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An explanatory mechanism for the different decline in limb strength in older women

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ABSTRACT

The aim of the study was to compare the physical activity level and intensity of the upper and lower limbs in Brazilian women who are usually active, functionally independent, and living in a medium size city. Seventy-two women were assigned into a younger group (YG; $n = 38$; mean age 23.08 ± 2.80 years) and older group (OG; 60.68 ± 7.16 years; $n = 34$) groups. To discriminate the physical activity level of the upper and lower limbs, a daily activity record questionnaire (DARQ) was developed based on Bouchard's three-day physical activity record (3-day PAR). When compared to the YG, the OG presented: (a) higher levels of daily physical activity for upper limbs compared to the lower limbs and (b) higher levels of perceived exertion for both sets of limbs. In conclusion, these results suggest that women change their inter-limb pattern of daily physical activity with age; that is, they increase upper limb activity and decrease lower limbs activity. Furthermore, they decrease the exertion intensity for both sets of limbs. These findings may help to explain the more accentuated decline in lower limbs muscle strength during the aging process.

1. Introduction

As regards the biological dimension, aging is characterized by irreversible and progressive changes that lead to reduction in functional fitness. Functional fitness can be defined as an individual's physical capacity to meet ordinary and unexpected demands of daily life safely and effectively (Clark, 1989) without undue fatigue.

However, the effects of the aging process and its associated factors are not uniform, including those related to the components of functional fitness. For example, muscle strength does not decrease in the same way for all muscle groups and for every type of movement, neither in humans nor in animal models (Lynch et al., 1999; Nikolic et al., 2001; Onder et al., 2002).

The decrease in the quantity (or level) and/or the intensity of physical activities is one of the crucial factors related to the decline in the functional fitness components, particularly of muscle strength. The practice of physical activity on a regular basis (including physical training) can even provide partial reversion to a higher level of functional fitness, maintenance at an adequate level or deceleration in the rate of decline in strength. Fortunately, this indicates that the aged organism retains training capability and adaptation plasticity (Frontera et al., 1988; Fiatarone et al., 1990; Lynch et al., 1999; Nikolic et al., 2001; Harris et al., 2004).

Due to aging and/or its associated factors, a larger effect is noted in the reduction of strength of the lower limbs muscles when compared to the upper ones (Lynch et al., 1999; Nikolic et al., 2001; Onder et al., 2002). An explanatory hypothesis for the different inter-limb decline in strength during aging is associated with distinct changes in the levels of the physical activity in upper and lower limbs. In other words, the reduction of the activity level may be limb-dependent.

The state of the art of scientific knowledge has been limited to evidence regarding morphological- and histological-enzymatic changes to explain the different decline in strength between limbs during aging. No studies were found on the inherent and crucial question related to these different inter-limb changes in strength; that is, whether such changes occur due to natural biological processes of aging and/or to factors associated with it. In this sense, possible non-similar changes in the level of physical activity between limbs would contribute to the non-similar changes in strengths.

Therefore, an answer to the question whether different inter-limb changes in physical activity level and/or intensity occur seems to be relevant as a possible explanatory mechanism for widely acknowledged differences in inter-limb strength changes. Such answer would benefit: (a) the human movement sciences, providing a better understanding of the relationship between aging and the different decline in muscle strength; (b) physical

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activity professionals, to foster competence in diagnosis, prediction, elaboration, delivery and control of physical activity programs for the elderly; (c) for the elderly people, providing a better understanding on a matter that may contribute to a more effective practice of physical activity.

Along these thoughts, the aim of this study was to analyze whether there is a difference of decline in the level of physical activity between lower and upper limbs during aging.

2. Methods

2.1. Participants

Seventy-two Brazilian women were assigned into a younger group (YG; $n = 38$; mean age 23.08 ± 2.80 years old) and older group (OG; 60.68 ± 7.16 years old; $n = 34$).

The participants of OG were recruited by: (a) invitation to the participants and ex-participants of a physical activity program for older people; (b) announcements for newspapers and TV in the city; (c) verbal communication among friends. All of them were independent and community dwelling; approximately 50% of them was engaged in structured physical activity program, approximately 82% of them presented some diseases, which were controlled by medications (beta-blockers, diuretics, anticonvulsant, etc.), and none of them presented absolute contraindications to regular physical activity. The medical conditions of the OG are shown in Table 1.

The YG subjects were recruited among the graduate and undergraduate students by means of announcements.

The local Committee on Ethics in Research approved the research, and all the participants signed an informed consent form.

2.2. Anthropometric measurements

In order to better describe the sample, the body mass, body fat and body height of the participants were assessed. In addition, their body mass indexes (BMIs) were calculated. The body fat mass was assessed by means of a system of bioelectrical impedance (BIA), according to the protocol described by Heyward and Stolarczyk (1996).

2.3. Physical activity levels of the upper and lower limbs

Aiming to discriminate the physical activity level of the upper and lower limbs, the DARQ was developed based on the 3-day PAR (Bouchard et al., 1983) by adapting the first in two aspects regarding the: (1) activity groups: while the 3-day PAR classifies the activities into 9 groups regarding the energy expenditure (kcal/(kg min)), the DARQ classifies the activities into 4 groups based on the predominant use of limbs; (2) intensity scale: the DARQ added an intensity scale of 3 levels (light, moderate and heavy). For all the other aspects, the DARQ is similar to the 3-day PAR.

Table 1
Distribution (%) of the medical conditions of the OG ($n = 34$).

Cardiovascular	
Hypertension	37.5
Dysrhythmias	3.12
Metabolic: Obesity, Diabetes mellitus.	6.25
Lung: Asthma	6.25
Vestibular disorder: Benign paroxysmal positional vertigo	9.37
Musculoskeletal	
Arthrosis, Osteoporosis	6.25
Tendonitis	3.12
Central nervous system: Convulsive disorders.	3.12
No medical conditions	18.75

Table 2
A list of examples of daily activity classification.

(1) PUL	*Activities*: Housework (washing windows, sweeping, etc.); standing (cooking, dusting, shaving, etc.); cleaning trees
(2) PLL	*Activities*: Walking; cycling; going up stairs
(3) Undetermined prevalence of limbs	*Activities*: Swimming; gymnastics; hydrogymnastics
(4) Rest without movement	*Activities*: Sleeping; resting in bed; seated, listening to the radio or TV

Table 3
An example of the record table.

Hour	Number of activity groups				Intensity scale		
8.01–8.15 am	1	2	3	4	Light	Moderate	Hard
8.16–8.30 am	1	2	3	4	Light	Moderate	Hard
8.31–8.45 am	1	2	3	4	Light	Moderate	Hard
8.46–9.00 am	1	2	3	4	Light	Moderate	Hard

One important concern related to the use of physical activity records is the reliability and validity. However, for the purpose of our study the DARQ was the only feasible method of assessing habitual physical activity, by predominance of limbs. Furthermore, such a potential limitation regarding the validity and reliability of the DARQ seems to be attenuated by: (a) physical activity assessment via diary recordings and accelerometer shows a reasonable estimates of intra-class correlation coefficient = 0.78 (Temple and Walkley, 2003); (b) the similarity of the DARQ and the 3-day PAR, which has been widely used for, showing a reliability of 0.97 (Bouchard et al., 1983; Argiropoulou et al., 2004) and a validity of 0.63 related to the accelerometer (Argiropoulou et al., 2004).

The DARQ contains the following three sections. (1) Instruction page, referring to the objective of the DARQ and detailed instructions for its use. (2) List of daily activities: this was based on questionnaires of physical activity and was designed to assess each of the daily activities and rest situations. All the situations were divided into defined subclasses: prevalence of upper limbs (PUL); prevalence of lower limbs (PLL); undetermined prevalence of limbs; and rest without movement (Table 2). (3) Record table: the table was divided into 15-min intervals for each hour of the day. The participants were instructed to mark the number corresponding to the predominant activity performed in each 15-min interval, and in addition, to their perceived intensity of effort (light, moderate or hard) (Table 3). An additional illustrated visual scale was used together with the intensity scale to facilitate the interpretation (Fig. 1).

The 15-min intervals were established in DARQ so that the participants wrote down their activities. It is reasonable to hope that such a short period of time is suitable to detect important variations in the physical activity type, and it may facilitate the annotations.

The participants filled in the DARQ for a period of 3 days. The first 2 days could be any day of the week, but the 3rd day had to be Saturday or Sunday. The results of physical activity level were expressed in time units (TU) where 1 TU = 15 min. The final result

Fig. 1. Illustrated visual intensity scale.

Table 4
An example of the reported results on the activity record table.

	Activity groups				Intensity scale		
	1	2	3	4	Light	Moderate	Hard
Day 1	30	24	12	30	35	49	12
Day 2	36	20	8	32	25	63	8
Day 3	36	16	16	28	20	68	8
Total	102	60	36	90	80	180	28

Note: ULI = 102/60 = 1.7.

was the number of times that each group of activities was marked in the 3 days. Based on the results of PUL and PLL, the upper and lower limb index (ULI) was calculated (Table 4). The ULI (PUL/PLL) represents how much that each volunteer used the upper in relation to the lower limbs. For example, if PUL = 102 and PLL = 60; ULI = PUL/PLL; then ULI = 1.7.

The DARQ is an original instrument of assessment in the sense that it can: (a) discriminate inter-limb level of physical activity, while no other instrument was able to assess such variables; (b) assess different types of activities that probably vary throughout the day; (c) assess rest periods.

2.4. Statistical analysis

Power analysis revealed that the PUL, PLL and ULI produced power values of 1.0, 0.99 and 0.99, respectively. Kolmogorov–Smirnov's test was applied and confirmed the normal distribution of data. For comparison of physical activity level between groups, the Student's *t*-test for independent measures was applied. The data are presented as mean ± S.D. The level of significance was set at $p < 0.05$.

Rating of perceived intensity (RPI) was compared between the groups by means of descriptive statistics (percentage).

3. Results and discussion

The characteristics of the sample and the results for daily living activities with PUL and PLL in both groups are presented in Table 5. When OG is compared to the YG, the OG women presented: (a) lower stature, heavier body mass, higher body fat mass and higher BMI; (b) higher physical activity level with PUL and lower one with PLL. Consequently, they presented a higher ULI, that is, they perform more activities by upper limb compared to the lower ones. The RPI recorded during 3 days of daily living activities is shown in Fig. 2. When compared to the YG, the OG reported more time spent on activities with PUL at light RPI and less time spent on activities with PLL at hard RPI (Fig. 3).

Table 5
Sample characteristics and daily activities with PUL, PLL and the ULI in YO and OG (mean ± S.D.).

	YG (n = 38)	OG (n = 34)
Characteristics		
Age (years)	23.08 ± 2.80	60.68 ± 7.16*
Weight (kg)	57.60 ± 7.63	69.80 ± 12.65*
Height (cm)	163.00 ± 7.00	159.00 ± 5.00*
BMI (kg m^{-2})	21.64 ± 3.07	27.45 ± 4.77*
Body fat (%)	24.55 ± 5.07	42.55 ± 4.75*
Daily activities		
PUL (TU)	90.84 ± 22.73	137.94 ± 14.64*
PLL (TU)	42.16 ± 21.53	13.5 ± 7.72*
ULI	3.19 ± 2.64	15.93 ± 13.69*

* Significant statistical difference between the age-groups ($p < 0.01$).

The method of assessment and findings of present study regarding the inter-limb physical activity level are original. The OG presented lower physical activity level with PLL and a higher one with PUL, when compared to YG. Furthermore, it was found that older women presented different RPI compared to the younger ones, and such difference was also limb-dependent.

Despite the fact that no studies were found assessing the physical activity level of the limbs separately, our findings seem to be consistent with those reported by the others authors in relation to functional assessment. Brach et al. (2004) analyzed specifically the performance of lower limbs by means of the EPESE battery of motor tests. They observed that inactive women presented significant difficulties in accomplishing the tests, with 49.9% showing functional limitations in the lower limbs compared to 28.4% of the active women. In another research, Hamdorf et al. (2002), reported limitations in the capacity to walk associated with aging.

In our analysis of the PUL compared to the PLL, one can note that older women presented higher ULI. This suggests that as women grow older, they become engaged in more activities with upper limbs and reduce the lower-limb activities. This is an important factor, which may contribute to a greater decline in the lower-limb strength (Izquierdo et al., 1999; Frontera et al., 2000).

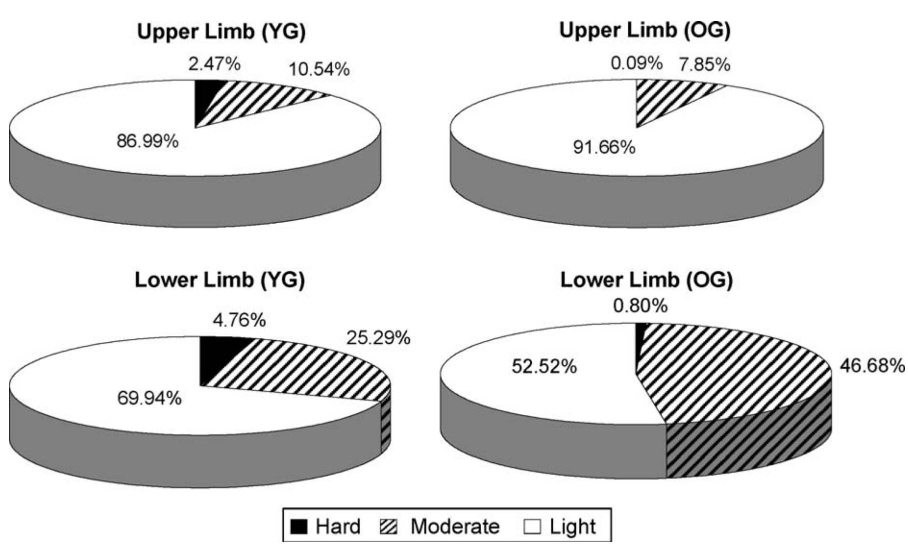

Fig. 2. Percentages related to the three perceived intensities reported by the YG and OG for upper and lower limbs. Values represent 3-day activities of daily living.

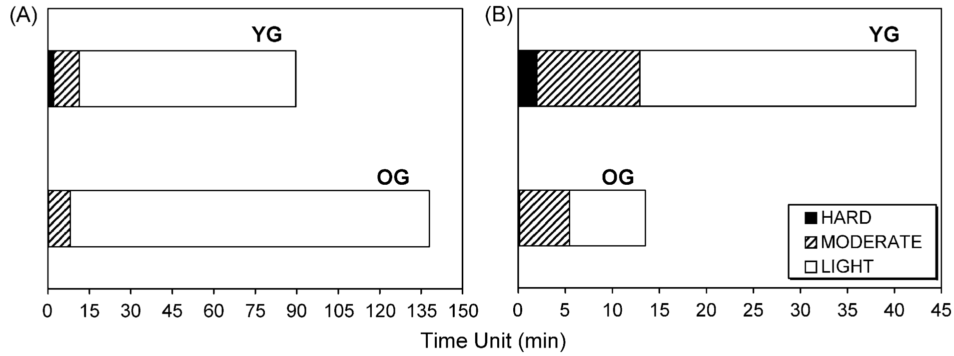

Fig. 3. Total and partial times related to the three RPI expended by YG and OG for activities with PUL (A) and PLL (B). Values represent 3-day daily activities.

At present the older women in Brazil carry out more domestic activities of daily life than the younger ones (to wash clothes manually, to cook, to clean the house, gardening, to sweep, etc.). Those activities are accomplished with PUL. On the other hand, the younger women accomplish more daily activities with PLL (walking, jogging, cycling, sports in general, etc.).

On the other hand, the YG reported higher RPI, which suggests that the activities in which they are engaged, are more intense (Fig. 2). This finding is consistent with those of: (a) Hamdorf et al. (2002), who reported that people with 60 and plus year of age presented less participation in vigorous activities; (b) Mota et al. (2002), who observed that 95.38% of the time spent in daily activities by older people in Portugal can be classified as low intensity activities (<3 metabolic equivalents = METS), and only 4.57% as moderate-vigorous intensity (3.00–8.99 METS); (c) Monteiro et al. (2003) who found greater participation of Brazilian women in walking compared to sports activities (basketball, volleyball, swimming) and gymnastics, which are usually more intense activities.

The importance of the intensity of the daily activities can be verified when analyzing the results of: (a) Brach et al. (2004) who showed that older people (70–79 years) who had been exercising on a regular basis in a supervised and more intense program of physical activity, presented much higher levels of functional fitness than those considered inactive. (b) Chang et al. (2003), who classified participants in two groups based on their participation in strenuous sport and recreational activities, such as jogging, cycling, tennis, aerobic dance, or other similar activities.

These authors found that older people who had presented higher functional levels of lower limbs, and those who had been engaged in more intense physical activities, showed more positive attitudes regarding exercise. These results stressed that regular physical activity in the elderly is not only modulated by its volume, but also by its intensity. Thus, these parameters (volume and intensity) should be taken into account when providing programs for this population. Besides, difference in the results of RPI between the groups can still be larger, since the older people tend to overestimate the effort (Allman and Rice, 2003).

Our findings revealed a possible decrease in the use of the lower limbs in older women, and several biological factors are considered as indicative of disuse of the lower limb muscles. The relationship of these factors with limb-dependent physical activity levels was suggested, but not investigated, by: (a) Coggan et al. (1992) who observed a lower capillary density in the gastrocnemius muscle of older people compared to younger ones; (b) Frontera et al. (2000), who demonstrated a reduction in capillary density in vastus lateralis after having followed up older people with a mean age 65.4 years for a period of 12 years; (c) Chilibeck et al. (1997) who found no capillarity differences in the vastus lateralis muscle between younger and older people with the same general level of physical activity; (d) Lynch et al. (1999) who reported a 20% decline in the muscular quality for lower compared to upper limbs; (e) Nikolic et al. (2001), who showed an increase in the proportion of type I fibers, but a decrease in type II fibers, in the vastus lateralis muscle with aging; (f) Kirkeby and Garbarsch (2000), who found atrophy of the type II fibers in the elderly due to the loss of motor neurons, similar to the effects seen during immobilization due to health problems or voluntary inactivity; (g) Kubo et al. (2003) who showed evidence that the older the person, the cross-sectional area (CSA) and penation angle are smaller only for the vastus lateralis muscle, but not for the brachial triceps; (h) Chung et al. (2005), who observed that aging is mainly associated with the generation of slower and weaker strength, probably due to changes on the proportion of type II fibers. This explanation may support the hypothesis that the more accentuated the disuse of lower limbs with aging (as we have shown in the present study), the lower may be the proportion of type II fibers.

Although all women use regularly on a day-to-day basis the muscles investigated by the studies described previously, we found that older women use less the lower-limb muscles and at a weaker intensity, which can help to explain the biological differences observed in muscles with aging. Therefore, even though our study did not directly measure biological factors, the possible prevalent disuse of lower limbs found, is coherent with the biological factors evidenced by other studies.

Although no studies were found reporting different limb-dependent changes in physical activity level, there is some evidence, including the general physical activity level, that lower levels of physical activity with aging are associated with the decrease in lower limb strength. Hunter et al. (2001) have calculated the rate of decline in general physical activity level associated with reduction in strength of knee extension. The interpretation of their data suggests that, as individuals grow older, they became less physically active, and as a consequence, their strength also declines. This decline in lower limb strength can jeopardize mobility; increase the risk of falls, and altogether can become a strong barrier to physical activity and the independent performance of daily tasks. Rantanen et al. (1999) have also shown that moderately active participants present greater lower limb strength compared to less actives ones. The control of strength is fundamental for the accomplishment of those daily tasks that demand performance of the lower limbs (Seynnes et al., 2005).

Muscle disuse has also an impact on energy expenditure. A recent study by Roberts and Dallal (2005) demonstrated that total energy expenditure and physical activity level decline with aging. Particularly, when the disuse occurs in lower limbs, as shown in our study, it can cause atrophy of a large muscle mass, which in turn also causes a reduction in daily energy expenditure that can lead to fat mass increments.

The control of strength is fundamental for the accomplishment of those daily tasks that demand PLL. The maintenance or increase of the physical activity level with PLL can be decisive for the quality of life in the elderly. Lebrão and Laurent (2005) have shown that the main functional limitations in older Brazilians are related to tasks that require squatting, getting up from a chair, climbing up one flight of stairs, and walking around the block. Such limitations are directly related to strength and posture (Seynnes et al., 2005), which in turn, are associated with physical activity level with PLL. In other words, a higher level of physical activity with PLL can provide better control of strength and body posture.

4. Conclusion

In conclusion, older Brazilian women who are usually active, functionally independent, and community-dwelling, when compared to younger ones, present: (a) a higher volume and lower intensity of physical activity level with PUL, and (b) both a lower volume and intensity of physical activity with PLL.

These findings seem to be: (a) an important explanatory mechanism for the different decline of strength between upper and lower limbs, which has been shown in several previous studies, (b) an indication that women at different ages present level of physical activity in different ways with respect to the PUL and PLL, and (c) a support to the recommendation that, when programming and implementing physical activity programs for older women, special care should be taken to exercise the lower limbs.

Conflict of interest

None.

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