



Relationship between grip strength and global muscle strength in community-dwelling older people



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ABSTRACT

There are still conflicting results regarding the association between grip and global muscle strength in older people. Therefore, the objective of the present study was to determine the association between grip strength and global muscle strength, as well as between grip strength and individual trunk, hip, knee and ankle muscle strengths.

Methods: Grip strength was assessed using a manual dynamometer, and trunk, hip, knee and ankle muscle strength with an isokinetic dynamometer, in order to obtain the global muscle strength variable, in 150 older men and women from the community. The association between grip and global muscle strength and between grip strength and the strength of each muscle group was determined through the Pearson correlation test, followed by multivariate linear regression adjusted for sex, age, body mass index, level of physical activity and number of comorbidities.

Results: A positive significant association was found between grip strength and global muscle strength in older people ($r = 0.690$; $\beta = 10.07$; $p < 0.001$; $R^2 = 0.604$), even after adjustment. There was also a low to moderate association between all the muscle groups and grip strength. However, when the model was adjusted, the relationship between grip strength and ankle dorsiflexor peak torque lost significance ($p = 0.924$).

Conclusion: Grip strength can represent global muscle strength in younger older people in the community, even when confounding variables are considered in the statistical model. However, grip strength does not eliminate the need for specific assessment of different muscle groups, when indicated.

1. Introduction

During the aging process, older people become more vulnerable to falls, hospitalizations, comorbidities, functional incapacity and mortality (Fried, Ferrucci, Darer, Williamson, & Anderson, 2004). Muscle weakness, resulting from physiological changes in the musculoskeletal system, is an important predisposing factor for such outcomes (Cruz-Jentoft et al., 2010, 2018; Samuel & Rowe, 2012).

A quick and easy-to-use, low-cost tool, often utilized with older people to assess global muscle strength, is the manual dynamometer, which is recognized in clinical practice and the literature as a standard instrument for measuring grip strength, with good indices of validity and reliability (Figueiredo, Sampaio, Mancini, Silva, & Souza, 2007). However, studies that have examined the association between grip strength and global muscle strength have also yielded conflicting results (Bohannon, 2015). Many studies which investigated the relationship

between grip strength and global muscle strength included lower and upper limb muscle groups to represent global muscle strength. However, previous studies have already established the direct association between grip strength and upper limb muscle strength (Bohannon, 1998, 2009). Based on these statements, it is reasonable to hypothesize that the inclusion of upper limb strength in order to estimate the global muscle strength may tend to increase the correlation between grip and global muscle strength. Furthermore, given the importance of the trunk, hip, and ankle muscle groups for mobility, functionality and falls in older people (American College of Sports Medicine, 2018; Suri, Kiely, Leveille, Frontera, & Bean, 2011), it is important to incorporate them in the measurement of global muscle strength, without an inclusion of upper limb strength, as well as to determine whether grip strength can be used to represent the strength of these muscles.

Therefore, the objective of the present study was to determine the association between grip strength and global muscle strength, as well as

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between grip strength and individual trunk, hip, knee, and ankle muscle group strengths.

2. Methods

2.1. Sample

A total of 150 independent men and women, aged 60–80 years old, participated in this cross-sectional study. The study presents a convenience sample in which participants were directly recruited from the community (associations and senior citizens clubs) and at events held for older people by the University of São Paulo (Ribeirão Preto). The study was approved by the local Human Research Ethics Committee (CAAE: 62209916.5.0000.5440), and all the participants signed free and informed consent forms prior to the assessments. The assessments were performed at the Integrated Rehabilitation Center of the State Hospital (Ribeirão Preto - SP), from March 2017 to May 2018.

The exclusion criteria were: individuals who reported musculoskeletal conditions that could impair the muscle function of any of the assessed muscle groups, such as the presence of daily pain, hip or knee prostheses, recent fractures or sequelae thereof, or any other symptomatic dysfunction of the dominant upper limb, trunk or lower limbs (such as arthritis, tendonitis, among others). Older people were also excluded if they had a low score on the mini-mental state examination, according to the level of education (Brucki, Nitrini, Caramelli, Bertolucci, & Okamoto, 2003); and the presence of neurological diseases and decompensated cardiovascular disease, or any other condition that would contraindicate physical effort.

2.2. Procedures

Each participant went to the data collection site on two different days, with an interval of two to seven days between the visits. On the first day, the sample was characterized by collecting the following data: sex, age, weight, height, body mass index (BMI), level of physical activity (IPAQ - International Physical Activity Questionnaire - short version) (Matsudo et al., 2001; Tomioka, Iwamoto, Saeki, & Okamoto, 2011) and self-reported comorbidities. A test was also performed to obtain the grip strength of the dominant upper limb (preferred upper limb for writing) using a manual dynamometer (Jamar, Sammons Preston, Illinois, USA), and isometric contractions of the trunk and dominant lower limb (preferred limb for kicking a ball) were performed for a familiarization at an isokinetic dynamometer (Biodex System 4 Pro, New York, USA). On the second day, maximum voluntary isometric contractions of the trunk and dominant lower limb were performed to obtain the peak torque of each muscle group and, in turn, the global muscle strength variable.

2.2.1. Grip strength

A manual dynamometer was used to assess grip strength (Jamar, Sammons Preston, Illinois), in line with the recommendations of the American Society of Hand Therapy (Fess, 1992) and the American College of Sports Medicine (2018). The test was conducted with the participant seated on a chair (with a back and no arm rests), with the lower limbs resting on the ground. The shoulder of the limb to be tested remained adducted and neutral for rotation, with the elbow flexed at 90°, the forearm neutral for pronosupination and wrist extension between 0° and 30° with 0–15 degrees of ulnar deviation. During the test, constant verbal encouragement was given to the participants to use their maximum strength. The test was repeated three times to obtain the mean.

2.2.2. Global muscle strength

Global muscle strength was defined as the sum of the peak torques of ten trunk and dominant lower limb muscle groups: trunk, knee, and hip flexors and extensors, hip abductors and adductors, and ankle

plantar flexors and dorsiflexors. For practical reasons, the order of execution of the tests was: trunk extensors and flexors – knee extensors and flexors – ankle plantar flexors and dorsiflexors – hip flexors and extensors – hip abductors and adductors, for one-half of the sample, and the order was reversed for the other half.

After a 5-minute warm-up on an ergometric bicycle, the peak torque of each muscle group was obtained through isometric contractions using an isokinetic dynamometer (Biodex System 4 Pro, New York, USA), calibrated according to the manufacturer's instructions. The assessment protocol consisted of three 5-second maximum voluntary isometric contractions (MVIC), with a 30-second rest for each muscle group. The contractions of the agonist-antagonist muscle groups were performed in an alternating manner. The mean of the three MVICs from each muscle group was used for calculating global muscle strength and for the analyses. Constant verbal encouragement was given during all the contractions (Baldon et al., 2009; Crozara et al., 2013).

A semi-standing position was adopted for assessing the trunk extensors and flexors, with the trunk, pelvis, and thighs secured with straps, and the hips flexed at 70° in relation to the vertical position. The mechanical axis of the dynamometer was aligned with the anterior superior iliac spine, and a position of 10° of trunk flexion was adopted in relation to the initial position for assessing extensors and 10° of extension for assessing the trunk flexors (Porto, Marques, Freire, & Abreu, 2015).

The hip abductors and adductors were assessed in the lateral decubitus position, with the limb to be tested upward at 15° of hip abduction. The trunk and contralateral lower limb were secured with straps. The mechanical axis of the dynamometer was aligned with the point corresponding to the intersection of a line drawn from the posterior superior iliac spine in a longitudinal direction and another drawn from the greater trochanter of the femur in a transverse direction (Baldon et al., 2009). The lever of the dynamometer was positioned 5 cm above the upper edge of the patella. To avoid muscle compensation during the test, participants were requested to keep the toes of the feet forward and not flex the knee of the limb being tested (Baldon et al., 2009).

The hip flexors and extensors were assessed in the supine position, with the pelvis and contralateral lower limb secured with straps. The mechanical axis of the dynamometer was positioned on the hip joint axis (region of the greater trochanter of the femur) and the lever of the dynamometer was positioned 5 cm above the upper edge of the patella. The dominant limb to be tested was positioned at 60° of hip flexion (Morcelli et al., 2015).

The knee flexors and extensors were assessed with the participant seated, with hip flexion of 90° and the trunk, pelvis and contralateral lower limb secured by straps. The mechanical axis of the dynamometer was aligned with the lateral epicondyle of the femur and the lever of the dynamometer was positioned above the upper edge of the lateral malleolus (Crozara et al., 2013). The limb to be tested was positioned at 60° of knee flexion (Ploutz-Snyder, Manini, Ploutz-Snyder, & Wolf, 2002).

The ankle plantar flexors and dorsiflexors were assessed with the participant seated, with the hip of the limb to be tested flexed at 70° and the knee at 45°. The pelvis and contralateral lower limb were secured with straps. The mechanical axis of the dynamometer was aligned with the inner edge of the lateral malleolus (Crozara et al., 2013) and the ankle was positioned in neutral for plantar flexion and dorsiflexion (Laroche, Cremin, Greenleaf, & Croce, 2010).

2.2.3. Statistical analysis

The statistical analyses were performed using SPSS for Windows - Version 18.0 (SPSS Inc.) and the significance level was set at 5% ($p \leq 0.05$). Means, standard deviations and frequencies were used to characterize the sample. The association between grip strength and global muscle strength, as well as between grip strength and peak torque of each muscle group, was determined through the Pearson

Table 1
Characterization of the sample. Values presented in means (standard deviation).

Variable	n = 150
Age (years)	68.78 (5.23)
Weight (kg)	69.16 (14.17)
Height (m)	1.57 (0.08)
BMI (kg. m ⁻²)	27.99 (4.56)
Female (%)	81.34
Level of physical activity (%)	
Low	24.66
Moderate	68.66
High	6.66
Number of comorbidities	2.23 (1.58)
Number of comorbidities by category (%)	
0–1 comorbidity	36
≥ 2 comorbidities	64
Comorbidities (%)	
Systemic arterial hypertension	46
Osteopenia/osteoporosis	18.66
Type 2 diabetes mellitus	16

BMI: body mass index.

correlation test, followed by multivariate linear regression adjusted for sex, age, BMI, level of physical activity and number of comorbidities. The sample power of 99% was calculated based on the lowest R² found (R² = 0.275), alpha of 0.05, and sample size used (n = 150), through the G*Power software program, Version 3.1.92 (Universitat Kiel – Germany).

3. Results

The sample was composed predominantly of younger older people (mean age of 68.78 years), non-obese individuals (mean BMI of 27.99 kg m⁻²), and women (81.34%). Systemic arterial hypertension (46%), osteoporosis/osteopenia (18.66%) and diabetes mellitus (16%) were the most self-reported comorbidities. The characterization and muscle strength data of the sample are presented in Tables 1 and 2, respectively.

The correlation and linear regression analysis demonstrated a positive significant association between grip strength and global muscle strength in older people (r = 0.690; β = 10.07; p < 0.001; R² = 0.604), even after adjustment (Table 3).

Individually, there was a moderate positive association between all the muscle groups and grip strength, except for the hip extensor (r = 0.476; p < 0.001) and ankle dorsiflexor (r = 0.369; p < 0.001) muscle groups, which had a low correlation (Table 3). When the model was adjusted for sex, age, BMI, level of physical activity and number of

Table 2
Grip strength, global muscle strength, and trunk, hip, knee and ankle peak torque of the older people (n = 150). Values presented in means (standard deviation).

Variables	n = 150
Grip strength (kgf)	25.51 (8.07)
Global muscle strength (Nm)	684.31 (223.40)
Trunk extensor PT (Nm)	171.53 (59.13)
Trunk flexor PT (Nm)	63.88 (31.91)
Hip extensor PT (Nm)	72.21 (26.95)
Hip flexor PT (Nm)	34.68 (14.33)
Hip abductor PT (Nm)	51.08 (17.43)
Hip adductor PT (Nm)	48.68 (18.64)
Knee extensor PT (Nm)	106.89 (37.94)
Knee flexor PT (Nm)	52.86 (23.13)
Ankle plantar flexor PT (Nm)	57.11 (27.31)
Ankle dorsiflexor PT (Nm)	25.39 (9.25)

PT: peak torque.

Table 3
Relationship between grip strength and global muscle strength and between grip strength and trunk, hip, knee and ankle peak torque in community-dwelling older people (n = 150).

Variable	Grip strength				
	Pearson correlation		Linear regression Adjusted model ^a		
	r	p-value	β	p-value	R ²
Global muscle strength (Nm)	0.690	0.000 [*]	10.07	0.000 [*]	0.604
Trunk extensor PT (Nm)	0.528	0.000 [*]	1.45	0.032 [*]	0.439
Trunk flexor PT (Nm)	0.700	0.000 [*]	1.41	0.000 [*]	0.629
Hip extensor PT (Nm)	0.476	0.000 [*]	1.07	0.003 [*]	0.272
Hip flexor PT (Nm)	0.673	0.000 [*]	0.75	0.000 [*]	0.538
Hip abductor PT (Nm)	0.627	0.000 [*]	0.77	0.000 [*]	0.475
Hip adductor PT (Nm)	0.511	0.000 [*]	0.77	0.002 [*]	0.294
Knee extensor PT (Nm)	0.615	0.000 [*]	1.35	0.001 [*]	0.527
Knee flexor PT (Nm)	0.680	0.000 [*]	0.81	0.000 [*]	0.627
Ankle PF PT (Nm)	0.557	0.000 [*]	1.66	0.000 [*]	0.364
Ankle DF PT (Nm)	0.369	0.000 [*]	-0.01	0.924	0.275

* p < 0.05. r: Pearson correlation coefficient; β: regression coefficient; PT: peak torque; PF: plantar flexor; DF: dorsiflexor.

^a Model adjusted by sex, age, BMI, level of physical activity and number of comorbidities.

comorbidities, the relationship between grip strength and trunk and lower limb peak torque was maintained, except for the ankle dorsiflexors (β = -0.01; p = 0.924; R² = 0.275).

The associations between grip strength and global muscle strength and between grip strength and the peak torque of each muscle group are shown in Figs. 1 and 2, respectively.

4. Discussion

The present study demonstrated that there is a positive correlation between grip strength and global muscle strength and between grip strength and trunk, hip, knee and ankle isometric peak torque in older people. Therefore, grip strength can be used as a screening tool for impairments in global muscle strength in independent community-dwelling older people. However, the clinical use of grip strength to represent the specific muscle strength of the trunk and lower limb must be done carefully, since when adjusted for sex, age, BMI, level of physical activity and number of comorbidities, there was no longer an association in the present study between grip strength and muscle strength of the ankle dorsiflexors. There were also low coefficients of determination (R²) for other muscle groups, such as hip extensors (R² = 0.272), hip adductors (R² = 0.294) and plantar flexors (R² = 0.364).

Grip strength is a measurement that has been widely studied in the literature, as well as used clinically and in epidemiological studies, as a

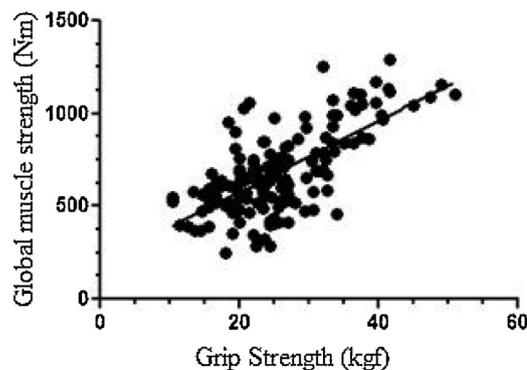


Fig. 1. Association between grip strength and global muscle strength.

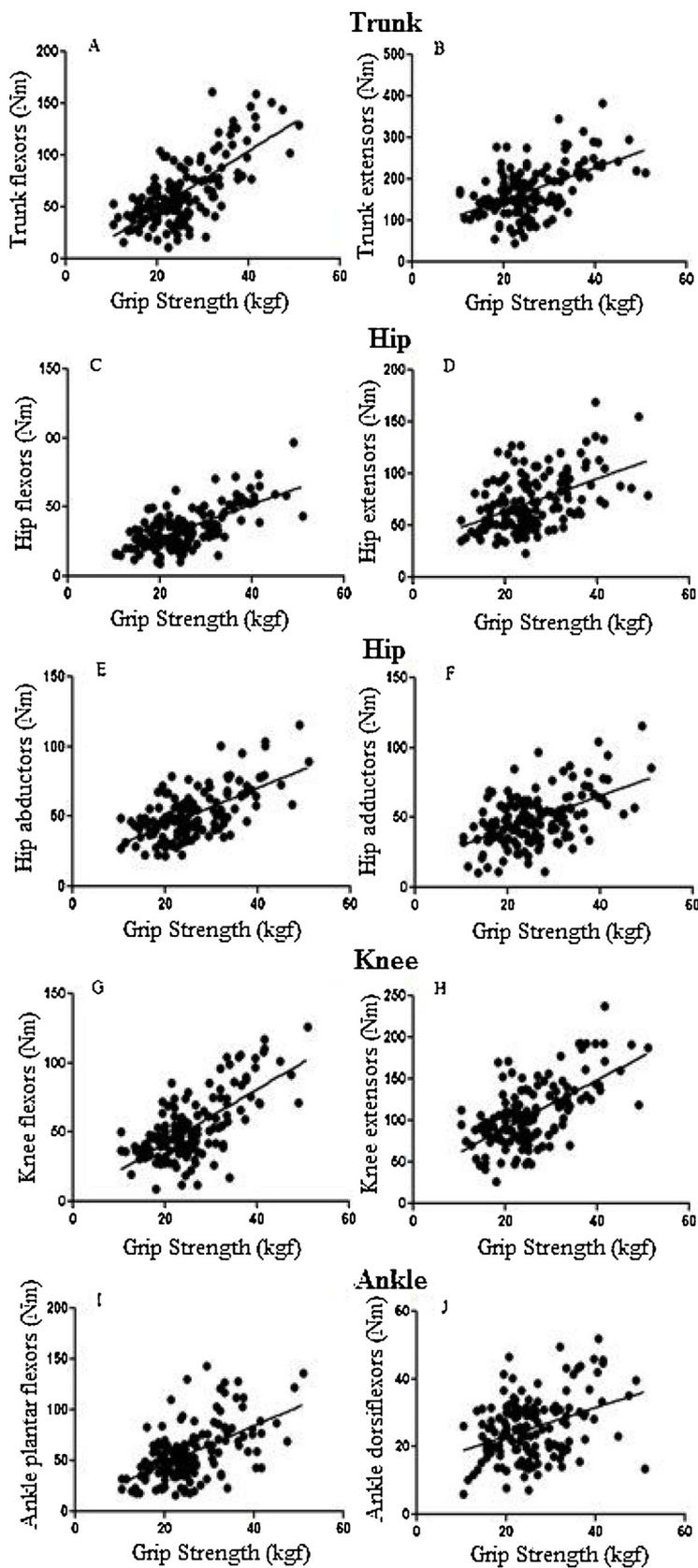


Fig. 2. Association between grip strength and (A) trunk flexors; (B) trunk extensors; (C) hip flexors; (D) hip extensors; (E) hip abductors; (F) hip adductors; (G) knee flexors; (H) knee extensors; (I) ankle plantar flexors; (J) ankle dorsiflexors.

representative of global muscle strength of older people (Cruz-Jentoft et al., 2018). However, apart from the conflicting results as to the association between grip strength and the muscle strength of various muscle groups, most studies have considered global strength as the objective assessment of few muscle groups (Samson et al., 2000; Samuel et al., 2012) or have included upper limb muscle groups (Rantanen, Era, Kauppinen, & Heikkinen, 1994; Wind, Takken, Helders, & Engelbert, 2010).

Studies whose samples have been composed only of older people have found low to moderate correlations between grip strength and muscle force of various lower limb muscle groups. A study by Rantanen et al. (1994) with 295 older people from the community (75 years of age; 104 men and 191 women) found a low to moderate correlation between grip strength and isometric strength of elbow flexors, knee extensors and trunk flexors and extensors, assessed using a dynamometer. Garcia, Dias, Santos, and Zampa (2001) identified a low to moderate correlation between grip strength and isokinetic peak torque of hip and knee flexors and extensors and ankle plantar flexors and dorsiflexors in 81 older people (39 men and 42 women) divided into three age groups (65–69 years old; 70–79 years old; 80 years old or more). Samuel and Rowe (2012) found a low to moderate correlation between grip strength and isometric muscle strength of knee and hip flexors and extensors and hip abductors and adductors, in 82 older people (42 men and 40 women, with a mean age of 73.2 years).

On the other hand, Felicio et al. (2014) did not find any correlation between grip strength and the majority of muscle function parameters (isokinetic peak torque, work and muscle strength) for knee flexors and extensors in 221 older people (mean age of 71.01 years). Jenkins et al. (2014) also observed that there was no correlation between grip strength and isometric/isokinetic peak torque of knee extensors in 16 men (mean age of 72.1 years).

The authors of the present study decided not to include the upper limb muscle groups in global muscle strength, since previous studies have already established the association between grip strength and upper limb muscle strength (Bohannon, 1998, 2009), which may tend to increase the correlation between grip and global muscle strength, and in view of the fact that trunk and lower limb muscle function is essential for most of the motor activities engaged in by humans (American College of Sports Medicine, 2018; Suri et al., 2011), including locomotion activities. To the authors knowledge, this is the first study of independent community-dwelling older people using a gold standard tool (isokinetic dynamometer) to objectively assess the main trunk and lower limb muscle groups for representing global muscle strength, including ten important muscle groups: trunk flexors and extensors, hip flexors, extensors, abductors and adductors, knee flexors and extensors and ankle dorsiflexors and plantar flexors.

The low and moderate association found in the present study between grip strength and global muscle strength and trunk and lower limb muscle strength coincides with previous studies (Garcia et al., 2001; Rantanen et al., 1994; Samuel & Rowe, 2012). However, this association should not be understood as a causal relationship. In fact, some studies have suggested that grip strength serves as a marker of reserve muscle capacity and intrinsic factors that reflect a person's vitality, level of physical activity, nutrition and motivation, and may indicate subclinical diseases (Al Snih, Markides, Ottenbacher, & Raji, 2004; Bohannon, 2001; Felicio et al., 2014; Frederiksen et al., 2006; Rantanen et al., 1999). In this context, impaired grip strength could indicate early outcomes such as functional decline and morbidity, during a period when individuals do not report any deficiencies (Al Snih et al., 2004; Bohannon, 2001; Rantanen et al., 1999), and its use can therefore be beneficial for independent older people still inserted within society.

However, the present study not only determined that there is an association between grip strength and muscle strength, but also took other factors into consideration (adjustment for sex, age, BMI, level of physical activity and number of comorbidities) that could influence the

relationship between grip strength and the other muscle groups, since daily demands on the upper limbs differ from those on the lower limbs.

One factor that could limit the use of grip strength for representing global muscle strength is body mass. Obese individuals need a higher level of lower limb muscle strength to move their body mass than people whose weight is within a normal range (Bohannon, Magasi, Bubela, Wang, & Gershon, 2012; Sallinen et al., 2010). On the other hand, grip strength is not very important in situations where the weight itself is supported (Geraldes, Oliveira, Albuquerque, Carvalho, & Farinatti, 2008; Norman, Stobäus, Gonzalez, Schulzke, & Pirlich, 2011). Despite maintenance of the relationship between grip strength and global muscle strength and between grip strength and most of the muscle groups (except for ankle dorsiflexors) observed in the present study after adjustment for BMI, more studies are needed that specifically investigate this relationship in obese people.

In addition, Samuel et al. (2012) concluded that the profile of muscle loss in the upper limbs (including grip strength) and lower limbs differs as age increases, since there is greater decline in muscle strength in the lower limbs than the upper limbs. Therefore, although the present study also made adjustments for age, the sample was predominantly younger (mean age of 68.78 years). Investigating the association between grip strength and trunk and lower limb muscle strength in older people more than 80 years old would also provide supplementary information in order to identify whether grip strength can also be used to represent global muscle strength in more elderly people.

Other precautions must be taken when trying to generalize global muscle strength from grip strength in older people. Various factors should be considered, such as the presence of acute or chronic diseases that affect the trunk and upper and lower limbs differently, disease severity, comorbidities, and even medical treatment and immobilization to which older people are sometimes subjected (Garcia et al., 2001; Norman et al., 2011).

Once such precautions have been considered, and taking into account the results of the present study and the advantages of measuring grip strength (cheaper equipment, that is more accessible and easy to apply), grip strength can be used in clinical practice and epidemiological studies with younger, non-obese elderly people as a general indicator of global muscle strength, as corroborated by previous studies (Garcia et al., 2001; Geraldes et al., 2008; Wind et al., 2010). However, when other variables are included in the model that could interfere with the associations (sex, age, BMI, level of physical activity and number of comorbidities), changes occur in the relationship between grip strength and peak torque in the different muscle groups. Overall, the results of the present study indicate that grip strength can be used primarily to represent flexor muscle groups, including trunk ($R^2 = 0.629$), hip ($R^2 = 0.538$) and knee ($R^2 = 0.627$) flexors. On the other hand, its relationship with the ankle dorsiflexors decreases in significance ($p = 0.924$). Also, the coefficients of determination (R^2) for other muscle groups, including hip extensors ($R^2 = 0.272$), hip adductors ($R^2 = 0.294$) and ankle plantar flexors ($R^2 = 0.364$) become low, indicating that the measurement of grip strength does not eliminate the need to specifically assess the different muscle groups, when indicated. The greater correlation of the grip strength with certain muscle groups can be explained by the new myofascial chains paradigm, which suggests the existence of long muscle chains, with direct morphological continuity between the muscles by means of a viscoelastic myofascial envelope (Dischiavi, Wrighta, Hegedusa, & Bleakleya, 2018; Wilke, Krause, Vogt, & Banzer, 2016). These myofascial chains could act in a similar way to organized muscle synergies (Dischiavi et al., 2018; Wilke et al., 2016). Therefore, grip strength may belong to the same myofascial chain as the trunk, hip and knee flexors, explaining its greater relation with such muscle groups. However, since there is still no consensus on which muscle groups compose each myofascial chain, more studies are needed to verify such hypothesis.

The present study has certain limitations. The cross-sectional study

design does not show whether grip strength can predict a reduction of global muscle strength with aging, and the sample was composed predominantly of younger older people (mean age of 68.78 years). Including older people over 80 years old could provide additional information, since previous studies have demonstrated that decline in muscle strength is different in the lower and upper limbs (Onder et al., 2005; Samuel & Rowe, 2012). In addition, despite the inclusion of confounding variables in the analysis of the relationship between grip strength and global muscle strength, it was not possible in the present study to extrapolate the results for other populations, such as people over the age of 80, obese people, or individuals with functional limitations or specific diseases (such as Parkinson's disease, stroke or peripheral neuropathy). Also, nutritional status was not evaluated consistently, which could be incorporated into the adjusted model.

Due to the methodological choice, the sample was not divided by sex, although the sex was considered in the adjustment of the regression model. Thus, future studies investigating such correlations exclusively in men and women may be clinically relevant.

5. Conclusion

The present study demonstrated that grip strength can be used to represent global muscle strength in younger community-dwelling older people, even when variables that could interfere in the relationship between the measurements are taken into account (sex, age, BMI, level of physical activity and number of comorbidities). However, when such confounding variables were included in the model, grip strength no longer had an association with ankle dorsiflexor peak torque, and low coefficients of determination (R^2) occurred for the other muscle groups, such as hip extensors and adductors and ankle plantar flexors, indicating that grip strength does not eliminate the need for specific assessments of different muscle groups, when indicated. In terms of knowledge, this is the first study to include an analysis of the isometric muscle strength of ten major trunk and lower limb muscle groups, assessed with an isokinetic dynamometer, for representing global muscle strength.

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Conflict of interest statement

The authors declare that none had any conflict of interest which could bias the results of this study.

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