J Musculoskelet Neuronal Interact 2015; 15(3):249-256

Hylonome

Original Article

Mechanography performance tests and their association with sarcopenia, falls and impairment in the activities of daily living – a pilot cross-sectional study in 293 older adults

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Abstract

Objectives: Muscle mass and muscle power considerably decline with aging. The aim of the present study was to determine the association between muscular function using mechanography and sarcopenia, falls and impairment in the activities of daily living (ADL) in a sample of 293 community-dwelling women and men aged 60-85 years in Berlin, Germany. **Methods:** Muscle function was determined by muscle power per body mass in vertical countermovement jumps ($2LJP_{rel}$) and the chair rising test ($CRTP_{rel}$) on a force plate. Sarcopenia status was assessed by estimating appendicular muscle mass with dual-X-ray absorptiometry. Self-reported ADL impairment and falls in the last 12 months were determined. **Results:** ADL impairment was significantly correlated with all performance tests but not with muscle mass. The $2LJP_{rel}$ (OR 0.88, 95%-CI 0.79-0.98), the Esslinger Fitness Index (EFI) (OR 0.97, 95%-CI 0.94-1.00) and the maximal velocity of the CRT (OR 0.70, 95%-CI 0.53-0.93) remained significant correlates for sarcopenia independent of age in men but not in women. The EFI could differentiate female individuals who had past fall events (OR 0.96, 95%-CI 0.93-0.98). **Conclusion:** The results of the present study highlight the importance of assessing muscle power in older individuals as a relevant correlate for functional decline.

Keywords: Falls, Sarcopenia, Muscle Power, Mechanography, Aged

Introduction

One of the serious consequences of aging is the gradual loss of muscle function, a phenomenon called sarcopenia. While this term was originally used solely to describe the age-associated decrease in muscle mass, it has been suggested that age-related muscle weakness should also be included in the definition[1,2]. Indeed, both have been strongly linked to physical impairment and disability among the elderly[3-6]. Muscle force and muscle power also decrease with advancing age, particularly in the lower body, and to a greater degree than muscle mass[7,8]. Skeletal muscle power declines earlier than muscle force with advancing age[5,9] and current evidence suggests that it is more strongly related to functional status than isometric muscle force[10,11] or knee extensor torque[12]. A review of muscle parameters and their relation to mobility in older individuals highlights the role of muscle power, as it explains more variance in mobility than muscle force or torque[13]. The decrease of muscle power with aging has been linked to a decrease in the number and size of type II muscle fibres, an increase in muscle fat infiltration, changes in muscle architecture and neuromuscular activation, as well as alteration in hormonal status, protein synthesis and inflammatory mediators[14,15].

Age-associated falls frequently occur during circumstances with increased environmental demands, when older people are unable to manage these conditions[16]. A decreased capacity for high-velocity movements - especially in the legs - has been linked to delayed responses in maintaining postural stability and thus with age-associated fall risk in older adults[17].

The muscle power required for a single-joint movement does

The authors have no conflict of interest.

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Edited by: J. Rittweger
Accepted 26 May 2015

not accurately reflect the necessary muscle power for coordinated multiple-joint movements in daily life activities. In the present study, mechanography was used to assess leg extensor power. The system measures the time course of ground reaction forces, the velocity of the vertical movements of the centre of gravity and derives power as the product of force and velocity.

With this mechanical approach, the assessment of muscle function and the integration with the neural coordination of the muscle contraction in complex physiological movements such as jumping or sit-to-stand against gravity is possible, which has been shown as a robust indicator of muscle function that is relevant for daily life[18-21].

The purpose of this population-based, cross-sectional study in older men and women living in Berlin, Germany was to test the hypothesis that in older adults muscle power output derived by mechanography performance tests is significantly associated with sarcopenia, self-reported falls and impairment in the activities of daily living (ADL) independent of sex and age in a quick and precise way.

Materials and methods

Study sample

For this population-based cross-sectional study, subjects were recruited from a random sample of all districts in Berlin, Germany, provided by the resident registration office. The sample size was calculated to be 30 subjects in each five-year band between 60 and 85 years, stratified for sex. The entry criteria for the study excluded those with: i) invalid estimates of body composition due to the presence of metal implants or artificial prostheses, edema or medications affecting water-mineral homeostasis; ii) the inability to walk without an walking aid; iii) no allowance for X-ray exposure; or iv) the inability to understand the nature of the study and follow the instructions.

The present study was approved by the local ethics committee (EA4/095/05), as well as the German Radiation Protection Ordinance (Z5-22462/2-2005-063). Written informed consent was obtained from all participants before they were included in the study.

Measurements dependent variable

Anthropometry

Body weight was determined to the nearest 0.1 kg and stature was assessed to the nearest 0.1 cm using a digital weight scale and stadiometer (Seca 764). Body mass index (BMI) was calculated as weight (kg) divided by height (m^2).

Sarcopenia

DXA (Lunar Prodigy Advance, GE Medical Systems, Wisconsin, USA; EnCore Software v9.3) total body scans were performed according to the standard GE LUNAR operator manual by the same operator. Appendicular skeletal muscle mass (ASM), described as the sum of arms and legs lean mass (kg)[22], was adjusted to the stature index (ASM/h^2)[3]. Sarcopenia employing ASM/h^2 was defined using the cut-off values of the Rosetta Study, which are based upon two standard deviations below the mean of young adults (men: $ASM/h^2<7.26$ kg/m^2, women: $ASM/h^2<5.5$ kg/m^2)[3].

Falls

Fall history was taken retrospectively for the last 12 months. According to the recommendations of the PROFANE group, a fall was defined as "an unexpected event in which the participants come to rest on the ground, floor, or lower level"[23]. Syncopal falls and "high-trauma falls" (e.g. due to an external force like a car accident) were excluded from the analysis. For analysis, subjects were categorized into "no fall" versus "one or more falls" within the last 12 months.

Activities of daily living

Activities of daily living (ADL) were assessed using the subscale of the questionnaire used in the European Vertebral Fracture Study, where subjects are asked if they are able to perform twelve functional tasks related to dressing, washing, rising from bed, mobility, sitting on a chair for one hour, standing in line for 30 minutes, reaching an object, picking something from a floor or lifting and carrying a heavy object[24]. A maximum sum score of 24 points was derived, where zero is equivalent to no impairment and 24 to severe impairment in the ADL.

Assessment of neuromuscular performance

To assess muscle function of the lower extremity, the Leonardo Mechanograph® Ground Reaction Force Plate (Novotec Medical, Pforzheim, Germany) with software package 4.2 was used. Three two-leg jumps (2LJ) were performed as a vertical countermovement jump with a break of one minute between each jump. Subjects were asked to jump as high as possible, whereby the jump achieving the greatest power per body mass of the valid tests was used for this study analysis. Variables of interest included the maximal total relative power per body weight during lift off ($2LJP_{rel}$), maximal jump height ($2LJ_h$), maximal velocity ($2LJ_v$) and the Esslinger Fitness Index (EFI). The EFI describes the maximal 2LJP per body mass normalized to age and gender, expressed as the percentage of the mean value of the sex matched age group. The chair-rise test (CRT) was performed on a bench of 45 cm height, anchored onto the force plate[25]. The time was measured to stand up to full extend and sit down five times at maximum speed without break and without using the arms. For analysis, the maximal total relative power per body weight during the rise phases of five chair stands ($CRTP_{rel}$) and the maximal velocity (CRT_v) were used. Sufficient reproducibility and reliability for both tests have been documented in healthy young adults as well as physically competent older subjects[19,21,26,27].

Statistical analysis

Descriptive statistics for anthropometric data, ADL, muscle mass and muscle function are reported as means ± standard deviation for quantitative variables and as percentages in cat-

	Females n=142			Males n=146		
	normal n=130	**sarcopenia n=12**	**p-value**	**normal n=124**	**sarcopenia n=22**	**p-value**
Age (yrs)	71.4 (±7.2)	70.3 (±8.6)	0.60	71.6 (±7.4)	76.9 (±6.5)	**0.003**
Height (cm)	160.4 (±6.1)	163.7 (±5.7)	0.07	172.6 (±6.4)	171.1 (±6.0)	0.3
Weight (kg)	68.0 (±9.4)	58.9 (±5.7)	**0.001**	84.0 (±11.7)	71.5 (±11.9)	**<0.0001**
BMI (kg/m²)	26.5 (±3.4)	22.0 (±2.3)	**<0.0001**	28.2 (±3.3)	24.4 (±4.0)	**<0.0001**
ADL score (0-24)	4.7 (±4.2)	4.3 (±3.2)	0.90	2.8 (±3.6)	4.5 (±4.5)	0.06
>=1 fall (n,%)	27 (20.8)	2 (16.7)	1.00	12 (9.7)	3 (13.6)	0.70
$2LJP_{rel}$ (W/kg)	25.1 (±5.4)	23.1 (±4.6)	0.25	31.4 (±6.7)	25.6 (±5.6)	**0.0003**
EFI (%)	97.8 (±17.5)	88.3 (±14.0)	0.09	93.0 (±15.3)	84.7 (±20.1)	**0.03**
$2LJ_v$ (m/s)	1.6 (±0.3)	1.5 (±0.2)	0.50	1.9 (±0.3)	1.7 (±0.3)	**0.0009**
$2LJ_h$ (m)	0.2 (±0.1)	0.2 (±0.0)	0.50	0.3 (±0.1)	0.2 (±0.1)	**0.002**
$CRTP_{rel}$ (W/kg)	8.9 (±2.1)	9.7 (±1.2)	0.30	11.1 (±2.4)	9.5 (±2.5)	**0.01**
CRT_v (m/s)	0.9 (±0.2)	0.9 (±0.1)	0.60	1.1 (±0.2)	0.9 (±0.2)	**0.0004**

Table 1a. Characteristics of participants by sarcopenia status.

	Females n=146			Males n=147		
	no fall n=115	**>=1 fall n=31**	**p-value**	**no fall n=131**	**fall n=16**	**p-value**
Age (yrs)	70.7 (±7.2)	73.6 (±7.4)	0.10	72.1 (±7.4)	75.3 (±7.8)	0.07
Height (cm)	160.5 (±6.3)	160.9 (±5.2)	0.77	172.4 (±6.4)	172.3 (±6.4)	0.85
Weight (kg)	66.8 (±9.4)	70.8 (±11.3)	**0.05**	82.8 (±12.5)	78.9 (±15.0)	0.25
BMI (kg/m²)	25.9 (±3.5)	27.4 (±4.4)	0.06	27.8 (±3.7)	26.4 (±3.9)	0.16
ADL score (0-24)	4.5 (±4.1)	5.5 (±4.1)	0.36	3.0 (±3.7)	3.6 (±4.4)	0.47
ASM/h² (kg/m²)	6.4 (±0.7)	6.4 (±0.7)	0.66	8.1 (±0.9)	7.9 (±0.8)	0.23
Sarcopenia (n,%)	10 (8.9)	2 (6.9)	1.0	19 (14.5)	3 (20.0)	0.70
$2LJP_{rel}$ (W/kg)	25.7 (±5.1)	22.6 (±7.1)	**0.03**	30.5 (±6.9)	29.9 (±6.7)	0.75
EFI (%)	99.2 (±16.5)	87.5 (±18.1)	**0.001**	91.1 (±16.4)	95.1 (±16.4)	0.37
$2LJ_v$ (m/s)	1.6 (±0.2)	1.5 (±0.4)	**0.03**	1.9 (±0.3)	1.9 (±0.3)	0.63
$2LJ_h$ (m)	0.2 (±0.1)	0.2 (±0.1)	0.10	0.3 (±0.1)	0.3 (±0.1)	0.41
$CRTP_{rel}$ (W/kg)	9.2 (±1.9)	8.2 (±2.6)	0.07	10.8 (±2.5)	11.1 (±2.6)	0.69
CRT_v (m/s)	0.9 (±0.2)	0.8 (±0.2)	0.08	1.1 (±0.2)	1.1 (±0.2)	0.45

All continuous variables are presented as mean±SD, categorical variables as number and percentage.
ADL= activities of daily living, ASM= appendicular skeletal lean mass arms and legs (kg).
Sarcopenia: females ASM/h²≤5.5, males ASM/h²≤7.26;
$2LJP_{rel}$= maximum two leg jump power per kg body mass; EFI=Esslinger Fitness Index.
$2LJ_v$=maximum two leg jump velocity; $2LJ_h$=maximum two leg jump height.
$CRTP_{rel}$= maximum chair rise test power per kg body mass; CRT_v=maximum chair rise test velocity.

Table 1b. Characteristics of participants by fall status.

egorical variables. Differences between subjects with and without sarcopenia and falls were examined in quantitative variables using a Student T-Test or Wilcoxon Test for independent samples based upon data distribution and with exact Fisher Test for categorical variables. The correlation between ADL score and muscle parameters was determined by calculating the Spearman correlation coefficient with and without adjustment for age. Correlates for sarcopenia and falls are presented in odds ratios with 95% confidence intervals using logistic regression analysis. Odds ratios were determined before and after adjusting for age. A p-value of $p<0.05$ was considered as the significance level. The statistical calculations were performed using the Statistical Analysis System SAS version 9.3 (SAS Institute Inc., Cary, North Carolina, USA).

	Females		Males	
	Correlation 1	**Correlation 2**	**Correlation 1**	**Correlation 2**
BMI (kg/m^2)	r=0.119	r=0.142	r=0.190	r=0.244
	p=0.156	p=0.119	**p=0.021**	**p=0.004**
ASM/h^2 (kg/m^2)	r=-0.019	r=-0.007	r=-0.119	r=-0.028
	p=0.828	p=0.940	p=0.152	p=0.750
$2LJP_{rel}$ (W/kg)	r=-0.355	r=-0.247	r=-0.391	r=-0.308
	p<0.0001	**p=0.006**	**p<0.0001**	**p=0.0003**
EFI (%)	na#	r=-0.266	na#	r=-0.300
		p=0.002		**p=0.0003**
$2LJ_v$ (m/s)	r=-0.326	r=-0.209	r=-0.394	r=-0.309
	p=0.0001	**p=0.020**	**p<0.0001**	**p=0.0003**
$2LJ_h$ (m)	r=-0.298	r=-0.170	r=-0.396	r=-0.314
	p=0.0005	**p=0.060**	**p<0.0001**	**p=0.0002**
$CRTP_{rel}$ (W/kg)	r=-0.359	r=-0.221	r=-0.479	r=-0.401
	p<0.0001	**p=0.014**	**p<0.0001**	**p<0.0001**
CRT_v (m/s)	r=-0.342	r=-0.192	r=-0.502	r=-0.434
	p<0.0001	**p=0.034**	**p<0.0001**	**p<0.0001**

Correlation1: crude; Correlation 2: partial correlation with age
#: The EFI is already adjusted for age.
For abbreviations see Table 1.

Table 2. Correlation between ADL score and muscle mass and mechanography performance.

Results

146 women and 147 men between 60-85 years participated in the study. Based upon the sarcopenia definition by Baumgartner et al.[3], 11.8% of the participants were classified as sarcopenic. Men were affected almost twice as much as women (15.1% versus 8.5%) (Table 1a). In both sexes, subjects with sarcopenia presented with significantly lower body mass and BMI than participants without sarcopenia (Table 1a). Only in men were sarcopenic subjects significantly older and presented with significant lower values in all neuromuscular performance tests than normal subjects (Table 1a). No differences in retrospective falls were observed between sarcopenic and non-sarcopenic subjects (Table 1a). 16% of the participants had experienced one or more falls in the last 12 months. Self-reported falls occurred twice as often in women compared to men (21.2% versus 11%) (Table 1b). In bivariate analysis, fallers presented with significant lower values in the $2LJP_{rel}$ (p=0.03), EFI (p=0.001) and $2LJ_v$ (p=0.03) in women, but not in men (Table 1b). No difference in muscle mass was observed between fallers and non-fallers (Table 1b).

A negative correlation between ADL score and muscle parameters were found for all muscle performance tests but not for muscle mass (Table 2). The correlation was stronger in men than in women and became weaker after adjustment for age. In men the partial correlation was strongest for CRT_v (r=0.434, p<0.0001) and in women for the EFI (r=0.266, p=0.002).

After logistic regression analysis, the $2LJP_{rel}$ (OR 0.88, 95%-CI 0.79-0.98), the EFI (OR 0.97, 95%-CI 0.94-1.00) and the CRT_v (OR 0.70, 95%-CI 0.53-0.93) remained significant correlates for sarcopenia independent from age in men, but not in women (Table 3a). Although the crude ORs of $2LJ_h$, $2LJ_v$ and $CRTP_{rel}$ were significantly associated with sarcopenia status in men, the observed association diminished after adjustment for age. In females, all mechanography performance tests were associated with falls in the last 12 months in the unadjusted model (Table 3b). After adjustment for age, only the EFI remained a significant correlate for falls in women (OR 0.96, 95%-CI 0.93-0.98) (Table 3b). No association between falls and muscle mass was observed.

No adverse events were observed in the neuromuscular tests on the Leonardo platform.

Discussion

In the present study, we examined neuromuscular performance applying mechanography and their association with sarcopenia, fall status and ADL impairment in 293 older adults.

Through bivariate analysis, we found significant differences in jumping and chair rising power between sarcopenic and non-sarcopenic subjects in men, but not in women. In a previous comparable American study using mechanography, a significant difference in $2LJP_{rel}$ between normal subjects and those with sarcopenia in a sample of females and males aged 55-75 years was also reported[28]. However, reference data on $2LJP_{rel}$ show that men present with higher values in all age groups[29], indicating that analysis should take into account sex as a confounder. Additionally, our results might be partly explained by differences in subject selection, given that 15.1% of men in our study were classified as sarcopenic based upon

	Females		Males	
	Model 1 OR (95%-CI)	**Model 2 OR (95%-CI)**	**Model 1 OR (95%-CI)**	**Model 2 OR (95%-CI)**
$2LJP_{rel}$ (W/kg)	0.93 (0.83-1.05)	0.87 (0.74-1.01)	**0.86 (0.78-0.94) *****	**0.88 (0.79-0.98) ***
EFI (%)	na#	0.97 (0.93-1.00)	na #	**0.97 (0.94-1.00) ***
$2LJ_v$ (m/s) (unit 0.1)	0.92 (0.72-1.16)	0.80 (0.59-1.10)	**0.76 (0.64-0.90) ****	0.82 (0.66-1.01)
$2LJ_h$ (m) (unit 0.1)	0.65 (0.21-2.10)	0.3% (0.08-1.54)	**0.35 (0.17-0.71) ****	0.49 (0.20-1.20)
$CRTP_{rel}$ (W/kg)	1.24 (0.88-1.75)	1.24 (0.82-1.87)	**0.77 (0.62-0.95) ***	0.86 (0.68-1.08)
CRT_v (m/s) (unit 0.1)	1.10 (0.76-1.56)	1.02 (0.67-1.57)	**0.65 (0.50-0.84) ****	**0.70 (0.53-0.93) ***

The risk was modeled for having sarcopenia versus no sarcopenia.

Table 3a. Association between sarcopenia and mechanography performance tests.

	Females		Males	
	Model 1 OR (95%-CI)	**Model 2 OR (95%-CI)**	**Model 1 OR (95%-CI)**	**Model 2 OR (95%-CI)**
ASM/h^2 (kg/m^2)	0.95 (0.52-1.75)	1.00 (0.54-1.85)	0.71 (0.38-1.34)	0.82 (0.42-1.60)
Sarcopenia †	0.76 (0.16-3.69)	0.79 (0.16-3.87)	1.47 (0.38-5.72)	1.14 (0.28-4.65)
$2LJP_{rel}$ (W/kg)	**0.90 (0.83-0.97) ****	0.91 (0.83-1.01)	0.99 (0.91-1.07)	1.05 (0.95-1.16)
EFI (%)	na#	**0.96 (0.93-0.98) ****	na#	1.01 (0.98-1.05)
$2LJ_v$ (m/s) (unit 0.1)	**0.79 (0.67-0.94) ****	0.81 (0.66-1.00)	0.96 (0.81-1.14)	1.10 (0.87-1.39)
$2LJ_h$ (m) (unit 0.1)	**0.42 (0.19-0.93) ***	0.56 (0.22-1.44)	0.75 (0.37-1.50)	1.21 (0.46-3.18)
$CRTP_{rel}$ (W/kg)	**0.78 (0.64-0.96) ***	0.81 (0.63-1.04)	1.05 (0.84-1.30)	1.17 (0.91-1.50)
CRT_v (m/s) (unit 0.1)	**0.77 (0.61-0.98) ***	0.81 (0.61-1.08)	1.11 (0.86-1.43)	1.26 (0.94-1.70)

The risk was modeled for one or more falls versus no falls in the last 12 months.
** p<0.05, ** p<0.01, *** p<0.001;*
Model 1: crude; Model 2: adjusted for age;
† No sarcopenia was set as the reference.
 # The EFI is already adjusted for age.
For abbreviations see Table 1.

Table 3b. Association between falls and low muscle mass and mechanography performance tests respectively.

ASM/ height^2 in contrast to 8.5% in women, whereas Singh et al.[28] report sarcopenia in 15% males and 24% females, applying the same operational definition for sarcopenia. The prevalence of sarcopenia based upon the ASM/ height^2 definition in our female study population is less than in the large American epidemiological studies[3,30,31], although it is comparable to other European populations[32-34]. Muscle function and muscle size considerably decrease with age. While the prevalence of sarcopenia increases with aging[3,30,3135], the decline of muscle power adjusted for body mass in the 2LJ test and CRT from the third to the ninth decade varied between 40-50% in both sexes[29]. Hence, the analysis of the neuromuscular performance tests should be age-adjusted. For men, our results showed a significant association of the performance tests with sarcopenia status in bivariate analysis. After controlling for potential confounders, the $2LJP_{rel}$, the EFI and chair rise velocity remained strongly associated with sarcopenia.

Consistent with previous research, in our investigation females were more affected by age-associated falls in the last 12 months compared to males[35]. However, self-reported falls only occurred in 16% of our study population, which is less than the commonly reported 25-30% in subjects 60 years and older[36,37]. Through bivariate analysis, we could show that muscle power performance tests were significantly associated with falls in women. Further multiple logistic regression analysis results indicated that only the EFI could differentiate female individuals who had past fall events. Similar to our results, Cheng et al.[38] displayed an inverse association of maximum power normalized for body mass during sit-to-stand movement with previous falls using force plate technology (OR 0.5, 95% CI 0.4-0.8), indicating that the larger the muscle power, the lower the possibility of previous falling events. However, the effects of age and sex were not included in the analysis, which means that confounding might have biased the results. In line with our findings, previous articles applying other measurement techniques to estimate muscle power output have described the relationship between muscle power and retrospective falls using a portable force transducer[39] or a leg extensor power rig[40], suggesting that low muscle power output of the lower legs could be a relevant predictor of fall risk among the elderly.

Former studies have demonstrated that there is no clear linearity between muscle function and muscle mass[41,42] and that the age-associated decline in muscle function is much stronger related to adverse health outcomes than loss of muscle mass[43,44]. In line with those findings our results illustrate that ASM/h^2 was neither associated with self-reported falls nor with impairment in the activities of daily living indicating that muscle power output might be more relevant for functional ability in older adults than muscle mass alone. Because of this disassociation, other authors argue that the loss of muscle function should be discussed separately from the loss of muscle mass and the term "dynapenia" has been coined to define the loss of muscle force and torque associated with aging[45]. Others have suggested that lean mass measures may become relevant only after subjects are already affected by physical impairments because the amount of lean mass reflects not only the level of physical impairment but also the overall health status[43]. Hence, in well-functioning community-dwellers as in our study the assessment of muscle power might be more meaningful than the assessment of muscle mass.

The Esslinger Fitness Index (EFI) reflects the percentage of the mean value of the peak $2LJP_{rel}$ matched for sex and age group. Accordingly, it takes into account the most relevant confounding factors. The EFI was about 10% lower in sarcopenic females and female fallers and 15% lower in sarcopenic males compared to controls. However, future research should focus on the determination of optimal cut-off values of the EFI concerning the onset of disability and fall risk in a larger longitudinal study to identify those who might benefit from a preventive exercise intervention for reducing or postponing the consequences of sarcopenia, age-associated falls and ADL impairment.

In line with other studies in physical competent elderly subjects[20] as well as older subjects with osteoporosis and vertebral fractures[46], no adverse events with jumping mechanography occurred in our population-based study. Older adults who are unable to jump might benefit from CRT mechanography as a safe meaningful tool[38].

As physical exercise directly affects muscle function and muscle size, it might be considered as the first therapeutic option. In a meta-analysis of 49 trials, Peterson et al.[47] demonstrate that lean body mass can be increased with resistance training among healthy older adults, particularly through higher volume programs. In a Cochrane meta-analysis of 121 trials, Liu and Latham show that progressive resistance training performed 2-3 times per week not only has a modest to large effect on muscle function but also a small but significant effect on functional disability in older adults[48]. In the present study, we discovered an association between muscle power output and sarcopenia or falls among the elderly, which raises the question of whether muscle power can be reversed by specific exercise regimes and whether this increase is helpful to postpone functional disability. Current evidence suggests that a high-velocity resistance muscle power program can not only restore muscle power of the lower legs[49,50], but also shows a benefit on balance[51] and functional performance such as sit-to-stand time[17,52] or gait speed[17,53]. Although no adverse events with high velocity training have been reported amongst elderly persons with a self-reported disability[54] or subjects older than 80 years[55], the efficacy and safety in older adults suffering from osteoarthritis or osteoporosis as well as the value in the prevention of falls still needs to be determined.

Our study has some limitations that must be considered. When retrospectively assessing falls, the data might be inaccurate due to recall bias[56]. For this reason, prospective fall monitoring with regular postal questionnaires or telephone interviews are been recommended[23]. All of the subjects in this study were relatively healthy, well-functioning older men and women, given that participants unable to walk without a walking aid were excluded. The degree of impairment in the activities of daily living was comparatively low and no significant difference in the ADL score between sarcopenic and non-sarcopenic subjects or between fallers and non-fallers could be observed. Therefore, selection bias towards well-functioning adults might have influenced the results. Furthermore, the study had an explanatory character and was not powered for the outcomes sarcopenia or fall status; hence, the unequal prevalence of falls and sarcopenia between the sexes could have resulted in diverse parameters found to be statistically significant. After all, the results of this preliminary study can be helpful for estimating the optimal sample size in future longitudinal studies focusing on the association of muscle power tests applying mechanography and the outcomes sarcopenia, falls and ADL impairment.

Conclusions

In conclusion, measuring the peak power of countermovement jumps and chair-rising with mechanography is a safe and useful tool to assess muscular function in older adults. The findings of our study suggest that low muscle power needs to be considered as a relevant and modifiable risk factor of sarcopenia, age-associated falls and ADL impairment. From the perspective of primary prevention, the assessment of peak muscle power with mechanography can be helpful to identify those who are at high risk for future functional decline at an early stage. Additionally, it may provide a useful tool to monitor and evaluate preventive strategies for combating functional decline.

Acknowlegements

We gratefully acknowledge the cooperation of all subjects who participated in this study.

References

1. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. Age Ageing 2010;39:412-423.
2. Newman AB, Kupelian V, Visser M, Simonsick E, Goodpaster B, Nevitt M, et al. Sarcopenia: alternative definitions and associations with lower extremity function. J Am Geriatr Soc 2003;51:1602-1609.
3. Baumgartner RN, Koehler KM, Gallagher D, Romero L, Heymsfield SB, Ross RR, et al. Epidemiology of sarcopenia among the elderly in New Mexico. Am J Epidemiol 1998;147:755-763.
4. Janssen I, Heymsfield SB, Ross R. Low relative skeletal muscle mass (sarcopenia) in older persons is associated with functional impairment and physical disability. J Am Geriatr Soc 2002;50:889-896.
5. Lauretani F, Russo CR, Bandinelli S, Bartali B, Cavazzini C, Di Iorio A, et al. Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. J Appl Physiol 2003;95:1851-1860.
6. Visser M, Kritchevsky SB, Goodpaster BH, Newman AB, Nevitt M, Stamm E, et al. Leg muscle mass and composition in relation to lower extremity performance in men and women aged 70 to 79: the health, aging and body composition study. J Am Geriatr Soc 2002;50:897-904.
7. Frontera WR, Hughes VA, Lutz KJ, Evans WJ. A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women. J Appl Physiol 1991;71:644-650.
8. Metter EJ, Lynch N, Conwit R, Lindle R, Tobin J, Hurley B. Muscle quality and age: cross-sectional and longitudinal comparisons. J Gerontol A Biol Sci Med Sci 1999; 54:B207-218.
9. Metter EJ, Conwit R, Tobin J, Fozard JL. Age-associated loss of power and strength in the upper extremities in women and men. J Gerontol A Biol Sci Med Sci 1997; 52:B267-276.
10. Bean JF, Leveille SG, Kiely DK, Bandinelli S, Guralnik JM, Ferrucci L. A comparison of leg power and leg strength within the InCHIANTI study: which influences mobility more? J Gerontol A Biol Sci Med Sci 2003; 58:728-733.
11. Skelton DA, Greig CA, Davies JM, Young A. Strength, power and related functional ability of healthy people aged 65-89 years. Age Ageing 1994;23:371-377.
12. Foldvari M, Clark M, Laviolette LC, Bernstein MA, Kaliton D, Castaneda C et al. Association of muscle power with functional status in community-dwelling elderly women. J Gerontol A Biol Sci Med Sci 2000;55:M192-199.
13. Kidde J, Marcus R, Dibble L, Smith S, Lastayo P. Regional muscle and whole-body composition factors related to mobility in older individuals: a review. Physiother Can 2009;61:197-209.
14. Aagaard P, Suetta C, Caserotti P, Magnusson SP, Kjaer M. Role of the nervous system in sarcopenia and muscle atrophy with aging: strength training as a countermeasure. Scand J Med Sci Sports 2010;20:49-64.
15. Lexell J. Human aging, muscle mass, and fiber type composition. J Gerontol A Biol Sci Med Sci 1995;50 Spec No:11-16.
16. Connell BR, Wolf SL. Environmental and behavioral circumstances associated with falls at home among healthy elderly individuals. Atlanta FICSIT Group. Arch Phys Med Rehabil 1997;78:179-186.
17. Pereira A, Izquierdo M, Silva AJ, Costa AM, Bastos E, Gonzalez-Badillo JJ, et al. Effects of high-speed power training on functional capacity and muscle performance in older women. Exp Gerontol 2012;47:250-255.
18. Fricke O, Weidler J, Tutlewski B, Schoenau E. Mechanography - a new device for the assessment of muscle function in pediatrics. Pediatr Res 2006;59:46-49.
19. Rittweger J, Schiessl H, Felsenberg D, Runge M. Reproducibility of the jumping mechanography as a test of mechanical power output in physically competent adult and elderly subjects. J Am Geriatr Soc 2004;52:128-131.
20. Runge M, Rittweger J, Russo CR, Schiessl H, Felsenberg D. Is muscle power output a key factor in the age-related decline in physical performance? A comparison of muscle cross section, chair-rising test and jumping power. Clin Physiol Funct Imaging 2004;24:335-340.
21. Veilleux LN, Rauch F. Reproducibility of jumping mechanography in healthy children and adults. J Musculoskelet Neuronal Interact 2010;10:256-266.
22. Heymsfield SB, Smith R, Aulet M, Bensen B, Lichtman S, Wang J, et al. Appendicular skeletal muscle mass: measurement by dual-photon absorptiometry. Am J Clin Nutr 1990;52:214-218.
23. Lamb SE, Jorstad-Stein EC, Hauer K, Becker C. Development of a common outcome data set for fall injury prevention trials: the Prevention of Falls Network Europe consensus. J Am Geriatr Soc 2005;53:1618-1622.
24. O'Neill TW, Cooper C, Cannata JB, Diaz Lopez JB, Hoszowski K, Johnell O, et al. Reproducibility of a questionnaire on risk factors for osteoporosis in a multicentre prevalence survey: the European Vertebral Osteoporosis Study. Int J Epidemiol 1994;23:559-565.
25. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994;49:M85-94.
26. Matheson LA, Duffy S, Maroof A, Gibbons R, Duffy C, Roth J. Intra- and inter-rater reliability of jumping mechanography muscle function assessments. J Musculoskelet Neuronal Interact 2013;13:480-486.
27. Buehring B, Krueger D, Fidler E, Gangnon R, Heiderscheit B, Binkley N. Reproducibility of jumping mechanography and traditional measures of physical and muscle function in older adults. Osteoporos Int 2014.

28. Singh H, Kim D, Kim E, Bemben MG, Anderson M, Seo DI, et al. Jump test performance and sarcopenia status in men and women, 55 to 75 years of age. J Geriatr Phys Ther 2014;37:76-82.
29. Dietzel R, Gast U, Heine T, Felsenberg D, Armbrecht G. Cross-sectional assessment of neuromuscular function using mechanography in women and men aged 20-85 years. J Musculoskelet Neuronal Interact 2013;13:312-319.
30. Iannuzzi-Sucich M, Prestwood KM, Kenny AM. Prevalence of sarcopenia and predictors of skeletal muscle mass in healthy, older men and women. J Gerontol A Biol Sci Med Sci 2002;57:M772-777.
31. Delmonico MJ, Harris TB, Lee JS, Visser M, Nevitt M, Kritchevsky SB, et al. Alternative definitions of sarcopenia, lower extremity performance, and functional impairment with aging in older men and women. J Am Geriatr Soc 2007;55:769-774.
32. Tanko LB, Movsesyan L, Mouritzen U, Christiansen C, Svendsen OL. Appendicular lean tissue mass and the prevalence of sarcopenia among healthy women. Metabolism 2002;51:69-74.
33. Gillette-Guyonnet S, Nourhashemi F, Andrieu S, Cantet C, Albarede JL, Vellas B, et al. Body composition in French women 75+ years of age: the EPIDOS study. Mech Ageing Dev 2003;124:311-316.
34. Verschueren S, Gielen E, O'Neill TW, Pye SR, Adams JE, Ward KA, et al. Sarcopenia and its relationship with bone mineral density in middle-aged and elderly European men. Osteoporos Int 2013;24:87-98.
35. Ganz DA, Bao Y, Shekelle PG, Rubenstein LZ. Will my patient fall? JAMA 2007;297:77-86.
36. de Rekeneire N, Visser M, Peila R, Nevitt MC, Cauley JA, Tylavsky FA, et al. Is a fall just a fall: correlates of falling in healthy older persons. The Health, Aging and Body Composition Study. J Am Geriatr Soc 2003;51:841-846.
37. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. N Engl J Med 1988;319:1701-1707.
38. Cheng YY, Wei SH, Chen PY, Tsai MW, Cheng IC, Liu DH, et al. Can sit-to-stand lower limb muscle power predict fall status? Gait Posture 2014;40:403-407.
39. Fleming BE, Wilson DR, Pendergast DR. A portable, easily performed muscle power test and its association with falls by elderly persoms. Arch Phys Med Rehabil 1991;72:886-889.
40. Skelton DA, Kennedy J, Rutherford OM. Explosive power and asymmetry in leg muscle function in frequent fallers and non-fallers aged over 65. Age Ageing 2002;31:119-125.
41. Goodpaster BH, Carlson CL, Visser M, Kelley DE, Scherzinger A, Harris TB, et al. Attenuation of skeletal muscle and strength in the elderly: The Health ABC Study. J Appl Physiol 2001;90:2157-2165.
42. Visser M, Newman AB, Nevitt MC, Kritchevsky SB, Stamm EB, Goodpaster BH, et al. Reexamining the sarcopenia hypothesis. Muscle mass versus muscle strength. Health, Aging, and Body Composition Study Research Group. Ann N Y Acad Sci 2000;904:456-461.
43. Newman AB, Kupelian V, Visser M, Simonsick EM, Goodpaster BH, Kritchevsky SB, et al. Strength, but not muscle mass, is associated with mortality in the health, aging and body composition study cohort. J Gerontol A Biol Sci Med Sci 2006;61:72-77.
44. Visser M, Deeg DJ, Lips P, Harris TB, Bouter LM. Skeletal muscle mass and muscle strength in relation to lower-extremity performance in older men and women. J Am Geriatr Soc 2000;48:381-386.
45. Clark BC, Manini TM. Sarcopenia =/= dynapenia. J Gerontol A Biol Sci Med Sci 2008;63:829-834.
46. Buehring B, Krueger D, Binkley N. Jumping mechanography: a potential tool for sarcopenia evaluation in older individuals. J Clin Densitom 2010;13:283-291.
47. Peterson MD, Sen A, Gordon PM. Influence of resistance exercise on lean body mass in aging adults: a meta-analysis. Med Sci Sports Exerc 2011;43:249-258.
48. Liu CJ, Latham NK. Progressive resistance strength training for improving physical function in older adults. Cochrane Database Syst Rev 2009:CD002759.
49. de Vos NJ, Singh NA, Ross DA, Stavrinos TM, Orr R, Fiatarone Singh MA. Optimal load for increasing muscle power during explosive resistance training in older adults. J Gerontol A Biol Sci Med Sci 2005;60:638-647.
50. Henwood TR, Taaffe DR. Improved physical performance in older adults undertaking a short-term programme of high-velocity resistance training. Gerontology 2005;51:108-115.
51. Orr R, de Vos NJ, Singh NA, Ross DA, Stavrinos TM, Fiatarone-Singh MA. Power training improves balance in healthy older adults. J Gerontol A Biol Sci Med Sci 2006;61:78-85.
52. Correa CS, LaRoche DP, Cadore EL, Reischak-Oliveira A, Bottaro M, Kruel LF, et al. 3 Different types of strength training in older women. Int J Sports Med 2012;33:962-969.
53. Ramirez-Campillo R, Castillo A, de la Fuente CI, Campos-Jara C, Andrade DC, Alvarez C, et al. High-speed resistance training is more effective than low-speed resistance training to increase functional capacity and muscle performance in older women. Exp Gerontol 2014; 58:51-57.
54. Marsh AP, Miller ME, Rejeski WJ, Hutton SL, Kritchevsky SB. Lower extremity muscle function after strength or power training in older adults. J Aging Phys Act 2009;17:416-443.
55. Caserotti P, Aagaard P, Larsen JB, Puggaard L. Explosive heavy-resistance training in old and very old adults: changes in rapid muscle force, strength and power. Scand J Med Sci Sports 2008;18:773-782.
56. Hale WA, Delaney MJ, Cable T. Accuracy of patient recall and chart documentation of falls. J Am Board Fam Pract 1993;6:239-242.