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Comparison of lower limb strength in younger and older female adults

Comparação da força muscular de membro inferior em mulheres jovens e idosas

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RESUMO: Age-related weakness results in slow movements, altered motor control, and higher sense of effort during activities of daily living. Thus, when an older adult performs tasks closer to the maximum functional capacity it may contribute to the onset of fatigue and increased risk of falling. *Objective:* The present study aimed to compare lower limb strength and strength ratio (isokinetic strength/isometric strength) in younger and older adults. Twenty one (66 older±6 years) and nineteen younger (22±2 years) women participated in this study. The maximum isometric and isokinetic strength were assessed at hip, knee and ankle joints at sagittal plane. Peak isometric and isokinetic torque were normalized by body mass ($Nm \cdot kg^{-1}$) and strength ratio was calculated dividing the maximum isokinetic strength over the maximum isometric strength of each joint in each movement. The evaluation of habitual gait speed was conducted on a walkway measuring 14 meters long. Younger adults had 11.6% higher ankle extension strength ratio ($p = 0.013$) and 17.6% higher ankle flexion strength ratio ($p = 0.001$) than older female adults. The isometric peak torque was higher in younger adults than in older adults during all movements tested ($p < 0.001$). The isokinetic peak torque was higher in younger adults than in older adults during all the movements tested ($p < 0.001$). Older female adults were weaker than younger women in all movements (flexion and extension) and lower limb joints assessed (hip, knee and ankle), which may predispose them to fatigue and increased risk of falling.

Key Words: Aging; Falls; Functional demand.

ABSTRACT: A fraqueza muscular decorrente do envelhecimento resulta em movimentos lentos, alteração do controle motor e maior sensação de esforço durante a realização das atividades de vida diária. Dessa maneira, quando o idoso realiza suas tarefas diárias próximo de sua máxima capacidade funcional pode favorecer a fadiga precoce e aumento do risco de quedas. Objetivo: o presente estudo teve como objetivo comparar a força de membros inferiores e a razão de força (força isocinética/força isométrica) em jovens e idosos. Vinte e uma idosas (66±6 anos) e dezenove jovens (22±2 anos) participaram desse estudo. A máxima força isométrica e isocinética foram avaliadas para o quadril, joelho e tornozelo. O pico de torque isométrico e isocinético foram normalizados pela massa corporal (Nm.kg-1) e a razão de força foi calculada por meio da divisão entre a máxima força isocinética e a máxima força isométrica. A avaliação da velocidade habitual de marcha foi realizada em uma passarela de 14 metros de comprimento. Os jovens apresentaram 11,6% maior razão de força de extensão do tornozelo e 17,6% maior razão de força de flexão do tornozelo em relação às voluntárias idosas. O pico de torque isométrico foi maior em jovens em relação aos idosos para todos os movimentos avaliados. O pico de torque isocinético foi maior em jovens em relação às voluntárias idosas para todos os movimentos avaliados. Mulheres idosas são mais fracas em relação às jovens para todos os movimentos (flexão/extensão) e todas as articulações avaliadas (quadril, joelho e tornozelo), o que pode predispor à fadiga e aumento do risco de queda.

Palavras-chave: Envelhecimento; Quedas; Demanda funcional.

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Introdução

The ability to complete activities of daily living (ADL) such as walking, chair rise, and climb stairs declines with aging[1]. Thus, the age-related alterations in neuromuscular system result in strength loss, decreased functional capacity and increased risk of falling in older adults[2]. In addition, falls is the major cause of injuries and death in older population and represents an important issue for health care systems[3].

The age-related strength loss also results in slow movements, altered motor control, and higher sense of effort during ADL[4]. Strength loss is more pronounced at lower limbs, which has clinical implications to older adults, particularly, when it involves falls prevention[5]. In addition, older adults with lower limb weakness perform ADL tasks using efforts closer to the maximum functional capacity[6]. Thus, when an older adult performs ADL closer to his/her maximum functional capacity it may contribute to the early onset of fatigue and increased risk of falling[7].

Only few studies[6,8-9] have investigated the functional demand placed on lower limbs. These previous studies have suggested that older adults operated at a higher proportion of their maximum capacity when compared to younger pairs with a high loading placed on knee and ankle joints during stair negotiation[5,10,11]. However, the calculation of the functional demand requires a complex and expensive instrumentation, composed by a 3-D motion system, force plates and isokinetic dynamometer[5-6]. Considering that functional demand is calculated by a ratio of force between the strength generated during a dynamic contraction over the isometric maximum contraction[12], the present study aimed to compare lower limb strength and strength ratio (isokinetic strength/isometric strength) of younger and older adults. Also, our second objective was to determine the association between preferred walking speed and strength ratio in younger and older adults. We hypothesized that older adults would have a reduced lower limb strength and strength ratio, which may predispose this population to perform ADL in an increased functional demand. Further, our second hypothesis is that strength ratio is positively associated with gait speed.

Methods

Subjects

This cross-sectional study evaluated of nineteen younger (22±2 yr) and twenty one older (66±6 yr) female, physically fit adults were considered for this study (Table 1). The sample size was determined based on data from a pilot study and the G*Power program was used, considering as the outcome variable the torque of the knee extensors (power = 0.80, effect size = 0.85, error α = 0,05). The younger adults were recruited from an university student population and older adults were recruited from a senior community physical activity group, both groups were classified as physically active according to the IPAC questionnaire.

Inclusion criteria were: not falling during the previous 12 months[13]. Exclusion criteria included pain, fracture, muscle, tendon or ligament injuries during the previous 6 months, cognitive impairment, cardiovascular or respiratory problems. All subjects signed an informed consent form and the institutional Ethical committee approved the study (9032/2013).

Strength measures

Before testing, the subjects completed a warm up walking on a treadmill for 5 minutes at self-selected pace[14]. Then, the subjects were familiarized with the strength test conditions. All evaluations were performed by a single evaluator, in a controlled temperature environment, always in the same period of the day. After that, the subjects completed three isometric and five isokinetic voluntary contractions on dominant leg of hip, knee and ankle joint movements at sagittal plane. Strength was assessed on an isokinetic dynamometer (Biodex®, New York, USA). The order of the tests were randomized and for the isokinetic concentric strength measure of knee and ankle was used the speed of 60 deg.sec^{-1} and for the hip join the contraction speed was set at 30 deg.sec^{-1} and five maximal repetitions were collected for data analysis[15,16].

The isometric strength was measure at 60° of flexion for hip, 30° of flexion for knee and neutral position for ankle[17]. All the isometric voluntary contractions were sustained for five seconds with 30 seconds of rest between each contraction. Strong verbal encouragement was provided to obtain maximal effort during data acquisition of each joint.

Hip extension and hip flexion torque were measured with each subject in a supine position. A resistance pad was secured with a strap around the thigh of the limb being tested, and each subject's pelvis and trunk were stabilized on the table using belts. The dynamometer was aligned to the approximate axis of rotation of the hip joint being tested (superior and anterior to the greater trochanter). The test was initiated with the hip flexed at 10°; hip flexion torque was assessed as the subject moved from this position to 60º of hip flexion. Hip extension torque was assessed starting from the position of 60 degrees of hip flexion up to 10 degrees of hip flexion[17-18].

Isokinetic knee flexion and extension torques were measured with participants seated with the hip flexed at 90º. The dynamometer was aligned to the approximate axis of rotation of the knee joint (a line traversing the femoral epicondyles) and the resistance pad was placed on the tibia, just proximal to the superior border of the medial malleolus. The subjects' thigh, trunk, and pelvis were stabilized with straps, and subjects crossed their arms in front of the chest throughout the test. Testing was initiated at 90º of knee flexion with the initial movement toward 60º of extension[15]. Isokinetic plantar flexion and dorsiflexion torques were measured with each subject lying in a supine position. The knees and hips were flexed while the ankle was in neutral inversion-eversion. The dynamometer was aligned to approximate the axis of rotation of the ankle joint being tested (the projection of a line passing obliquely through the distal tip of the tibia and fibula), and the foot was strapped securely to the footplate. Proximal thigh and trunk stabilization was provided using belts to prevent unwanted movement. The test was initiated with subjects at 10º of dorsiflexion, with the initial movement toward 30º of plantar flexion[19].

Figure 1a, 1b and 1c show the subject position during hip, knee and ankle joint torques measurement.

Figure 1. Position on the isometric dynamometer for assess of ankle (A), knee (B) and hip (C).

Habitual Gait Speed

The evaluation of gait was conducted on a walkway measuring 14 meters long and 2 meters wide. *Habitual Gait Speed*: the volunteers were instructed to "walk on the walkway at the speed at which you normally perform your daily activities"[20]. Habitual gait speed was calculated by dividing distance walked (10 m) by the time to cover this distance (s).

Data analysis

Peak torque of isometric and isokinetic contractions were normalized by subjects' body mass. Then, using normalized peak torque maximum functional force was calculated using the following equation:

$$\textit{Strength Ratio} = \frac{\textit{Maximum Isokinetic Torque}}{\textit{Maximum Isometric Torque}}$$

Statistical Analysis

PASW 18.0 (SPSS Inc.) was used for all statistical analyses and means and standard deviations were used to summarize participant characteristics. MANOVA test was used to compare isometric and isokinetic peak torque and maximum functional force between younger and older adults. Pearson correlation coefficient was computed to quantify the association between walking speed and strength ratio. The significant level was set at $p < 0.05$.

Results

Characteristics of subject

Table 1 presents the anthropomorphic characteristics of voluntary young and older participants of this study. There was a significant difference for age, height and usual walking speed ($p < 0.001$).

Table 1. Subjects characteristics.

	Younger (n = 19)	**Older (n = 21)**	**p**
Age (years)	22 (±2)	66 (±6)	< 0.001*
Height (m)	1.62 (±0.05)	1.55 (±0.06)	< 0.001*
Body Mass (Kg)	61.4 (±7.5)	63.2 (±12.4)	0.601
BMI ($Kg{\cdot}m^{-2}$)	23.4 (±3.4)	25.3 (±3.4)	0.096
Walking Speed (ms^{-1})	1.26 (±0.19)	0.93 (±0.18)	< 0.001*

* p < 0.001.

Comparison of the strength measures between groups

ANOVA multivariate comparison showed a significant group effect ($F = 44.804$; $p < 0.001$).

Table 2. Repeated measures ANOVA results on the effect of group of isometric torque, isokinetic torque and strength ratio of ankle, knee and hip.

	Group Effect					
	MIVC ($Nm{\cdot}kg^{-1}$)		**MIsVC ($Nm{\cdot}kg^{-1}$)**		**Strength Ratio**	
	P	F	p	F	p	F
Ankle flexors	0.030*	5.082	0.006*	8.377	0.01*	12.336
Ankle extensors	>0.001**	45.049	>0.001**	45.435	0.013*	6.737
Knee flexors	>0.001**	75.679	>0.001**	107.407	0.819	0.053
Knee extensors	>0.001**	83.268	>0.001**	142.592	0.191	1.770
Hip flexors	>0.001**	65.308	>0.001**	60.247	0.356	0.870
Hip extensors	>0.001**	54.820	>0.001**	107.810	0.350	0.893

* p<0.05, ** p < 0.001; MIVC = maximum isometric voluntary contraction, MIsVC = maximum isokinetic contraction. $NmKg^{1}$ = Newtons.Meters/body weight

Younger adults were, respectively, 42.73, 44.48, 46.6, 42.2, 14.15 and 39.61% stronger than older adults for the follow isometric contractions: hip flexion ($F = 65.308$; $p < 0.001$), hip extension ($F = 54.820$; $p < 0.001$), knee flexion ($F = 75.679$; $p < 0.001$), knee extension ($F = 83.268$; $p < 0.001$), ankle flexion ($F = 5.082$; $p = 0.03$) and ankle extension ($F = 45.435$; $p < 0.001$).

With respect to the isokinetic peak strength, younger were, respectively, 37.80, 47.40, 45.13, 47.08, 26.39, 42.03% stronger than older adults for the follow movements: hip flexion ($F = 60.247$; $p < 0.001$), hip extension ($F = 107.810$; $p < 0.001$), knee flexion ($F = 107.407$; $p < 0.001$), knee extension ($F = 142.592$; $p < 0.001$), ankle flexion ($F = 5.082$; $p = 0.006$) and ankle extension ($F = 45.435$; $p < 0.001$).

Strength ratio were significant difference between groups only for ankle joint movements. Thus, younger adults had 11.6% higher ankle extension strength ratio ($F = 12.336$; $p = 0.013$) and 17.6% higher ankle flexion strength ratio ($F = 6.737$; $p = 0.001$) than older female adults.

Table 3. MANOVA for the comparisons of isometric torque, isokinetic torque and strength ratio of hip, knee and ankle of young and older adults.

	HIP			**KNEE**			**ANKLE**		
	Younger	Older	P	Younger	Older	p	Younger	Older	p
MIVC Flex ($Nm^{.}kg^{-1}$)	296.381±11.46	169.714±10.69	**>0.001***	133.570±5.29	71.274±4.81	**>0.001***	47.229±2.16	40.546±2.02	**0.030***
MIVC Ext ($Nm^{.}kg^{-1}$)	240.186±10.55	133.329±09.84	**>0.001***	271.796±9.30	157.087±8.45	**>0.001***	141.138±6.09	85.227±5.68	**>0.001***
MIsVC Flex ($Nm^{.}kg^{-1}$)	153.651±05.47	95.557±05.10	**>0.001***	103.996±3.35	57.061±3.04	**>0.001***	37.720±2.51	27.764±2.34	**0.006***
MIsVC Ext ($Nm^{.}kg^{-1}$)	104.142±03.50	54.391±03.26	**>0.001***	195.069±5.69	103.215±5.17	**>0.001***	69.622±3.17	40.353±2.96	**>0.001***
Strength Ratio Flex	0.541±0.034	0.584±0.032	0.356	0.781±0.028	0.772±0.025	0.819	0.677±0.037	0.501±0.034	**0.001***
Strength Ratio Ext	0.448±0.028	0.412±0.026	0.350	0.684±0.027	0.635±0.024	0.191	0.605±0.033	0.489±0.031	**0.013***

Values mean ± standard deviation. * denotes significant difference (P < 0.05), MIVC = maximum isometric voluntary contraction, MIsVC = maximum isokinetic contraction, Flex = flexion, Ext= extension.

Association between strength measures and walking speed

Younger subjects had 26% faster preferred walking than older subjects ($p<0.001$). We found a significant correlation between: ankle flexors ratio and habitual gait speed ($r = 0.352$, $p = 0.022$), ankle flexors ratio and age ($r = -0.643$, $p < 0.01$; Table 6); ankle extensor strength and age ($r = -0.366$, $p = 0.017$).

Table 4. Correlations between ankle ratio, age and habitual gait speed.

	Ankle Flexors Ratio	**Ankle Extensor Ratio**
Habitual Gait Speed	r = 0.352	r = 0.181
	p = 0.022	p = 0.251
Age	r = -0.643	r = -0.366
	p < 0.001	p = 0.017

Discussion

This study investigated the age-related alterations on lower limb strength in younger and older female adults. We also purposed the assessment of functional demand using a strength ration calculated using the maximum isokinetic strength over the maximum isometric strength. Our findings demonstrated that younger adults were stronger than older adults and had a lower strength ratio. In addition, we found a positive association between ankle flexor strength ratio and walking speed. Thus, our findings partially agree with our initial hypothesis.

Age-related weakness

We found that older female adults were weaker than younger pairs in all movements and joints during isometric and isokinetic contractions. The age-related weakness is explained by central and peripheral neuromuscular changes[2,21]. Among of these central and peripheral alterations are: the lower capacity to recruit motor units, the lower motor units fire rate, the relative increased number of type I muscle fibers and the atrophy of type II muscle fibers[2]. In addition, Hortobágyi *et al*.[10] demonstrated that the age-related strength loss is related to an increased antagonist coactivation. Despite studies suggested that the decline of strength is related to the muscle mass loss, according to studies it only explain 6-10% of strength impairments[22,23]. With respect to this study finding it is corroborating with the previous study to support the statement that age reduces the lower strength and it must be an important risk factor for mobility impairments and increased risk of falling[24]. Also, the novel aspect addressed in the present study was the strength ratio, which may be a predictor of functional demand, have positive correlation with walking speed.

Strength ratio

Strength ratio closes to 1 shows a higher capacity to generate forces under movements performed in functional speeds. Lower strength ratio also indicates that the individuals may be able to generate force in a static position, but there is significant reduced force during movements. In our study, older female adults were weaker during all static and dynamic contractions in all joints assessed. However, only for ankle joint movements the strength ratio was significant lower in older population.

The decreased strength ratio in ankle joint may interfere on gait pattern, increase the functional demand and increase the risk of falling. Ankle flexor strength is especially relevant during walking at the balance gait phase[25]. Thus, ankle flexor muscles are recruited during this phase to avoid the contact of feet against the ground and preventing a trip[18]. On the other hand, ankle extensor muscles are recruited during the push off phase to accelerate the center of mass and perform the next step. In addition, ankle extensor muscles also contribute to stabilize ankle joint at weight acceptance phase[25]. This distal deficit strength is compensated by a larger hip flexion moment resulting from an increase in the iliopsoas muscle force in this phase, known as the hip strategy[26].

A decreased strength ratio in older adults may be related to a reduced physiological muscle reserve and to the decline of physical capacities with aging, which results in higher functional demand in these subjects. Thus, when an older adult walks close to her/his maximum functional demand it put this person at high risk to early onset of fatigue, higher perception of effort, and reduces the ability to generate muscle power to recovery balance after a trip[5,6,9].

Habitual Gait Speed x Strength ratio

Our results also demonstrated that ankle strength ratio was positive associated with gait speed. However, the correlation between these variables was low, which may indicate that there are other factors that influence walking speed in the elderly population, such as knee extensor strength, length and step frequency, as observed in other studies. The weakness at ankle joint has been associated with a decline on mobility and the increased falls incidence in older population[25]. In addition, our findings are also in concordance with Rybertt *et al*.[27] study, which identified an association between lower limbs strength and walking speed. Thus, considering that the decline of walking speed has an intrinsic relationship with mobility status, functional independence and risk of falling[28], we suggested that ankle muscles strength have to be considered in the prescriptions of programs to improve walking and falls prevention.

Limitations

The present study considered for strength ratio calculation the maximum voluntary isometric and isokinetic strength with the aim to predict the functional demand. However, when the functional demand is calculated by inverse dynamic during walking it considers submaximal forces. Thus, our model (strength ratio calculation) to represent functional demand might not represent exactly the strength demand during activities of daily living, such as walking. The subjects of this study were older female adults physically active with low risk of falls. Thus, the extrapolation of our data for other populations should be made with caution.

Conclusion

According to our results older female adults were weaker than younger women in all movements (flexion and extension) and lower limb joints assessed (hip, knee and ankle). The most recent aspect of this study was to show that the force ratio is lower in older female, which indicates lower physiological muscle reserve capacity and may justify the lower walking speed in this population. In addition, the lower ratio may result in a higher risk of falls in this population since the elderly may not be able to generate sufficient muscular strength to regain balance after a stumble or slip since under normal conditions already working near their maximum capacities. Therefore, age-related weakness at lower limb may increase the functional demand in older adults, which may be put older adults at high risk to the early onset of fatigue, increased sense of effort and increased risk of falls.

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