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ORIGINAL RESEARCH

Influence of age and gender on knee and hip isometric strength of recreational physically active young and middle-aged subjects

Influência da idade e do sexo na força isométrica do joelho e do quadril de indivíduos jovens e de meia idade praticantes recreacionais de atividades físicas

Influencia de la edad y el sexo en la fuerza isométrica de la rodilla y la cadera de personas jóvenes y de mediana edad que practican actividades físicas recreativas

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ABSTRACT | Muscle strength is an essential part of the functional assessment of health professionals to select and analyze the effects of clinical interventions. This study aimed to determine the influence of gender and age on isometric strength of hip and knee muscle groups. A total of 127 subjects (50.4% men), aged from 20 to 49 years (stratified into three groups: 20–29 years; 30–39 years; and 40–49 years) participated in this study. A hand-held dynamometer was used to measure isometric normalized torque of the hip abductors, hip external rotators, knee extensors, and knee flexors muscles. Regressions and a two-way analysis of variance were used to identify the influence of age and gender on torque of each muscle group. Age and gender were included in the regression model for all groups. Generally, men aged 20–29 and 30–39 were stronger than age-paired women. For participants aged 40–49, torque was similar for men and women for all muscle groups. There was no difference among age groups for women. Generally, young men were stronger than older men. The association between age and gender in hip and knee strength was proved and liable of subgroup stratification after measurements with a hand-held isometric dynamometer.

Keywords | Muscle Strength Dynamometer; Torque; Lower Extremity; Sex Distribution; Age Groups.

RESUMO | A força muscular é um componente essencial da avaliação funcional de profissionais da saúde para selecionar e analisar efeitos de intervenções clínicas. O objetivo do estudo foi determinar a influência do sexo e da idade sobre medidas de força isométrica de grupos musculares do quadril e do joelho. Participaram da pesquisa 127 sujeitos (50,4% homens), com idade de 20 a 49 anos (estratificados em grupos: 20 a 29 anos; 30 a 39 anos; e 40 a 49 anos). O torque isométrico normalizado de abdutores e rotadores externos de quadril e extensores e flexores de joelho foi medido com dinamômetro manual. Regressões e uma análise de variância (Anova) foram usados para identificar a influência da idade e do sexo sobre o torque. Tanto idade quanto sexo foram incluídos no modelo para todos os grupos musculares. Em geral, homens de 20 a 29 anos

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e de 30 a 39 anos demonstraram mais força do que mulheres da mesma faixa etária. Para participantes de 40 a 49 anos, o torque foi similar entre homens e mulheres para todos os grupos musculares. Não houve diferença entre as faixas etárias no grupo de mulheres. Em geral, homens mais jovens se mostraram mais fortes do que homens mais velhos. A relação entre idade e sexo na força muscular do quadril e do joelho foi provada e se mostrou passível de estratificação após as medições feitas com o dinamômetro manual.

Descritores | Dinamômetro de Força Muscular; Torque; Extremidade Inferior; Distribuição por Sexo; Grupos Etários.

RESUMEN | La fuerza muscular es un componente básico de la evaluación funcional de los profesionales de la salud para seleccionar y analizar los efectos de las intervenciones clínicas. El objetivo de este estudio fue determinar la influencia del sexo y de la edad en las mediciones de fuerza isométrica de los grupos musculares de la cadera y la rodilla. En el estudio participaron 127 sujetos (50,4% hombres), de entre 20 y 49 años de edad (estratificados en grupos: 20 a 29 años; 30 a 39 años; y 40 a 49 años). El torque isométrico normalizado de los abductores y rotadores externos de la cadera y de los extensores y flexores de la rodilla se midió con un dinamómetro manual. Se utilizaron regresiones y el análisis de varianza (Anova) para identificar la influencia de la edad y el sexo en el torque. Tanto la edad como el sexo se incluyeron en el modelo para todos los grupos musculares. En general, los hombres de entre 20 y 29 años y los de 30 a 39 mostraron tener más fuerza que las mujeres del mismo grupo de edad. Para los participantes de 40 a 49 años, el torque fue similar entre hombres y mujeres para todos los grupos musculares. No hubo diferencias entre los grupos de edad en el grupo de mujeres. En general, los hombres más jóvenes demostraron ser más fuertes que los hombres de mediana edad. La relación entre la edad y el sexo en la fuerza muscular de la cadera y la rodilla se probó y demostró ser susceptible a la estratificación después de las mediciones realizadas con el dinamómetro manual.

Palabras clave | Dinamómetro de Fuerza Muscular; Torque; Extremidad Inferior; Distribución por Sexo; Grupos de Edad.

INTRODUCTION

Strength deficits have been associated with many lower limb injuries[1,2]. Additionally, the risk and incidence of injury are different between men and women[3,4], and can also be influenced by age[3]. Khayambashi et al.[1] found an increased risk of anterior cruciate ligament (ACL) injuries in athletes with weak hip abductors. Kollock et al.[2] reported that individuals with knee overuse symptoms had lower absolute strength of hip external rotators, knee extensors, and knee flexors muscles, as well as lower normalized strength of hip external rotators, extensors, and abductors, when compared to asymptomatic control participants. Some authors suggested that the main goal of rehabilitation is the reestablishment of muscle strength, because it has been associated with a better functionality[5]. Thus, muscle strength is an integral part of health professionals' functional assessment to select the best therapeutic strategy for each subject and monitor the effects of interventions over time for both healthy and impaired populations.

The use of isokinetic dynamometers to assess muscle strength is well accepted worldwide as the reference standard. However, it is about 40 times more expensive[6] than hand-held dynamometers (HHD) and demands more time for collecting data, especially when evaluating large samples. HHD is a valid, cheap, and quick tool that provides objective data compared to manual muscle testing[7]; it also has a high correlation to isokinetic dynamometers[8], and a good reliability[9,10].

Several studies have relied on regression analyses to predict a normative range of isometric strength assessed with hand-held dynamometers for clinical practice use[11-13]. Although it is well known that muscle strength is related to anthropometry, gender, and age[14], none of these studies have investigated the influence of different age groups of physically active young and middle-aged men and women on hip and knee strength normalized by body mass and size. This information is crucial for developing a normative database in future studies and for clinical assessments, categorizing strength for age groups and gender. Therefore, this study aimed to determine the influence of gender and age on normalized isometric strength of hip and knee muscle groups. It was hypothesized that men would be stronger than women in all ages and younger subjects would be stronger than older individuals.

METHODOLOGY

Study design and local

Every patient of a private laboratory that underwent biomechanical tests for assessing the risk of injuries in sports activities was recruited. Each participant came once to the laboratory to perform the assessments.

Population and selection criteria

Inclusion criteria were men or women, aged 20–49 years, and who practiced physical activity at least three times per week, minimum of 45 minutes per training session, totaling at least 150 minutes of exercise per week, for a minimum of one year. There was no limit of maximum physical activity, but no participant had been engaged in elite or professional sports activity. Exclusion criteria were active muscle-skeletal pain or chronic symptomatic conditions, pregnancy, clinical disorders that demand regular use of medication (e.g., cardio-pulmonary, endocrine, neurological, psychiatric), use of anabolic steroids (patient' self-report), or recent abuse of alcohol or drugs.

Sample definition and ethical aspects

Every participant signed an informed consent. Sample size was based on the study of Bittencourt et al.[15]. The analysis showed that each group should have 17 subjects to achieve a 0.8 power with a 1.00 effect size, using a 0.05 significance level. Thus, considering that the study included six groups, at least 102 participants (17 in each group) were necessary.

Data collection

Tests were performed on the dominant lower limb. Lever arm for torque calculation of thigh muscles was measured considering the distance between the proximal tip of the greater trochanter of the femur and a horizontal line drawn 5cm above the lateral knee joint line. Shank lever arm was defined as the distance between the knee joint line and 5cm above the lateral malleolus. Isometric strength was assessed with a hand-held dynamometer (Lafayette Instrument, Lafayette, IN, USA). Intra- and inter-rater reliability of these devices have been previously reported to be excellent, with values above 0.80[9,10,16].

Immovable straps were used to stabilize both the participants and the HHD to avoid potential bias by examiner's own strength. A "make" technique was performed because Stratford and Balsor[17] reported higher reliability against "break" test for HHD. Participants were asked to push against the dynamometer with maximum strength for 5s. A test run was performed, followed by three experimental trials, with 15s of rest in between. The peak force (N) of the three trials was recorded, multiplied by arm lever, and normalized by body mass (Nm/kg) for analysis. Normalized measures were used to reduce the influence of different body mass and size on strength[14]. Standardized verbal stimulus was given during the test for all participants to ensure peak performance[12,18].

Hip abductor strength (Figure 1A) was assessed using the methods described by Ireland et al.[19]. Participants assumed a lateral decubitus position with the limb to be tested facing up, while the pelvis was stabilized to the table with a strap and arms were crossed around the chest. The tested limb was in a neutral position, and the HHD was placed in the lateral of the thigh, 5cm proximal to the knee joint line and secured with a strap fixed on the table. Hip external rotation strength (Figure 1B) was measured with participants in a prone position with the assessed knee flexed in 90° to allow measurement closer to functional activities as gait and running, where hip flexion is lower than 60°[20,21] and the three portions of gluteus maximus act as external rotators at 0° of hip flexion. The other lower limb remained at anatomical position, the pelvis was stabilized to the table with a strap, and the arms rested along both sides of the trunk. The HHD was placed 5cm proximal to the medial malleolus.

To measure knee flexors strength (Figure 1C), participants were kept in the same position, but HHD was placed at the posterior aspect of the leg, 5cm proximal to the lateral malleolus with the knee being flexed at 90° and the other lower limb at anatomical position. Arms were resting along both sides of the trunk and the pelvis was stabilized to the table with a strap. Knee extensors

(Figure 1D) were tested in sitting position with the hip in neutral frontal and transverse plane rotation, flexed at 90°, and knee flexed at 90°. HDD was placed against the anterior aspect of the leg 5cm proximal to the lateral malleolus and was secured with a strap fixed under the table. For both knee assessments, pelvis was stabilized to the table with a strap. Arms were relaxed, with both hands lying on the thighs.

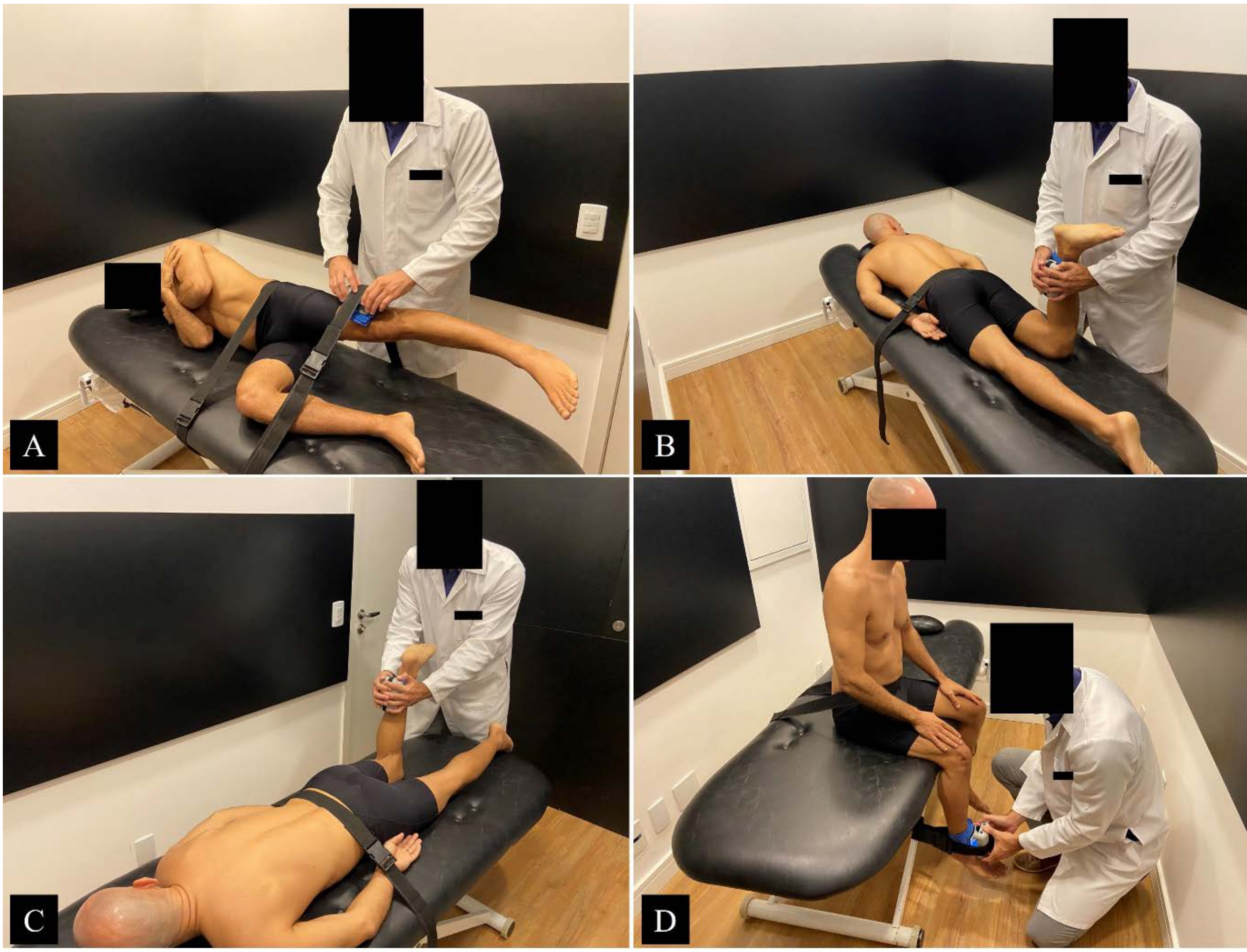


Figure 1. Isometric strength tests position. A: Hip abductors; B: Hip external rotators; C: Knee flexors; D: Knee extensors

Data analysis

Age and gender were the independent variables, and peak normalized isometric strength was the dependent variable in this study. Age was stratified into three groups: 20–29 years old; 30–39 years old; and 40–49 years old. Multiple regressions and a two-way analysis of variance were performed to identify the influence of age and gender on torque values (Nm/kg) of each muscle group. Akaike Information Criterion (AIC) was used to choose variables to be added or removed from the regression models. A Tukey-Kramer's post hoc test was performed to determine significance among age and gender groups. To estimate the magnitude of the difference between groups, Cohen's d effect size was calculated[22], and classified as insignificant ($d<0.19$), small ($0.2<d<0.49$), medium ($0.5<d<0.79$), large ($0.80<d<1.29$), and very large ($d>1.30$). Significance level was set at 0.05.

RESULTS

Demographics

In total, 136 subjects (70 men) were selected, based on the inclusion and exclusion criteria. Participants were allocated into subgroups according to gender and age. Nine subjects (6.6%) were considered outliers and were excluded from the study. Most outlier values were related to a reduction of peak force caused by excessive muscle fatigue or cramp. By the end of the study, 127 subjects (64 men) had been enrolled: 20–29 years old (20s group), being 17 males and 19 females; 30–39 years old (30s group), 27 males and 27 females; and 40–49 years old (40s group), 20 males and 17 females. Table 1 shows demographic characteristics.

Table 1. Demographic values, expressed as mean±standard deviation, stratified by gender and age

	Men			Women		
	Age (years)	Mass (kg)	Height (cm)	Age (years)	Mass (kg)	Height (cm)
20–29 yo	24.9±3.8	74.9±7.8	178.8±5.0	26.0±3.4	58.1±6.8	167.7±5.9
30–39 yo	35.2±2.7	82.2±10.4	179.9±7.1	35.4±3.3	61.9±9.5	166.4±6.2
40–49 yo	44.8±2.8	80.0±6.0	179.5±5.7	46.0±2.8	61.4±9.3	162.6±6.5

yo: years old.

Torque stratified by gender and age

Linear multiple regressions had a statistically significant fitting ($p<0.0001$), retaining both age and gender in all models. Hip abductors regression showed a r^2 of 0.24; for hip external rotators, r^2 was 0.19; for knee extensors and flexors, r^2 was 0.28 and 0.20, respectively.

Table 2 presents the normalized torque measures stratified by age and gender. Normalized hip abductors torque presented an effect of gender ($F_{1,126}=26.0$, $p<0.0001$, Table 2) and an interaction between gender and age ($F_{2,126}=7.2$, $p=0.001$, Table 2). Post hoc analysis showed that 20s men were stronger than 40s men (d=1.53, Figure 2). Furthermore, 20s and 30s men presented higher strength than 20s (d=1.81, Figure 2) and 30s women (d=0.75, Figure 2). Post hoc analyses showed no differences between the age groups among women (Figure 2).

Hip external rotators torque showed effect of both gender ($F_{1,126}=58.3$, $p<0.0001$, Table 2) and age ($F_{2,126}=6.7$, $p=0.002$, Table 2), and an interaction between factors ($F_{2,126}=5.2$, $p=0.007$, Table 2). Post hoc analysis evidenced that 20s men were stronger than 30s men (d=1.12, Figure 2) and 40s men (d=1.48, Figure 2). Additionally, 20s and 30s men presented higher strength than 20s (d=2.33, Figure 2) and 30s women groups (d=1.21, Figure 2). Post hoc analyses showed no differences between the age groups among women (Figure 2).

Both knee extensors and flexors torque presented differences for factors gender (extensors: $F_{1,126}=38.7$, $p<0.0001$; flexors: $F_{1,126}=23.1$, $p<0.0001$; Table 2) and age (extensors: $F_{2,126}=5.3$, $p=0.006$; flexors: $F_{2,126}=5.3$, $p=0.006$; Table 2), without interaction between factors (extensors: $F_{2,126}=1.43$, $p=0.24$; flexors: $F_{2,126}=0.4$, $p=0.65$; Table 2). For knee extensors, post hoc analysis revealed differences between 20s men and 40s men (d=0.93, Figure 2). Women presented reduced strength compared to men for the 20s (d=1.35, Figure 2) and the 30s (d=1.26, Figure 2) groups. For women, post hoc analyses showed that there was no difference between the age groups (Figure 2). The 20s men group had higher knee flexors torque values than the 20s women group (d=1.26, Figure 2). Post hoc analyses showed that there were no differences between the age groups for men and women (Figure 2).

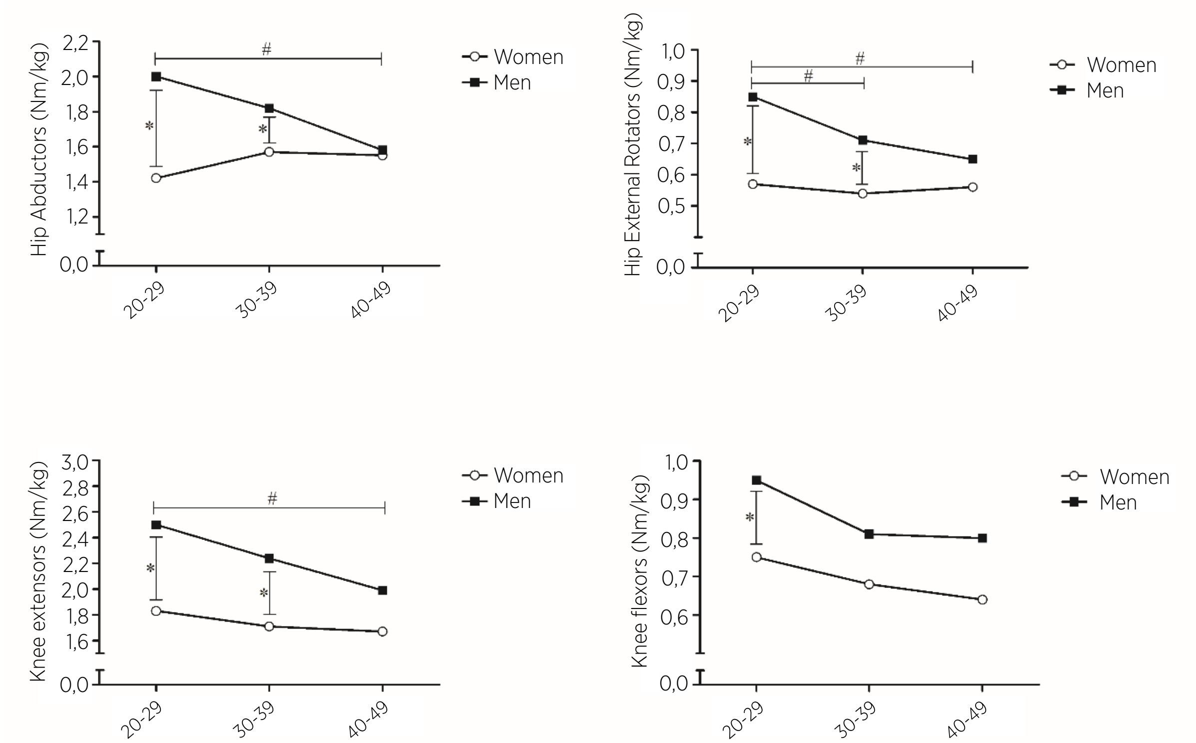
Table 2. Normalized torque values (Nm/kg), expressed as mean±standard deviation, stratified by gender and age

	Men			Women		
	20–29 yo	30–39 yo	40–49 yo	20–29 yo	30–39 yo	40–49 yo
Hip Abdu*§	2.00±0.32	1.82±0.20	1.58±0.22	1.42±0.32	1.57±0.36	1.55±0.27
Hip ER*#§	0.85±0.13	0.71±0.12	0.65±0.14	0.57±0.11	0.54±0.15	0.56±0.10
Knee Ext*#	2.50±0.60	2.24±0.41	1.99±0.49	1.83±0.36	1.71±0.43	1.67±0.36
Knee Flex*#	0.95±0.21	0.81±0.16	0.80±0.25	0.75±0.08	0.68±0.21	0.64±0.15

*Effect of gender; #Effect of age; §Interaction between gender and age.

yo: years old; Hip Abdu: hip abductors; Hip ER: hip external rotators; Knee Ext: knee extensors; Knee Flex: knee flexors.

Figure 2. Torque results (Nm/kg) stratified by gender and age



*Significant difference between men and women; #Significant difference between age groups.

DISCUSSION

The main finding of this study was that the relation of age and gender with hip and knee strength was proved and liable of subgroup stratification after measurements with a hand-held isometric dynamometer. Age and gender were both included in the regression models for all muscle groups assessed, showing that they have an influence on muscle strength and should be considered when clinically assessing strength parameters. However, they predicted 19–28% of the strength, showing that the strength is also influenced by other factors. When the participants were divided into age groups, there were no difference between 20s, 30s and 40s for women. On the other hand, 20s men differed from older men, specially from 40s men. Knee flexors did not differ between age groups both for men and women. The 20s men were stronger than women for all muscle groups, 30s men were stronger than women for hip abductors, hip external rotators and knee extensors. However, similar torque values were presented for the 40s men and women. Measuring and establishing normative range of strength by gender and age from 20 to 49 years would be significant for clinical practice.

The rationale for studying strength of hip abductors, hip external rotators, knee extensors, and knee flexors in this study was due to their association to many orthopedic dysfunctions and painful conditions, as patellofemoral pain syndrome (PFPS), iliotibial band syndrome (ITBS), and ACL tears. Leetun et al.[23] showed that athletes with hip weakness have increased risk of lower extremity injuries compared to stronger peers. Selfe et al.[24] found three subgroups of patients with PFPS, and two of them were related to knee extensors and hip abductors weakness. Knee extensors weakness has also been related to decreased Cincinnati questionnaire[25] and lower biomechanical performance[26] after ACL reconstruction, while Timmins et al.[27] showed biceps femoris strength deficits after ACL reconstructions.

Although the variability explained by the regression models was low—ranging from 19 to 28%— all models showed statistical significance, retaining both age and gender in the model. In clinical practice, physical therapists usually assess and compare patients' strength using normalized measures (% body mass or Nm/kg), so normative ranges based on quartiles of a reference population, instead of regression equations, may be more appropriate to reduce strength variability among different ages and genders, once that there are other aspects that contributes to the muscle strength determination. Bittencourt et al.[15] developed a model using normalized torque. Although both gender and age were retained in all models, the variability was low (<30%). Possibly, variables other than gender and age may influence strength and regression equations may result in large errors. Regression models proposed by other authors show similar or higher values, but absolute force, in Newtons or kilograms, were used as independent variables[7,9,14].

The influence of age and gender on strength measures has been previously suggested in other studies using isokinetic dynamometers[28,29], and confirms the importance of defining normative values stratified by age and gender[11]. We could not find any study comparing isometric strength using hand-held dynamometers among different age ranges and genders in recreational physically active young and middle-aged subjects. Most studies only developed regression equations to predict normative data[5,9,13,30].

However, using the information based on the effect size of these papers, we found that most of the data available support the results from this study. Harbo et al.[13] found stronger knee extensors in young men compared to older men and women. The effect size of women's knee extensors strength from 20 to 49 years old is low. Similar to our study, the National Isometric Muscle Strength Database Consortium[18] showed higher knee extensors and flexors strength values for men compared to women. However, these results reported strength in absolute values, not considering body mass and should be cautiously used[14]. Despite the fact that the strength reduced for men and women as the age increased, these differences were not significant for knee flexors. Possibly, the strength losses related to the aging process could be greater for sedentary individuals or it becomes more accentuated in people aged 50 or older. Future studies could investigate whether the reductions related to age are different for different muscular groups. Bohannon[6] and Phillips et al.[30] reported higher values of hip abductors strength in men compared to women. However, men and women's strength did not vary considerably from 20 to 49 years old. These different results may be related to the individual position in each test. Hip abductors in our study were tested with individuals in lateral decubitus, while Bohannon[6] and Phillips et al.[30] tested individuals in a supine position. Thorborg et al.[31] showed that strength values differ for these two positions.

A limitation of our study is that the sample was composed of young and middle-aged men and women, which are usually the most physically active population on recreational activities, limiting the generalizability to other populations. The maximum dedication and intensity of physical activity was not controlled. All data presented here is appropriate only for strength values obtained with identical testing and stabilization procedures.

CONCLUSION

Our study confirmed that both age and gender influence hip and knee strength. Men aged from 20 to 39 years were stronger than women for most muscle groups. However, men and women aged from 40 to 49 have similar strength for the tested muscle groups. Also, results confirmed that younger men are stronger than older ones, but women's strength remains consistent from 20 to 49 years old. These results should be considered when defining normative strength ranges for recreational physically active young and middle-aged men and women.

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