interfere with the accuracy of the data. The passive markers were fixed at the following anatomical points: lateral of the fifth metatarsal, lateral malleolus, lateral epicondyle, and the greater trochanter on the right side of the participants.

Data treatment

The processing of force plate variables was performed by data filter with a third order bandpass Butterworth filter in the three frequency ranges (0.05-0.5 Hz, 0.5-1.5 Hz and 1.5-10 Hz) related to sensor systems[12,14,16]. Kinematic data were smoothed using a 5th order low-pass Butterworth filter with a cut-off frequency of 6 Hz defined after spectral and residual analysis[17].

Variables analysis

The force plate variables were computed separately in lateral and anteroposterior axis: amplitude and total mean velocity of the signal. Additionally, both CoP coordinates were used to calculate the total oscillation displacement (DOT) and the area as the main variables for global analysis of pressure center measured by force plate[18].

The variables provided by the kinematic analysis were the amplitude of knee and ankle relative angle and the standard deviation, in the sagittal plane, performed by the participants for each trial. The amplitude of angular variation is given by the subtraction of the maximum value by the minimum, while the standard deviation in degrees (°) is the dispersion value around the mean angle values during the trials.

Statistical analysis

All data processing and statistical analysis were performed by Matlab (version 2009) and SPSS (version 20), respectively. In the analysis, the variables did not meet the normality assumptions, and only the kinematic variables and the intensity variable in the anteroposterior direction (IntAP) attended of variance homogeneity assumption. Thereby, to compare the conditions in each specific frequency range between groups we used the Mann-Whitney test.

For the comparison of the control conditions in the intra-group analysis, we chose the Friedman ANOVA test. The level of significance was set at $P < 0.05$.

Results

Figure 2 presents the median and quartile values corresponding to displacement amplitude and total mean velocity variables. Figure 3 displays center of pressure (COP) percentage intensity in the anteroposterior (AP) and lateral (ML) directions, area and displacement of the total oscillation (DOT) of both groups (GM and GNP).

For intra-group comparisons, in the GNP the percentage intensity in the higher frequencies in 3D condition presented lower values ($P = 0.01$) than the same

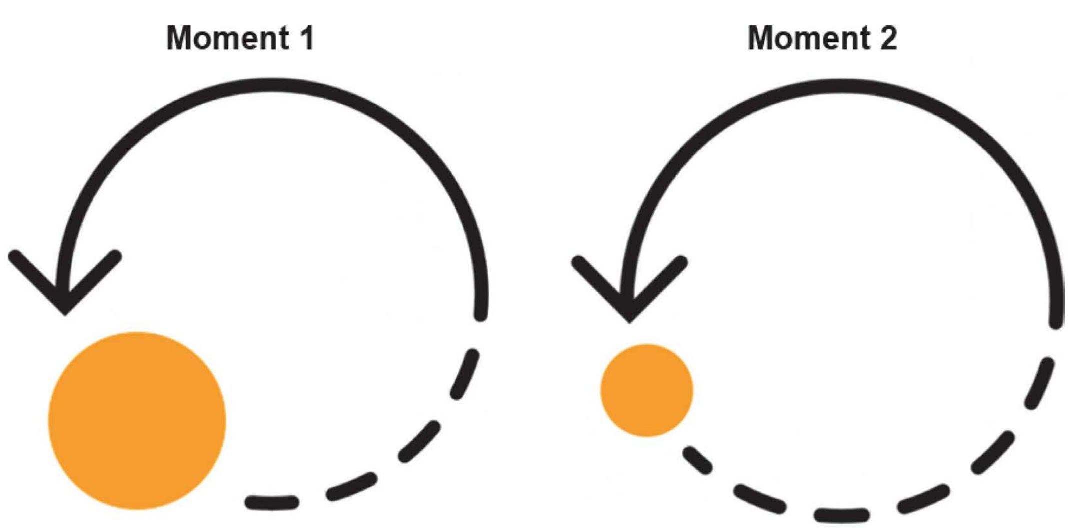

Figure 1 - Alternation between moments in condition 3 (tridimensionality, 3D).

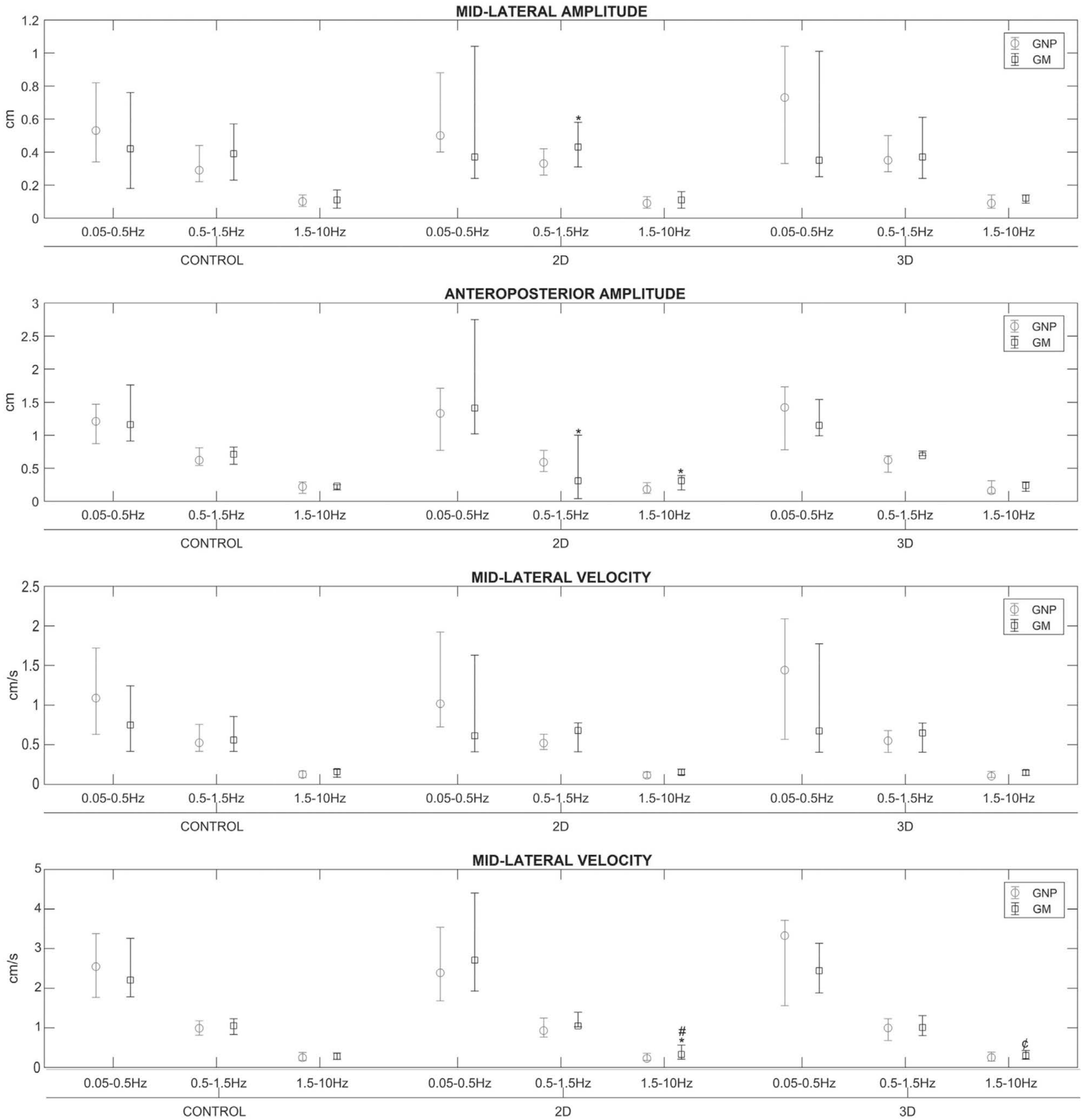

Figure 2 - Comparison of the variables (1st quartile, median, 3rd quartile) of amplitude and velocity in the mid-lateral and anteroposterior senses between the GNP and GM. *Statistically significant difference when compared to the same condition and frequency range to GNP; ¢ statistically significant difference when comparing the frequency band with the condition 2D intragroup; # statistically significant difference when comparing the frequency range with the intragroup control condition.

frequency range in control condition. For GM, we found higher values (P = 0.01) in the third frequency band (1.5-10 Hz) for amplitude and anteroposterior velocity and DOT in the 2D condition variables, when compared with the same range in control condition. For intragroup comparison in GM of 3D condition with 2D, in the high frequencies band, values were significantly lower (P = 0.01, P = 0.02 and P = 0.02, respectively) in the 3D condition for anteroposterior velocity, area and DOT.

When comparing the effects of exercise (between groups), the GM presented significantly larger measures when compared to GNP for medium-lateral amplitude in the second frequency band in the 2D

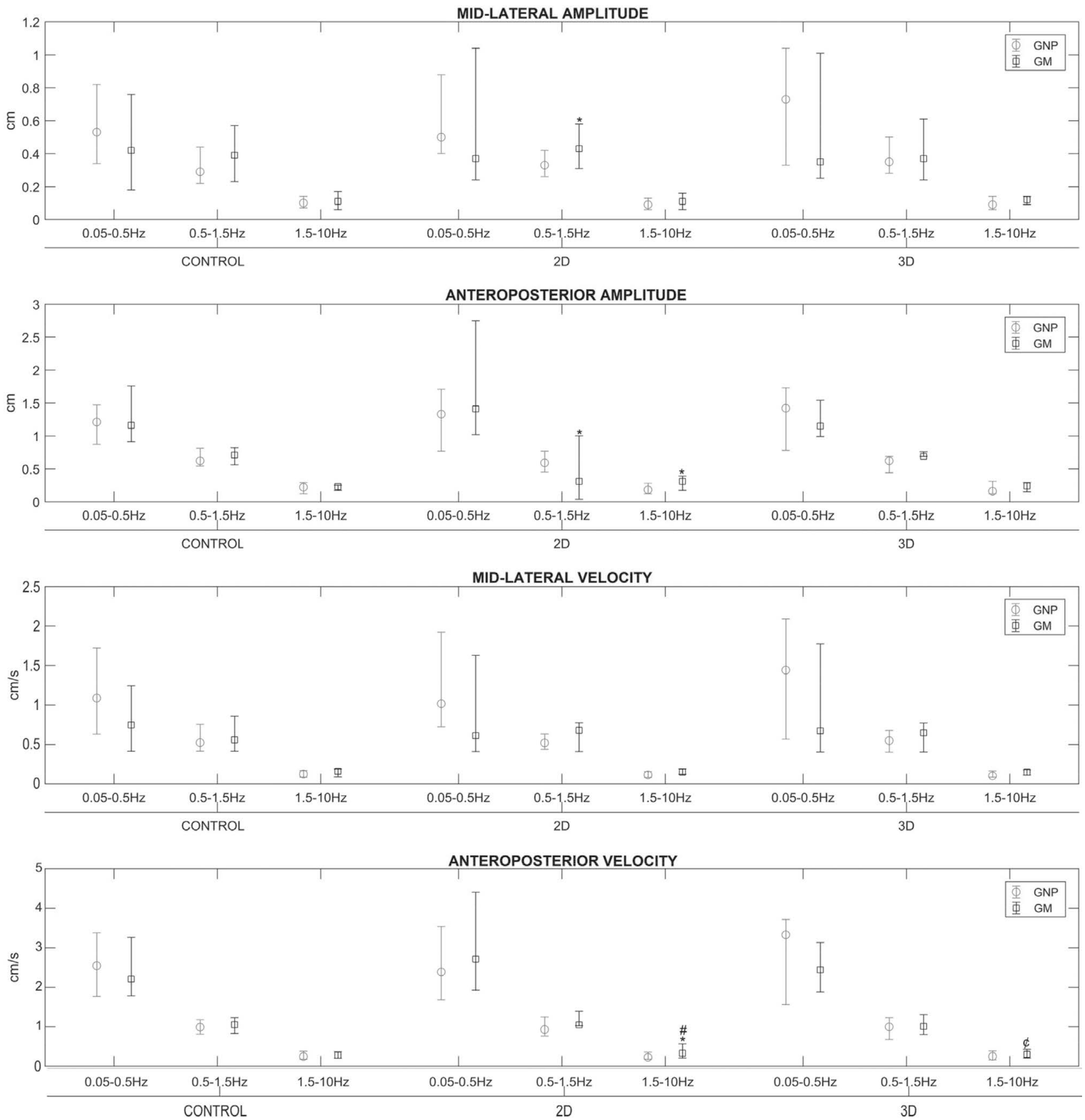

Figure 3 - Comparison of the variables (1st quartile, median, 3rd quartile) area, DOT and intensity in the mid-lateral and anteroposterior direction between the GNP and GM. *statistically significant difference when compared to the same condition and frequency band to GNP; ¢ statistically significant difference when comparing the frequency range with the 2D intragroup condition; # statistically significant difference when comparing the frequency range with the intragroup control condition.

condition, anteroposterior amplitude in the second and third frequency bands in the same condition (P = 0.04, P = 0.04 and P = 0.02, respectively). Also, for the area and DOT variables, in the second and third frequency bands, both in the 2D condition, higher values were found (P = 0.02, P = 0.03 for area, P = 0.02), and P = 0.02 for DOT, respectively the bands) when comparing GM to GNP, as well as for the variable percentage intensity in the lateral direction in the second frequency band in the control condition (P = 0.02), in the first and second band (P = 0.03 and P = 0.04, respectively) for the 2D condition and all the bands (P = 0.03, P = 0.04 and P = 0.04 respectively) in 3D condition.

Figure 4 presents the median and quartile values corresponding to the kinematic variables of amplitude of the angular variation and standard deviation of the trials in the all conditions, for the knee and ankle angle during a postural control task. No statistically significant differences were found when comparing GM values to GNP.

Discussion

With the objective of investigating postural control of older adults who regularly practice strength training in a postural control task with visual disturbance, the present study performed the analysis of variables related to postural control described in the literature and kinematic variables, as well as sought to investigate the collaboration of certain wavebands frequencies that are related to the sensory systems[12-14,16].

When comparing the different conditions in the GNP, differences were found only for the bands of the highest frequencies, compared to the 3D condition with the control. For GM, differences were found only in the comparison of the 2D conditions with control, in the higher frequencies for the variables of amplitude, velocity in the anteroposterior direction and DOT. However, when comparing 3D conditions with 2D, in the same frequency bands, we found lower values for anteroposterior velocity, area and DOT in the 3D condition.

For the comparison between the groups, there were significantly different values in the median frequencies for the lateral amplitude, for the median frequencies and also for the higher frequencies for the anteroposterior amplitude, area and DOT, all in the 2D condition. The only variable that presented different values in all conditions was the intensity percentage in the lateral direction, for a) the control condition in the median frequencies, b) for the 2D condition in the second and third frequency range and c) for the 3D condition, for all frequency bands when compared GM to GNP.

Other authors reported the same variables described in the present study in order to interpret the signal as a whole[19-21], through wavebands frequencies but in other modalities[22], and also investigated the visual disturbance[23], showing its importance for postural control[11,24]. However, few authors[12,14,16] have explored the wavebands for postural control, thus making the comparison of results more limited.

The few differences presented when compared to the control conditions, in both 2D and 3D circumstances, demonstrate that the visual manipulation was

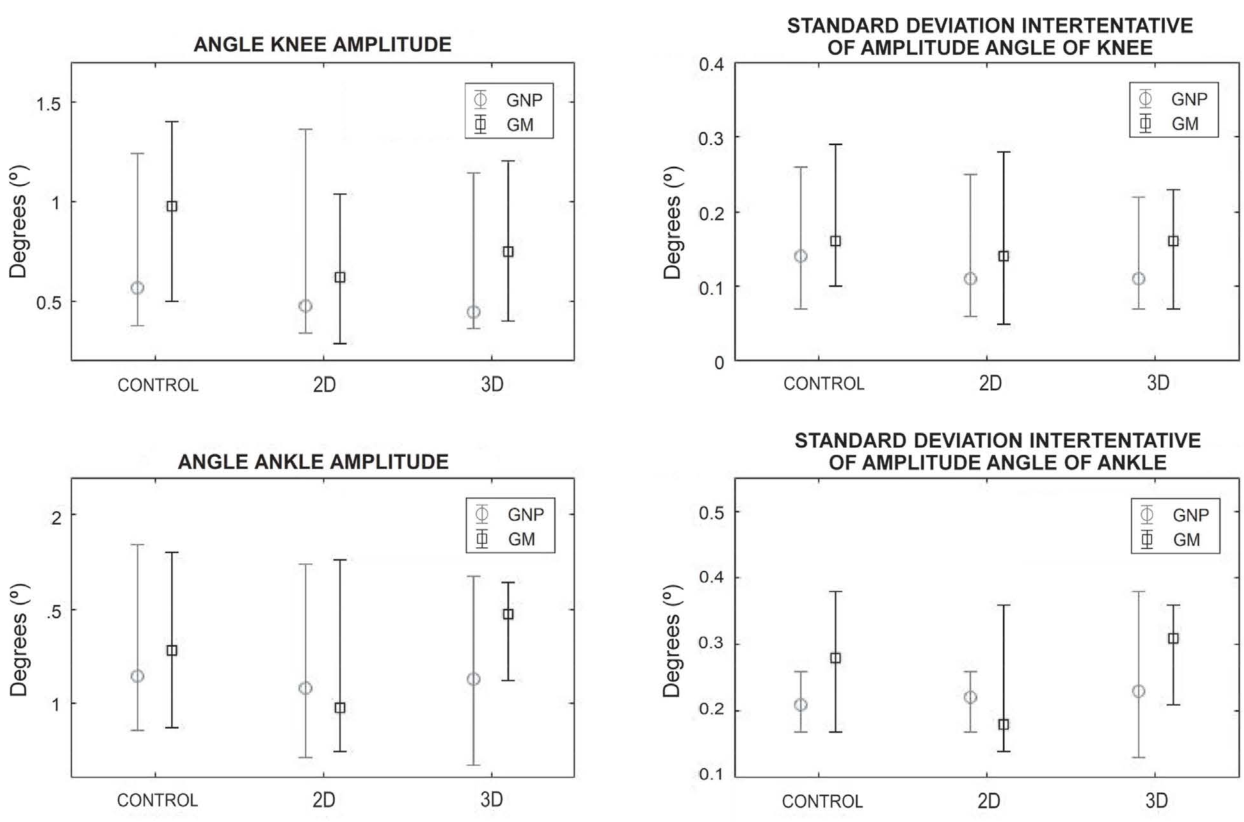

Figure 4 - Comparison of the kinematic variables (1st quartile, median, 3rd quartile) between GM and GNP.

not able to cause a great disturbance in participants postural control. However, the differences found between the control and 2D conditions in the third frequency range in the GM showed that the visual manipulation allowed a greater participation of the proprioceptive system of the participants who practiced strength training. The area variable is conditioned to other variables, so when we only observe the comparison of the 3D condition with the 2D, again in the third frequency range, there was a decrease in velocity in the anteroposterior direction, indicating that the visual manipulation presented an opposite effect, decreasing the values as manipulation of the disturbance increased. These results were found only for GM. For GNP, the only difference found was the change in the intensity. For kinematic variables, the absence of significant differences when compared the groups may be justified due to the postural strategy chosen. It may be possible to observe some difference between the kinematic data of the groups if in the analysis we evaluated the hip strategy, that is used of the proximal musculature of the trunk for the control of this joint[6].

However, even with the results presented, it is possible that the parameters of the visual stimuli (size and velocity) were not enough to disturb the postural control of the participants, once the intragroup comparison showed few significant differences between conditions in both groups. When identifying significant discrepancies between the intergroup comparisons, it is possible to verify specific distinctions caused by the practice of strength exercises, suggesting that there was a change at collaboration of sensorial systems mentioned previously.

The findings of this study may indicate that the effects of visual manipulations used were minimized for two main reasons: the low samples and the type of visual disturbance. Therefore, new studies are suggested to deal with these limitations, as well as investigate other variables of postural control, such as for example if there are differences in the amplitudes between strategies of hip and ankle in the participants analyzed in this study.

Conclusions

From the results obtained in this study, we can conclude that the practice of strength exercises seems to allow older women to become responsive to changes in the different conditions presented, but mainly to the frequency range related to the vestibular and somatosensory system. Also, these changes were presented in the percentage intensity variables in the lateral direction, amplitude ML and AP, AP speed, area and DOT. These findings indicate the possibility of analyzes of postural control using wavebands, allowing identifying the one specifically that may be more likely to be induced by practices or other processes, perhaps even by aging.

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AI use statement

No AI was used in this research.

Author contributions (CRediT)

Edson Gonsales da Cruz Filho: conceptualisation, investigation: methodology, data curation, visualization, writing - original draft, writing - review and editing. **Felipe Arruda Moura:** methodology, writing - original draft, visualisation, writing - review and editing. **Juliana Bayeux Dascal:** conceptualisation, methodology, data curation, resources, supervision, writing - original draft, writing - review and editing, visualisation.

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Data availability statement

The research data is available in the upon request.

Conflict of interest statement

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

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