


Physical Activity Protects Men but Not Women for Sarcopenia Development

Gerontology & Geriatric Medicine
Volume 2: 1–8
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sagepub.com/journalsPermissions.nav
DOI: 10.1177/2333721416667879
ggm.sagepub.com


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Abstract

Objective: Sarcopenia is among the most deleterious effects of aging. The objective of this study was to analyze the relationship between performance tests and muscular volume over the life span of male and female participants. **Method:** A correlation study was conducted with healthy individuals (50 males and 47 females) between the ages of 20 and 94; the study group included active older people, sedentary younger people, and young athletes. Muscular volume was determined by tomography and muscular performance (4-meter speed tests [4 MSTs], chair test, and handgrip test), and a correlation analysis between the groups was performed. **Results:** Sex-related differences were observed between the variables; in males, muscle volume and functional parameters were closely related with age and physical activity, whereas in females, they were not related at all. **Conclusion:** Male and female muscle volume and performance demonstrate strong differences, which should be considered during clinical evaluations of sarcopenia.

Keywords

clinical geriatrics, sarcopenia, muscular performance, active life/physical activity

Manuscript received: April 27, 2016; **final revision received:** July 25, 2016; **accepted:** August 4, 2016.

Introduction

Sarcopenia is among the most deleterious effects of aging. The involuntary loss of muscle mass (and consequently strength) and muscular function has a major impact on quality of life and in the development of complications among the elderly. The progressive loss of muscle mass poses health risks during aging, including a decrease in physical activity and a higher incidence of falls and associated fractures; all of these factors lead to decreased autonomy and an increase in the comorbidities associated with the elderly. The etiology of sarcopenia is not clearly established but is highly prevalent among older people today. In the coming years, sarcopenia will become a widespread public health problem that will affect 25% of the population under age 70 and more than 40% of those older than 70 (Baumgartner et al., 1998; Clark & Manini, 2010; Muscaritoli et al., 2010). It is essential to understand the mechanisms of muscular function and performance and to integrate this knowledge into a comprehensive and multidisciplinary approach for treating older patients.

In 2010, the Sarcopenia European Consensus determined the clinical criteria for diagnosing sarcopenia as loss of muscle volume, which can be quantified by two of the following three criteria: (a) computed tomography (CT) or magnetic resonance imaging (MRI), (b) the Short Physical Performance Battery (SPPB), and/or (c) handgrip dynamometry (Cabrero-García et al., 2012; Cruz-Jentoft et al., 2010; Guralnik et al., 1994). As a multifactorial process, many factors need to be considered—including ethnicity, age, comorbidities, and physical activity history—as all of these factors will influence the test

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results. Various studies have suggested that ongoing physical activity throughout one's lifetime is a protective factor against the sarcopenia process and can improve performance and functionality among the elderly (Fiatarone et al., 1994; Montero-Fernandez & Serra-Rexach, 2013; Yarasheski, Zachwieja, & Bier, 1993). When differences between the sexes are factored in, however, the clinical criteria become cloudier. Some of the final reference values are ambiguous, and the relationship between muscular functionality and muscular mass, and their association with strength (measured by handgrip), remains unclear. It is well known that functionality differs between elderly males and females; the fragility phenomenon is more deleterious among males, for example, whereas functionality is more noticeable in the female group, even among fragile and sarcopenic older females (Iannuzzi-Sucich, Prestwood, & Kenny, 2002). To acquire a better understanding of the muscular mass association with performance over people's life span and how efficient are the performance tests used in the clinic to determine muscular loss, our group performed a correlation analysis between performance tests commonly used in clinics (handgrip test, 4-meter speed tests [4 MSTs], and chair test) and muscle volume by tomography. We included 97 healthy participants in the study (50 males and 47 females) between the ages of 20 and 94, divided into three study groups: active older people, sedentary younger people, and young athletes.

Materials and Method

Participants

Muscle volume, muscular performance, and handgrip were tested in 97 male and female adults between the ages of 20 and 94. The participants were assigned to one of the three groups (years old): active older people (60-94yo), sedentary younger people (20-59yo), and young athletes (20-40yo). The athletes were determined according to metabolic equivalent (MET) values obtained by physical activity (Riebe, 2013). The American College of Sports Medicine (ACSM) has established that healthy and sedentary males and females have average MET values of eight to 10, whereas athletic males and females have average MET values of 18 to 24. The sedentary group was established according with ACSM criteria, considering sedentary people those with no intentional physical activity reported, with MET average value of eight to 10 METs, as well as over caloric intake of 150 to 200 (Kcal) per day, or the equivalent of a 2 to 3 hr of daily light physical activity.

All older participants were healthy, active, and free of chronic diseases or chronic compensated diseases; none of them had visual or severe sensory auditory disabilities. Anthropometric measurements were

performed on all participants. The basic functions of daily life in both sexes were measured using the Katz and Lawton scales (Barrantes-Monge, García-Mayo, Gutiérrez-Robledo, & Miguel-Jaimes, 2007; Yáñez-Luis, Fernández-Guzmán, & Rico-Jaime, 2009). All participants scored A and 8 to 6/8 points, respectively. Only patients with Grades 1 and 2 degenerative joint disease (determined by X-ray) were included. A test to discard monofilaments for diabetic feet in controlled diabetes mellitus cases was performed. The Ethics Committee approved the protocol with the number DI/13/110B/05/092; all the participants signed an informed consent free on any coercion.

Sample Size Calculation

The necessary sample calculations were obtained using the median differences in the quadriceps volume calculated by CT. A minimum of 412.09 cm³ between male and females was expected, with a standard deviation of 305.51 (Rivera et al., 2013). A minimum of 86 participants were required for the study to ensure a sufficient sample size, and we included 97 participants.

Handgrip Test

Grip strength was measured using a validated Hydraulic Hand Dynamometer (Base Line™, USA). Values were recorded in both kilograms and pounds. Participants were seated with their elbows at their sides, their arms flexed at right angles, and their wrists in a neutral position; the dynamometer handle was set at Position II, and support was provided underneath the dynamometer. This position, followed by calculation of the mean of three trials of grip strength for each hand, has been well documented as a reliable test method (Yoshimura, Oka, & Muraki, 2011). The participants' handgrip strength data were displayed as "left" or "right," regardless of hand dominance.

Muscle Volume

CT was performed in a single phase by conventional protocols. A multislice CT scanner was used for three-dimensional reconstruction of the quadriceps from the anterior superior iliac spine to the confluence of the quadriceps before the common tendon, approximately 8 cm from the edge of the femoral condyles (Park et al., 2006; Sayer et al., 1998).

For this study and previous observations by our group (Rivera et al., 2013), we decided to analyze two of the most relevant items of the SPPB, considering the most accurate test during the muscular performance evaluation. The 4 MST is the time needed to go 4 meters, using normal pace. The result is the average of 2 times.

In the chair test, the participant sits and raise 5 times without support from a chair, with crossed arms on the chest. The observer takes the time in seconds.

Table 1. Normality Analyses of the Variables Included.

Variable	Activity rate	<i>n</i>	Media	SD	95% CI
Women (<i>n</i> = 47)					
Volume	Sedentary	15	952.11	214.03	[524.64, 1,283.23]
	Old	20	1,121.06	222.86	[635.51, 1,379.40]
	Athlete	15	1,416.06	148.62	[1,116.17, 1,625.54]
Handgrip	Sedentary	15	22.31	6.50	[18.84, 25.78]
	Old	20	24.95	6.05	[22.11, 27.78]
	Athlete	15	32.00	4.55	[29.36, 34.63]
Chair test	Sedentary	15	8.97	4.13	[6.59, 11.36]
	Old	20	9.39	3.52	[6.13, 12.65]
	Athlete	15	5.04	1.30	[3.96, 6.1]
4-meter speed test	Sedentary	15	3.11	1.13	[2.46, 3.77]
	Old	20	3.25	1.13	[2.21, 4.30]
	Athlete	15	2.00	0.36	[1.66, 2.34]
Men (<i>n</i> = 50)					
Volume	Sedentary	15	1,213.58	294.85	[1,015.49, 1,411.66]
	Old	17	1,657.25	389.27	[1,480.05, 1,834.44]
	Athlete	15	2,562.74	342.88	[2,372.86, 2,752.63]
Handgrip	Sedentary	15	29.30	10.61	[22.17, 36.44]
	Old	17	42.14	10.83	[37.21, 47.07]
	Athlete	15	60.26	9.94	[54.75, 65.77]
Chair test	Sedentary	15	8.63	2.63	[6.60, 10.65]
	Old	17	8.11	2.00	[6.90, 9.32]
	Athlete	15	4.12	0.45	[3.83, 4.41]
4-meter speed test	Sedentary	15	3.07	0.96	[2.33, 3.81]
	Old	17	2.87	0.71	[2.44, 3.30]
	Athlete	15	1.79	0.20	[1.65, 1.92]

Note. $p > .05$ considered statistically significant. CI = confidence interval.

Statistical Analysis

Data abnormality was checked with the Kolmogorov–Smirnov test. Differences between variables were analyzed using the chi-square test and the Student's *t* test; the correlation between handgrip and muscle volume was analyzed using linear regression. The ANOVA and post hoc Bonferroni tests were used to evaluate each performance (chair test, 4 MST, and handgrip test) and muscle volume in the three groups.

For the analyses, we used the IBM SPSS Statistics 21 software.

Results

Each of the 97 participants was assigned to one of three groups: young athletes, sedentary younger people, and active older people. The distribution between sex, age, muscle volume, handgrip, functional test (chair test), and 4 MSTs is shown in Table 1.

The normality analysis showed a 95% confidence interval (CI); the median and standard deviation in the six different groups were homogeneous, indicating that the statistical analysis performed in the study groups was accurate in evaluating the differences between them in the context of volume and performance. The results of the ANOVA and the post hoc Bonferroni tests performed

with the male groups was as expected. Older participants demonstrated differences in muscle volume compared with the sedentary younger and the athletic participants; the maximum muscular volume belonged to the athletic group, which showed statistically significant differences from the sedentary younger group. These results support the importance of exercising throughout a male's lifetime to maintain muscle volume (Table 2 and Figure 1A). The strength measured by handgrip correlated with the muscular volume in all of the cases; more muscular volume equated to more kilograms/repetitions in the handgrip test, and it decreased with lack of physical activity. Less muscle volume leads to decreased muscular strength; thus, the handgrip test in males reflects muscular strength, which is closely related to muscle volume (Figure 1B). At this point in the study, we analyzed the volume and strength correlation; our next goal was to explore several items of the SPPB test in the male groups. These items of the SPPB test (4 MSTs and the chair test) are considered good parameters for evaluating muscular functionality and performance. We did observe the expected differences between the elderly group and the athletes, and we found no differences between the active older group and the sedentary younger group (Table 2 and Figure 1C and 1D). This finding could represent incipient data of the early presence of the sarcopenic process in those young males

Table 2. ANOVA With Post Hoc Bonferroni Statistically Test Performed in Males.

Variable	(I) Activity rate	(J) Activity rate	M difference (I - J)	SE	p
Volume	Old	Sedentary	-443.67143*	132.14083	.005
		Athlete	-1,349.16667*	140.93301	.0001
Handgrip	Old	Sedentary	12.83377	3.91182	.006
		Athlete	-18.12381*	3.55309	.0001
4-meter speed test	Old	Sedentary	-0.19752	0.29055	1.000
		Athlete	1.08526*	0.26824	.001
Chair tests	Old	Sedentary	4.50417*	0.81482	.0001
		Athlete	3.98878*	0.73973	.0001

* $p > .05$ considered statistically significant.

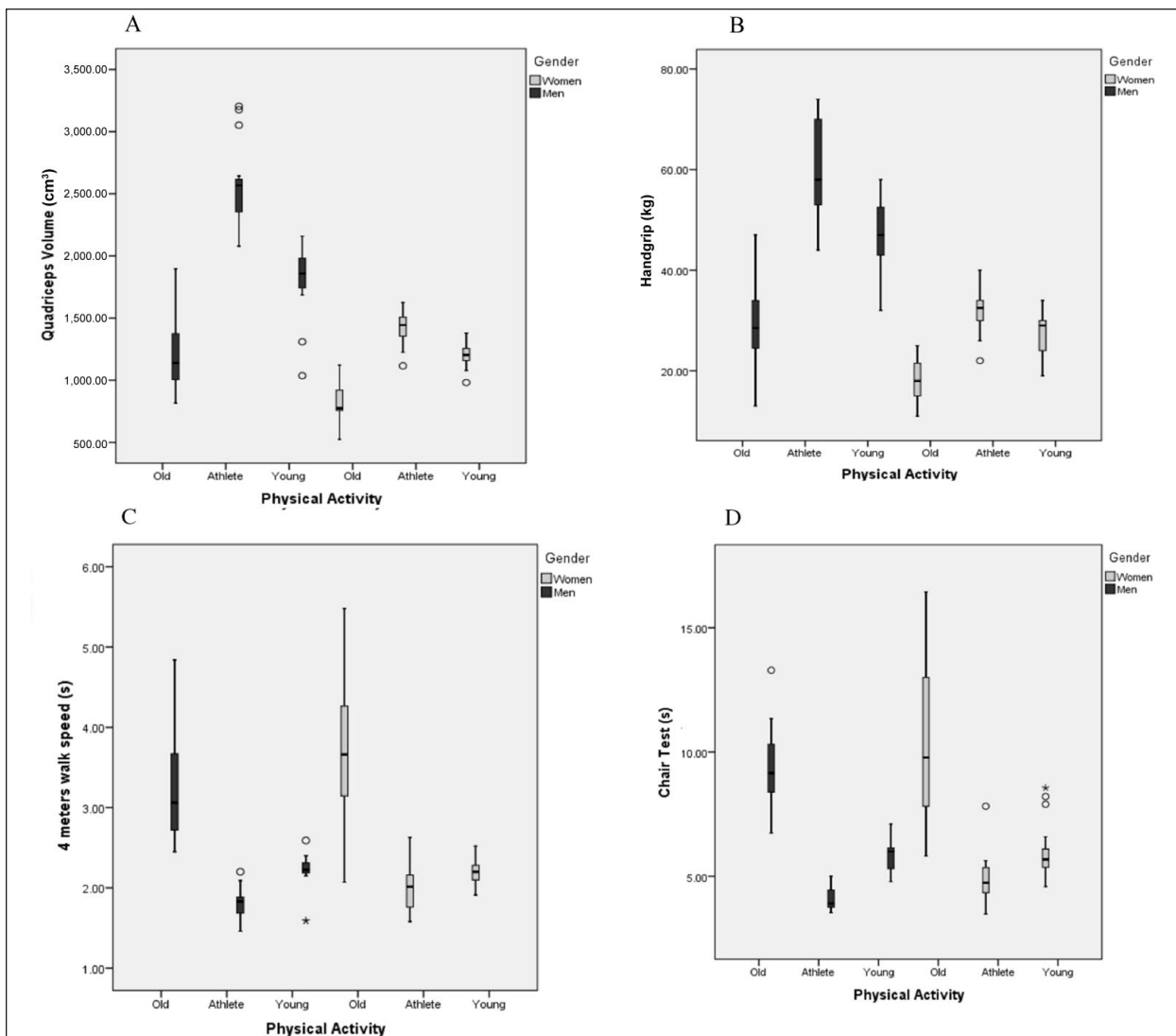


Figure 1. Box-plot: Box and whisker diagram showing the differences between and within distribution of males and females groups.

Note. Each box (A-D) indicates the parameter analyzed versus the physical activity in the three groups.

who do not engage in physical activity. The chair test evaluates strength and (in an indirect manner) muscular performance, including the fatigue phenomenon. This test showed differences between the three groups among males, which suggests that physical activity is related

with muscular volume and increased strength (and, as a consequence, better muscular performance and less fatigue). However, the results observed in the female groups were quite different and unexpected from those of the male groups. The ANOVAs between and within

Table 3. ANOVA With Post Hoc Bonferroni Statistically Test Performed in Females.

Variable	(I) Activity rate	(J) Activity rate	M difference (I - J)	SE	p
Volume	Old	Sedentary	-168.95	67.75	.049
		Athlete	-463.94	73.92	.0001
Handgrip	Old	Sedentary	2.63	1.95	.55
		Athlete	-7.05	2.03	.003
4-meter speed test	Old	Sedentary	1.11	0.46	.073
		Athlete	0.14	0.46	.83
Chair tests	Old	Sedentary	4.34	1.78	.066
		Athlete	-3.92	1.52	.049

the female groups demonstrated a significant difference in muscle volume in the three groups, although it is important to mention that the p value between the older group and the sedentary younger group was barely significant at .049. This indicates that physical activity does not have the same impact for females as it does for males. Handgrip analysis showed statistical differences only in the athletic female group; the elderly group and the younger sedentary group were similar, which suggests that muscular volume does not have a direct effect on strength among females. The functionality evaluation in the females (chair test and 4 MSTs) revealed no differences in the 4 MSTs, while in the chair test; the athletes showed a marginal difference ($p = .049$) compared with the elderly group (Table 3 and Figure 1A-1C). These observations suggest that muscle volume and strength in females are independent of physical activity, and that they do not have the same functional impact as on males' muscular performance. This finding indicates that functionality has different physiological mechanisms in both sexes: Males depend on muscle volume, whereas females do not. However, the lack of differences with the 4 MST and chair tests between the groups indicates that these tests are not totally reliable in the elderly population, because they cannot achieve statistical difference in younger populations. Finally, to analyze whether the clinical evaluation of the handgrip could be related with the muscle volume, a correlation analysis of these two important parameters was performed in all the groups. The linear correlation analysis showed that both items are related in males; a lineal behavior of the data was observed ($R \text{ adj} = .889$, $p = .0001$). Also of interest was the correlation between muscle volume and handgrip in the female groups, showing a lower $R \text{ adj}$ value but significant ($R \text{ adj} = .668$, $p = .001$).

Discussion

The evaluation of the relationship between muscle volume and muscular performance has important clinical implications for older patients, because the relationship will reflect on a person's functionality. Several studies have shown that muscular performance and muscle volume do not reflect muscular contractile capacity

(functionality) in the older population (Clark & Manini, 2008; Rivera et al., 2013). Physical activity is generally considered to be a protective factor throughout one's life; it has a positive impact on muscular mass and muscular performance among the elderly (Barnard, Edgerton, & Peter, 1970; Gollnick, Armstrong, Saltin, Saubert, Sembrowich, & Shepherd, 1973). To evaluate the relationship between muscle volume and muscular performance parameters used in clinics to measure sarcopenia, we conducted a comparative study that analyzed muscular mass and performance in three groups of males and three groups of females. We analyzed athletes, sedentary younger adults, and active older people.

The normality analysis in the groups permitted us to make a specific analysis between and within the groups. The post hoc Bonferroni test in males was as expected, demonstrating differences in muscle volume and handgrip among the three groups; this supports the fact that in males, muscle volume depends on age and physical activity (Figure 1A and 1B). The differences found between the male sedentary younger group and the male athletic group show that lack of physical activity throughout a male's life is a determinant for the loss of muscular mass, and that this phenomenon could start at an early stage of life. Lack of physical activity throughout a male's life is a determinant for loss of muscular mass. When males perform no physical activity, muscular loss begins at an earlier age, increases with age, and has a functional impact in the older population (Anderson & Kearney, 1982; Bottaro, Machado, Nogueira, Scales, & Veloso, 2007; Marx et al., 1998; Ringsberg, Gerdhem, Johansson, & Obrant, 1999; Tsourlou, Benik, Dipla, Zafeiridis, & Kellis, 2006). The evaluation of muscular mass and its relationship to the muscular performance items (handgrip test, 4 MSTs, and chair test) showed that all parameters in the male groups were related to muscle volume, which supports the premise that physical activity increases muscular performance (speed and strength). The observation in the 4 MSTs between the athletes and the elderly group represented unexpected data, suggesting that the sarcopenic process could start in the younger population and that physical activity could have a positive and protective impact against the sarcopenic process. However, these results indicate (as a previous

study reported) that the 4 MSTs are not the best parameters for sarcopenia evaluation, which could be attributable to multifactorial parameters in the walking process (Figure 1C; Kuh, Bassey, Hardy, Sayer, Wadsworth, & Cooper, 2002). The differences observed in our study between all of the male groups in the chair test, however, support the premise that this item is a good parameter for muscular performance during sarcopenia evaluations. This could be attributable to the fact that this test also explores the strength associated with muscular fatigue, thus reflecting the muscular contractile efficiency evaluated during standing and sitting. The chair test proved to be a good parameter for muscular performance evaluation; muscle volume and its close relationship with strength are good clinical parameters for evaluation and follow-up of the sarcopenic process in males, including the younger population (Figure 1D). These results state that physical activity performed throughout a male's lifetime is a protective factor against sarcopenia development and the degradation of muscular performance during the latter stages of a male's life. Our study presents the concept that older females have strong differences in functionality, even if the sarcopenic process is present, compared with the elderly male population (Boirie, Gachon, Cordat, Ritz, & Beaufrère, 2001; Ringsberg et al., 1999; Tseng et al., 2014). These differences were analyzed equally among the male and female groups in terms of age and physical activity during a person's entire lifetime. As expected, the female athletes had more muscular volume than the other two female groups, although greater strength was only observed between the older group and the athletes, and not with the young sedentary group. An interesting and unexpected finding was the fact that no differences were observed between the female groups in the functionality tests, which demonstrated homogeneous behavior in all analyzed items; this supports the premise that muscular bulk, performance, and functionality in females are not related to physical activity or age (Figure 1A-1D). Although females do experience muscular loss and significant differences in muscular volume and handgrip, they maintain good muscular performance and functionality during their lifetimes. This phenomenon could explain the better performance and longevity of the female population (Norman et al., 2012) and supports the premise that, unlike males, the sarcopenic process does not affect the muscular performance or functionality of older females. The differences observed in males and females are a topic for further studies; previous studies suggest that the differences in terms of muscular mass and functionality are the result of own gender differences (Miller, MacDougall, Tarnopolsky, & Sale, 1993), and our results suggest that these differences are not influenced by the physical activity. All reports in the literature have focused in the muscular mass and strength in both sexes, but few studies have evaluated the contractility and performance depending on the gender. Smith and Mittendorfer (2016) reported that muscle loss

is faster in men than in women, mainly mediated by hormonal factors. Females have muscular loss and significant differences in the volume and handgrip; however, females maintain good muscular performance and functionality during the life cycle. This phenomenon could explain the better performance and longevity in the female population (Hunter, 2016). In this article, the results suggest that the differences in the muscular contractile capacity are sex-dependent and physical activity independent; these differences should have implications for the rehabilitation prescribed in both sexes.

To explain these strong differences, we suggest that the dynapenia process could contribute to the differences that we observed in muscle volume and muscular performance (handgrip test, 4 MSTs, and chair test); this points to the fact that contractile efficiency in both sexes is different (Rantanen, Parkatti, & Heikkinen, 1992). In a previous report, our group showed that muscle volume does not explain muscular contractility or performance (Rivera, 2013). In our study, we have demonstrated that muscular efficiency in males depends on physical activity and muscular mass; this is in contrast to the female group, where contractile efficiency is independent of age, muscle volume, and physical activity. Our results highlight the fact that males and females differ not only in anthropometric parameters and structural differences but also in muscular performance (Figure 1A-1D). Females develop sarcopenia independent of physical activity (Clark, & Manini, 2008; Clegg, Barber, Young, Life, & Forster, 2014; Norman et al., 2012; Rantanen et al., 1992; Sipilä, Viitasalo, Era, & Suominen, 1991; Svensson, Sunnerhagen, & Johannsson, 2001), they stay functional even in the presence of sarcopenia, and the different parameters are not modified by age or the amount of exercise they perform during their lifetimes. In conclusion, this study demonstrates that male and female muscular performance tests are substantially different. The evaluation of the SPPB items used to evaluate muscular performance in our different age group and the results obtained, where no differences were observed in some of the analyses, suggest that the tests used in the muscular performance should be enhanced adding other clinical tools. The linear correlation between the muscular volume and handgrip observed in both sexes could be a useful tool during the clinical evaluation. We would like to suggest that different parameters should be considered in clinical evaluations of sarcopenia in males and females in the future.

Conclusion

The contractile efficiency in males depends on muscular mass and physical activity, unlike in the female group where contractile efficiency is independent on muscle volume and physical activity. Our results highlight the fact that males and females differ not only in anthropometric parameters and structural differences but also in

muscular performance. The impact in the muscular volume (and consequently with performance and functionality) during the sarcopenia evaluation must be evaluated with tests that closely explore different parameters, as is the case with the chair and handgrip tests.

Authors' Note

This work was performed in the Human Genetics and Geriatric Departments at Hospital General de México-Eduardo Liceaga, School of Medicine-Universidad Nacional Autónoma de México (UNAM), and the Research Division of the Hospital General de México.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was supported by CONACyT Grant 181798.

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