Original article

Lower limb strength, but not sensorial integration, explains the age-associated postural control impairment

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Summary

***Introduction*: The aging process leads to functional decline of sensorial organs, muscle mass and strength, as well as the sensorimotor integration, culminating in age-associated postural control impairments. The purpose of this study was to compare the balance, the sensorial integration process and the lower limb strength among three old aged groups.**
***Methods*: Eighty-one community-dwelling healthy old people (58% women), assigned into three age groups [60-69 years (n=30), 70-79 years (n=40), and ≥80 years (n=11)], participated in this study. All participants were submitted to anthropometric and stabilometric evaluation, and carried out a Chair stand test. Stabilometric parameters obtained from time [amplitude displacement of center of pressure (CoP)] and frequency (oscillations of CoP at sub 0.3 Hz and 1-3 Hz bands) domain analysis were used as the indicators of balance performance and sensorial integration, respectively.**
***Results*: Our results revealed that the CoP amplitude displacement was significantly greater in the older aged group, without differences in spectral bands, while the performance in the Chair stand test was smaller in the older aged group.**
***Conclusion*: These data indicate that the age-associated postural control impairment is explained by the lower limb strength declines, but not by the age-associated changes in sensorial integration.**
Level of evidence: III.

KEY WORDS: muscle strength, proprioception, postural balance, aging.

Introduction

Impairments of sensorial inputs from visual, vestibular and proprioceptive systems, as well as the sensorial integration at the Central Nervous System (CNS) level, are the most reported causes of balance impairments in old people[1-4], although skeletal muscle impairments (e.g., weakness)[5-7], alone or in an integrative way with sensorial impairments, might influence the postural control as well.
The mechanism involved in the balance keeping can be described as follows: the sensorial input, mainly from the visual, vestibular and proprioceptive sources, are integrated to generate an adequate motor respons[8], but when one, or more, of these elements (i.e., sensorial or motor system) is impaired, the CNS adjusts the "weight" from each sensorial source and gives an adequate motor command to keep the balance[8,9].
In this context, stabilometry is a useful tool that can be used to evaluate balance and the involved strategies to maintain a satisfactory postural control. It is possible through the time domain analysis, which allows to obtain information about the performance in a given task (i.e., maintaining the balance), with variables such as the amplitude of the Center of Pressure (CoP) displacement[10], and through the frequency domain analysis, which allows to evaluate the weight adjusts among the sensorial inputs to maintain the balance, since the oscillation frequencies of CoP below 0.3 Hz are influenced mainly by the visual and vestibular systems, and oscillation frequencies between 1 and 3 Hz are influenced mainly by the proprioceptive inputs[11,12].
Despite the exposed, according to our knowledge, previous studies investigating, in an integrative way, the influence of the sensorial integration and the muscle strength on the postural control of old people in different age groups are scarce. An integrative analysis (i.e., lower limb muscle strength, CoP oscil-

lations parameters from the time and frequency domains) will allow identifying the main age-associated mechanisms that determine the postural control maintenance and/or its impairment in old people.
Then, this study aimed to compare the balance, the sensorial integration process and the lower limb strength among three old aged groups (60-69 yrs old; 70-79 yrs old; >80 yrs old).

Materials and methods

All community-dwelling old people (≥60 years old) from Aiquara, Bahia, Brazil were invited to take part in this survey study. An extensive health questionnaire, as well as a clinical and physical examination, was conducted in 289 old people that volunteered. Subjects were excluded from the study if they presented diabetes or any orthopedic, neurological, cardiac, vestibular, visual, or psychiatric impairment which would not allow them to perform all the tasks in the study. The study meets the international ethical standards of the journal as described by Padulo et al.[13], and the local ethics committee gave approval for the study (protocol # 171.464). Each subject underwent testing under the same instructions and conditions and a written informed consent was obtained from all subjects.
After exclusion criteria, only eighty-one community-dwelling healthy old people (58% women) achieved the criteria to take part in the study. They were separated into three groups based on their age: 60-69 years (n=30; 50% women; 157.7±6.8 cm; 68.4±12.8 Kg), 70-79 years (n=40; 30% women; 154.9±7.6 cm; 62.0±12.2 Kg), and ≥ 80 years (n=11; 64% women; 156.9±9.9 cm; 57.5±16.6 Kg).

Lower limb strength

The Chair stand test was used to assess the lower extremities strength/endurance. During the test, the volunteers were instructed to cross their arms over their chest, and stand up and sit down five times from a chair as fast as possible, with time being measured in seconds[14]. Volunteers that completed the task in >60 seconds were considered incapable of performing the task and were excluded from statistical analysis.

Postural control parameters

Using a piezoelectric force platform (Footwork Pro AM CUBE, France) co-ordinates of the body's CoP (Fig. 1) were recorded during 30s of quiet barefoot standing and sampled at 40 Hz. Volunteers remained with the arms relaxed along the body and were asked to keep the feet parallel, separated at the shoulders' width, and to look to a target placed at eye level about 2 meter in front of them. The used equipment gives information about the CoP of each foot, allowing measuring the support base width, which was used with height to generate an index "height/support base width" to normalize the body's CoP displacements, since greater height and smaller support base width trend to increase the amplitude of body's CoP displacement.
The body's CoP displacement was analyzed in MATLAB® software with previously developed routines to obtain stabilometric parameters in the time domain (anteroposterior AP, and medial-lateral ML, amplitude displacement of the CoP) and in the frequency domain (contribution of spectral bands sub 0.3 Hz and 1-3 Hz). The power spectral density of body's CoP oscillations was obtained by applying the fast fourier transform (FFT). The area of the spectrum relating to the band 0-0.3 Hz (i.e., sub 0.3Hz) Hz and 1-3 Hz was calculated and normalized by the total area of the spectrum to obtain the contribution of these bands in the spectrum constitution as used by Pirpo et al.[11].

Statistical analysis

All data were tested for normality (Kolmogorov-Smirnov test) at a significance level of $p<0.05$. As some stabilometric variables did not exhibited normal distribution, nonparametric procedures were adopted.

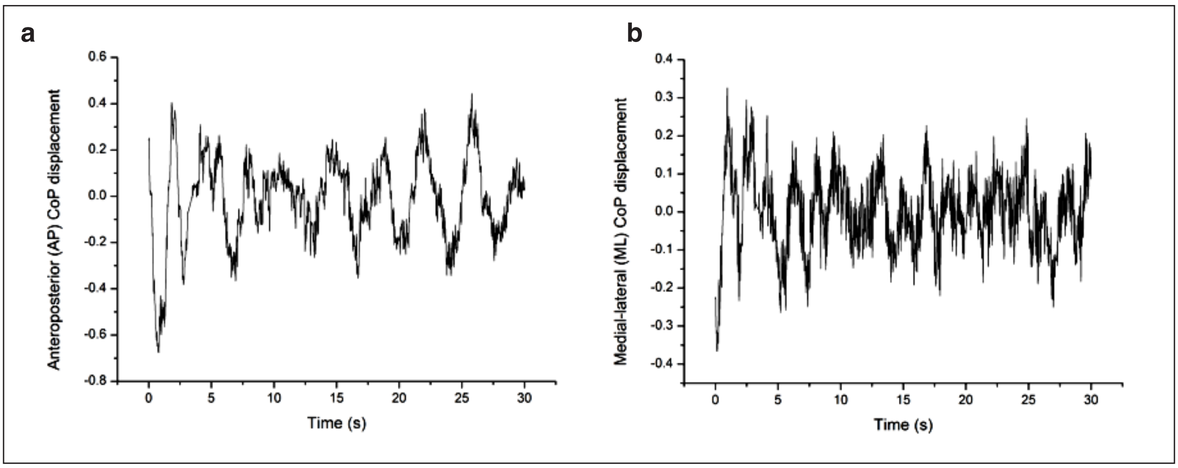

Figure 1. Recordings of anterioposterior (a) and medial-laterial (b) center of pressure (CoP) displacement along 30 seconds.

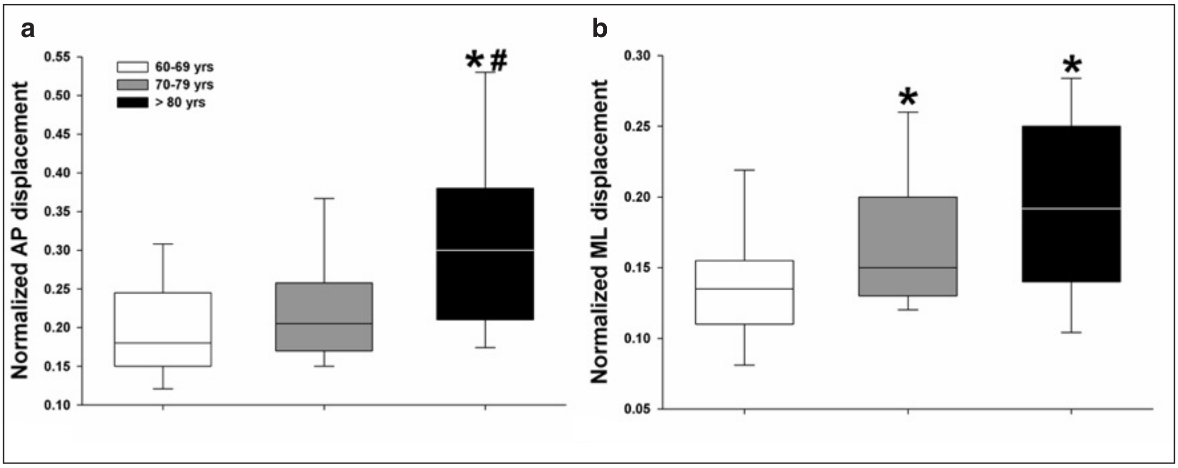

Figure 2. Normalized anteroposterior (a) and medio-lateral (b) displacement from old adults stratified by age groups (60-69; 70-79; >80 years old). *Significantly different from 60-69 yrs old ($p < 0.05$); #significantly different from 70-79 years old ($p<0.05$).

Thus, Kurkal-Wallis test was used to compare lower limb strength and stabilometric variables among the studied age groups and a Mann-Whitney test with Bonferroni correction for multiple comparisons was used as a post-hoc test. All statistical procedures were performed with SPSS 21.0 (SPSS Inc., IBM, Chicago, IL, USA) and a significance level of $p<0.05$.

Results

The older aged group exhibited a greater AP and ML displacement when compared to the 60-69 years old group ($p<0.05$). Greater AP displacement was also observed between the older group and the 70-79 yrs old group, while the ML displacement was greater in 70-79 yrs old group, when compared to the group 60-69 yrs old ($p<0.05$) (Fig. 2).

Despite differences in the CoP displacement, anteroposterior and mediolateral CoP oscillations at sub 0.3 Hz and 1-3 Hz were not different between groups ($p<0.05$) (Fig. 3).

The performance in the chair stand test, used as a indicator of lower limb strength, was significantly smaller in older aged group, when compared to the 60-69 yrs old group ($p<0.05$) (Fig. 4).

Discussion

This study aimed to compare the balance, sensorial integration and lower limb strength among old people stratified in three age groups. Our results showed that lower limb strength explains the age-associated postural control impairment, without significant differences in sensorial integration among studied age groups.

During the aging process, all the main components of the postural control are impaired. Declines in visual acuity, contrast sensitivity, glare sensitivity, dark adaptation, accommodation and depth perception tend to be observed from the fifth decade and onward[1,15].

The vestibular system is affected quantitatively and qualitatively, mainly from the 70 years-old, with a decrease in hair cells number and a general sensitivity loss in the vestibular system [1]. The aging process is associated to a quantitative reduction in the somatosensorial receptors as well (mechanoreceptors), leading to a poor plantar tactile sensitivity and joint position sense[1,16]. Together, these changes culminate in an impaired postural control in old people.

Despite of this, our results indicated that the age-associated impairments in postural control seem not to be explained by age-associated sensorial declines, since the spectral parameters from CoP oscillations at sub 0.3 Hz and 1-3 Hz were not different between studied age groups. We hypothesize that, in our studied groups, the CNS was able to reweight the integration from the sensorial information coming from the different sensorial sources to maintain the balance.

However, the function of the effector system (i.e., skeletal muscle) was different between age groups, which may contribute to explain the observed differences in balance. In fact, muscle mass and strength are also affected by aging, more specifically, muscle strength tend to reduce by ~10-15% per decade until 70 years old, and then by ~25-40% per decade thereafter[5,17]. Our results corroborate this trend to declining in muscle strength, and, when interpreted together with CoP displacement, allow hypothesizing a direct relationship between lower limb strength and balance performance impairments in old people. It is important to note that our results indicate this relationship is established in an independent way from sensorial integration, what is plausible, since the muscles are the effectors of the descending orders from the CNS, thus, the sensorial integration and its output to the muscles may be similar among age groups, but the postural control could be impaired owing to a compromised muscle strength.

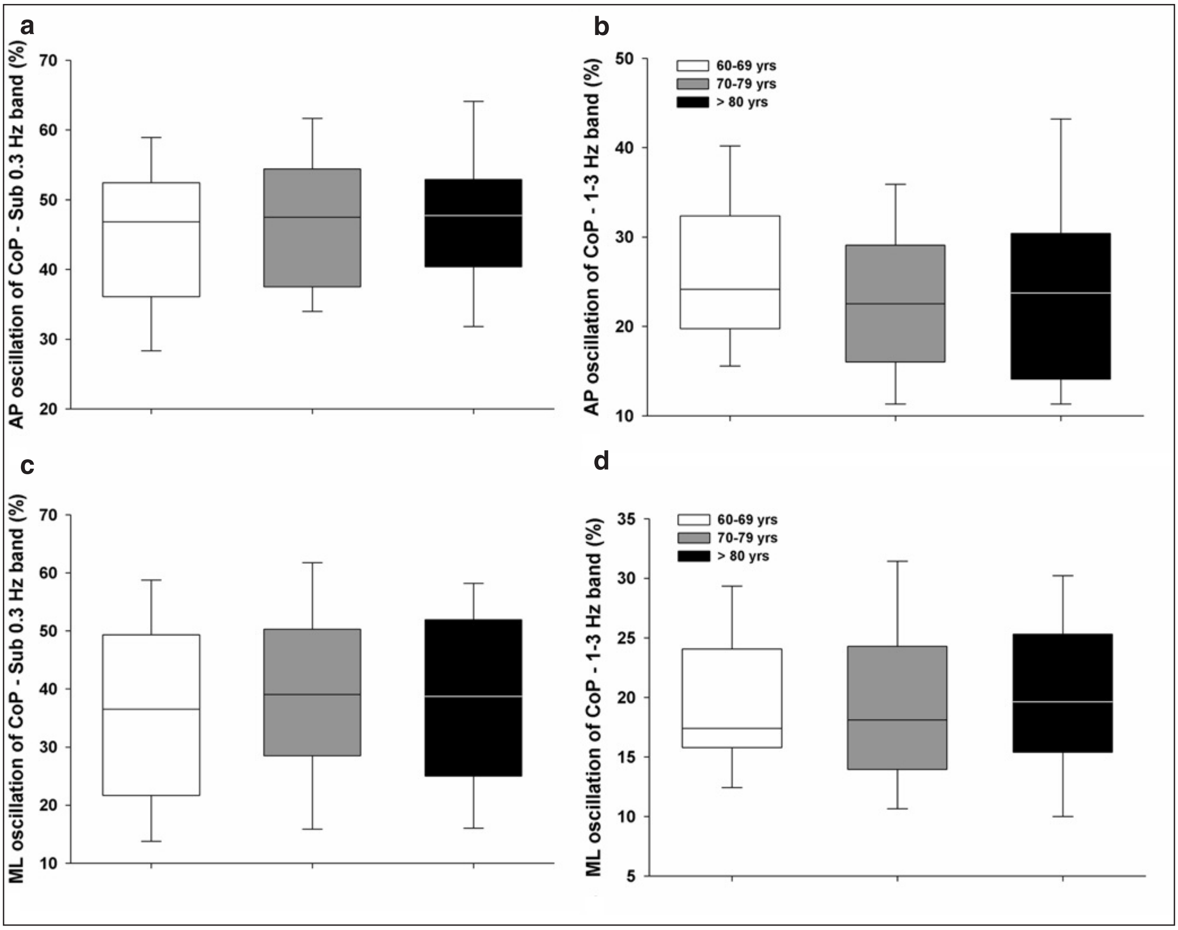

Figure 3. Anteroposterior (a, b) and medio-lateral (c, d) oscillation of center of pressure (CoP) in sub 0.3 and 1-3 Hz bands.

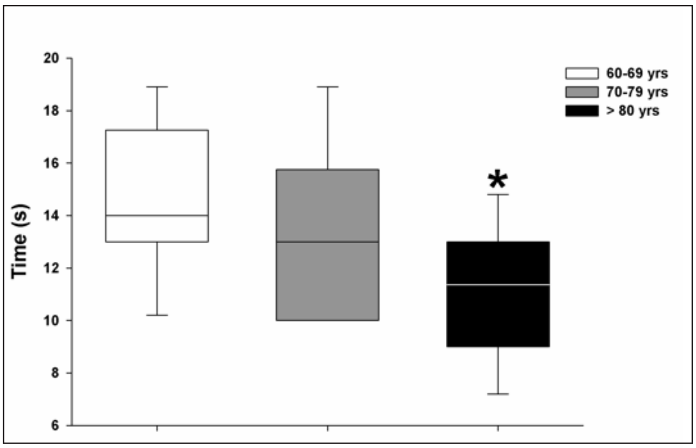

Figure 4. Chair stand Test performance from old adults stratified by age groups (60-69; 70-79; >80 years old). *Significantly different from 60-69 years old ($p<0.05$).

Further studies may consider the use of our analysis approach to investigate different elderly samples, as institutionalized elders, since there is evidence of significant association between postural control and length of institutionalization[18]. Additionally, the use of dual-task conditions[19] and the influence of anthropometrical characteristics[20] could be also investigated with our analysis approach.

Conclusions

The approach here used, studying together the lower limb strength, the sensorial integration at orthostatic position and the CoP displacement, allowed identifying the main age-associated mechanisms that determine the postural control maintenance and/or its impairment in old people. Despite of this, our results are limited to the postural control performance with all sensorial information available and reliable, so that further studies could use the same analysis approach to investigate the influence of sensorial manipulation on postural control of seniors from different age groups and muscle strength.

Our results expand the understanding about the age-associated mechanisms that determine the postural control maintenance and/or its impairment in old people, showing that the lower limb strength, but not sensorial integration, explains the age-associated postural control impairment.

Conflict of interest

The Authors have no conflicts of interest related to this study.

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