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ORIGINAL ARTICLE

Is handgrip force the best simple measure of muscular strength in elderly women?

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Abstract

Background: The measurement of handgrip force is a frequent component in field assessments of physical fitness, but the relationship between handgrip to overall strength is unclear. *Purpose*: To assess how handgrip force relates to overall muscularity of healthy elderly women. *Methods*: Subjects were 39 healthy females aged 65-75 yr. Lean body mass was assessed from body mass and bio-impedance measurements of body fat. Maximal grip force for the right hand was determined by dynamometer, and one-repetition maximum data were collected for the seated chest press, latissimus pull-down, seated row, knee extension, and leg press tests. Data were analyzed by univariate and multivariate regression and by principal component analysis with varimax rotation. *Results*: Strength data showed little variation with age across our sample. All strength measurements showed modest correlations with lean body mass, the largest (handgrip force, r = 0.54) predicting lean mass with a SEE of 11.5%. The first component of the principal component analysis accounted for 55.1% of the total variance in our data. Vectors from lean body mass, handgrip force and the five 1RM measurements all loaded on this factor, which appears to reflect overall muscularity. In multivariate analyses, handgrip predictions of lean body mass could not be improved significantly by incorporating the 1RM measures of muscle strength. *Conclusions*: Maximal handgrip force offers the simplest estimate of overall muscularity in healthy older women, although the precision of predictions is limited. **Health & Fitness Journal of Canada 2014;7(1):69-79.**

Keywords: Aging; Body composition; Muscle strength: Principal component analysis, Resistance exercise; Women.

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Introduction

Physical educators and clinical exercise physiologists have long sought a simple, single test of an individual's overall muscular strength. The test measurement most commonly used for this purpose in population surveys has been the maximal handgrip force, either for the dominant hand, or the average value for both hands (Shephard, 1986; Fitness Canada, 1987). Handgrip measurements are often presumed to provide a good assessment of general muscle function (see, for example, Rice et al., 1989). However, the validity of this assumption can be questioned, since the forearm muscles are relatively small, and are not necessarily representative of overall muscular development or functional ability (Reuter et al., 2011; McAniff and Bohannon, 2002). In the 18th centtury, Desaguliers (1763) cautioned: *"all men are not proportionately strong in every body part, but some are strongest in the arms, some in the legs..."*

In his original development of the handgrip dynamometer, Régnier cautioned that the handgrip force might not be representative of overall muscular development (Pearn, 1978). When testing the elderly, a further issue may be a differential weakening of the body muscles during aging (Brooks et al., 1994; Bemben et al., 1991); an acceleration in the regional loss of strength is seen after the age of 60 years, particularly in those individuals who are sedentary (Ikezoe et al., 2012; Ikezoe et al., 2011a; Ikezoe et al., 2011b; Park et al., 2010; Yazawa et al., 2007). The rate of loss of strength with aging commonly differs between the arms and legs (Kubo et al., 2003; Jansen et al., 2000), and it is thus important to make a critical examination of the utility of handgrip measurements relative to other simple tests using larger muscle groups in elderly populations.

The purpose of this study was to examine how well handgrip force predicted two "gold standard" measures of muscularity (a bioelectrical impedance analysis estimate of lean body mass and a principal component analysis of general muscularity that included lean body mass, maximal handgrip force and 1RM tests) in a sample of clinically healthy elderly women, and to compare such predictions withn other assessments based upon five simple alternative one-repetition maximum (1RM) tests of muscle strength. Hierarchical multiple regression analyses have also been used to test whether handgrip based predictions can be enhanced by adding information derived from simple 1RM strength measurements in healthy elderly women.

Methodology

Participants

A convenience sample of 73 inactive but otherwise healthy female volunteers aged 60 to 77 years was recruited from the Sao Paulo community. They were informed about the procedures and potential risks before giving their written consent to participation in a study approved by the research ethics committee of the University. A preliminary telephone screening that focused on current health status, drug and cigarette use, and habitual physical activity was followed by a hospital visit for a detailed history and physical examination covering past and current health status, symptoms of depression, self-reported ability to perform the basic and instrumental activities of daily living, a 12-lead electrocardiogram, an assessment of body composition, and general laboratory blood and urine tests according to the SENIEUR protocol. Thirty nine of the initial 73 volunteers were excluded for reasons that included: (i) participation in a regular physical activity program during the previous three months; (ii) involvement in alternative dietary therapy; (iii) undernourishment or obesity, (iv) cigarette smoking; (v) cardiovascular, pulmonary, or metabolic disease, chronic infectious or auto-immune disease; (vi) central or peripheral nervous system disorders; (vii) treatment for, or a history of cancer; (viii) chronic use of corticosteroids; (ix) any kind of surgery during the previous three months; (x) forced bed rest during the previous three months; and (xi) any orthopedic conditions that could limit exercise or be exacerbated by exercise testing.

Body composition

Body mass and height were measured by standard anthropometric techniques. Fat mass and lean body mass were determined using a bioelectrical impedance analysis instrument (Quantum model; RJL Systems, Inc, Miami, FL). The resistance and reactance were measured between the right wrist and the right ankle, with the subject lying supine.

Strength measurements

Maximal handgrip force

Maximal handgrip force was measured using an adjustable handgrip dynamometer (Takei TK005, Tokyo, Japan). Two attempts were allowed for each hand, alternating between right and left hands to avoid muscular fatigue. Volunteers were instructed to squeeze as hard as possible, and the best result for the right hand was used in the present analysis.

One repetition maximum tests

One repetition maximum test scores were obtained for five simple measures of muscle strength (seated chest press, latissimus pull down, seated row, knee extension, and leg press). The technique of measurement has been described elsewhere (Heyward, 2006). Definitive testing was preceded by a one week acclimation period that included three sets of 12 repetitions for each of performed three times a week. Initially, volunteers performed the exercises without any load; subsequent loading was set to achieve a rating of perceived exertion of 6 to 8 on Borg's 10 point scale. During this acclimation period, volunteers learned how to perform all exercises correctly (expiring during the concentric phase, and completing the movement at an adequate velocity of 1 to 2 sec for concentric and 2 to 3 sec for eccentric movements). Rest intervals of 120 sec were allowed between sets, and 180 sec between exercises. Five to 10 min of upper and lower-extremity mobility and stretching exercises preceded and followed all sessions.

The definitive one repetition maximum value (1RM) was the maximum force a subject could exert just once, using the specified muscle group, without exploiting momentum or changes in body position to complete the test. Overall muscle strength was considered as the sum of peak values for all tests.

Statistical analyses

A Shapiro-Wilk test demonstrated the normality of data distribution for all variables. Data are presented as means ± standard errors of the mean. Pearson product-moment correlation coefficients determined the univariate associations of individual measures of muscle force with age and lean body mass. A principal component analysis included lean body mass, handgrip force, and the five alternative measures of muscle performance: chest press, latissimus pull down, leg press, knee extension, and seated rowing. The interpretation of significant components was carried out following Varimax rotation (Gorsuch, 1983). Hierarchical multiple regression analyzes were also developed to provide optimal equations for the prediction of lean body mass in this population. All analyses were performed using *Predictive Analytics Software* 17.0 version for Windows package (PASW, Inc., Chicago, IL). Statistical significance was set at $p < 0.05$ throughout.

Results

General characteristics

With a few exceptions, women fell into the "young-old" age category (65-75 yr). There were some inter-individual differences in physical characteristics, but average values for body mass index and fat mass were typical for healthy Brazilians in this age group (Table 1).

Table 1: General characteristics of participants (*n* = 39, all women).

	Mean ± SEM	Range
Age (yr)	68.1 ± 0.7	61.0 - 77.0
Body height (m)	1.55 ± 0.01	1.43 - 1.71
Body mass (kg)	61.7 ± 1.8	43.8 - 80.0
Body mass index (kg·m^2)	25.5 ± 0.7	18.4 - 35.6
Lean body mass (kg)	42.4 ± 0.9	35.4 - 57.5
Fat mass (%)	31.4 ± 0.9	18.0 - 43.0
Grip strength (N)	249.5 ± 7.7	167.7 - 344.3
Latissimus pull-down (N)	334.3 ± 14.4	196.2 - 564.1
Knee-extension (N)	236.6 ± 8.5	147.2 - 367.9
Chest press (N)	180.5 ± 5.0	98.1 - 245.25
Seated rowing (N)	356.3 ± 7.0	245.3 - 515.03
Leg press (N)	733.3 ± 15.6	491.0 - 981.0
Overall muscle strength (N)	1840.9 ± 39.7	1373.4 - 2575.1

SEM: standard error of mean.

Relationship of muscle force to age

Probably because of the relatively small age range among our subjects, univariate regression coefficients showed little relationships between strength and age (Figure 1).

Relationships of muscle force to lean body mass

The number of trials needed to reach a stable 1RM value was relatively similar for all tests (ranging from 2.2 ± 0.1 [chest press] to 2.7 ± 0.1 [latissimus pull down]), and 3.6 ± 0.2 for leg press. All volunteers reported a maximum (10) RPE score immediately after completing the 1RM test (data not shown). In univariate analyses, lean body mass was significantly correlated with all measures of muscularity except the latissimus dorsi pull-down, although the correlations were relatively weak, accounting for only 20-25% of thre total variance (Table 2, Figures 2 and 3). The closest correlation (r = 0.54) was with handgrip force (a SEE of 4.86 kg, or 11.5%); this correlation coefficient was higher than that seen for either single 1RM measurements or an overall estimate of muscular strength based upon all five 1RM measurements.

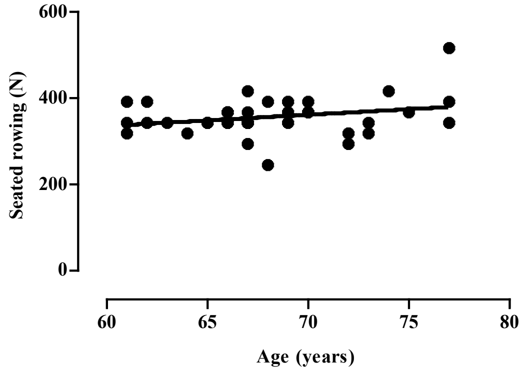
Relationship of handgrip data to other measurements of muscle strength

The handgrip data was significantly correlated with the two upper body measurements (latissimus dorsi pull-down and chest press) and also with knee extension, seated rowing and the overall 1RM score, although correlations were again only in the 0.4-0.5 range.

Principal component analysis

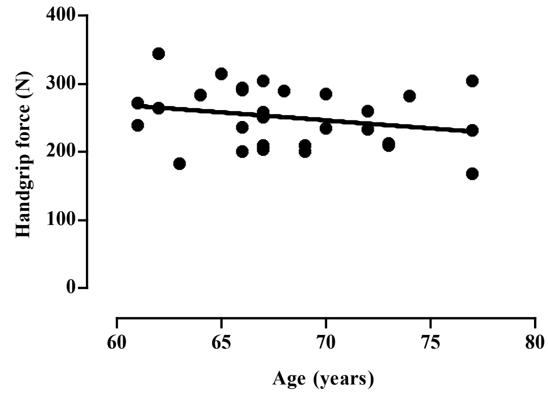
The data for handgrip force, chest press, latissimus pull down, leg press, knee extension, seated row, and lean body mass were subjected to a principal component analysis (PCA). The Kaiser-Meyer-Olkin value was .83, with Bartlett's test of sphericity reaching statistical significance (p = 0.0005).

Figure 1: Scatterplot showing limited influence of age upon measures of muscularity.



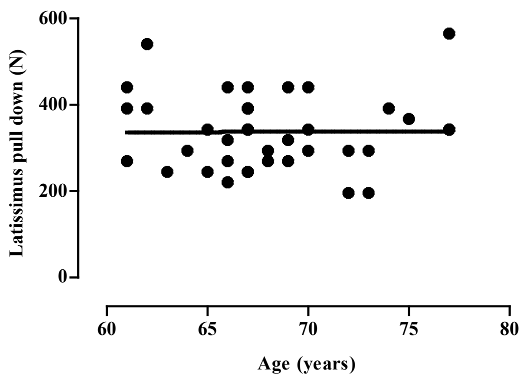
r=-0.10 (adjusted r^2=0.01, β=-.101 ± .168, p=0.552)

E. Seated rowing exercise.



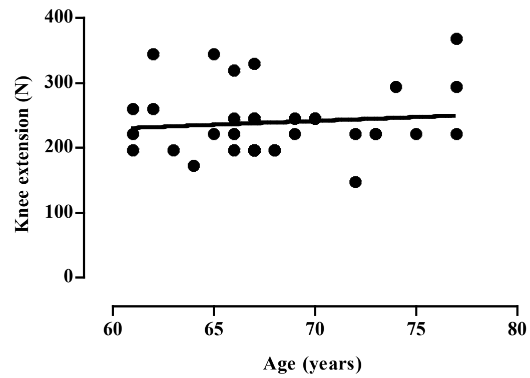
r=-0.10 (adjusted r^2=0.01, β=-.097 ± .185, p=0.604)

F. Handgrip force.



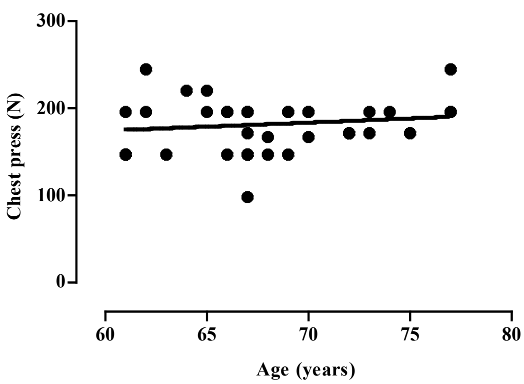
r=0.08 (adjusted r^2=0.01, β=-.167 ± .344, p=0.630)

C. Latissimus pull down exercise.



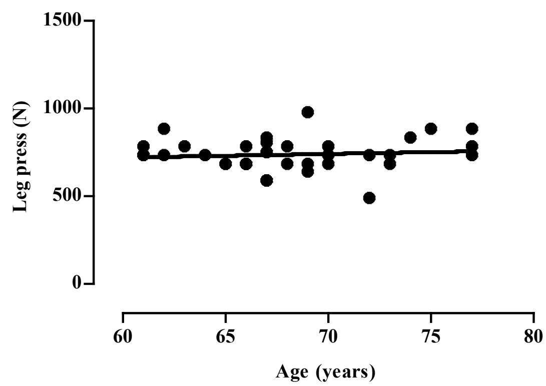
r=-0.35 (adjusted r^2=0.10, β=-.423 ± .190, p=0.033)

D. Knee extension exercise.



r=-0.31 (adjusted r^2=0.07, β=-.225 ± .114, p=0.057)

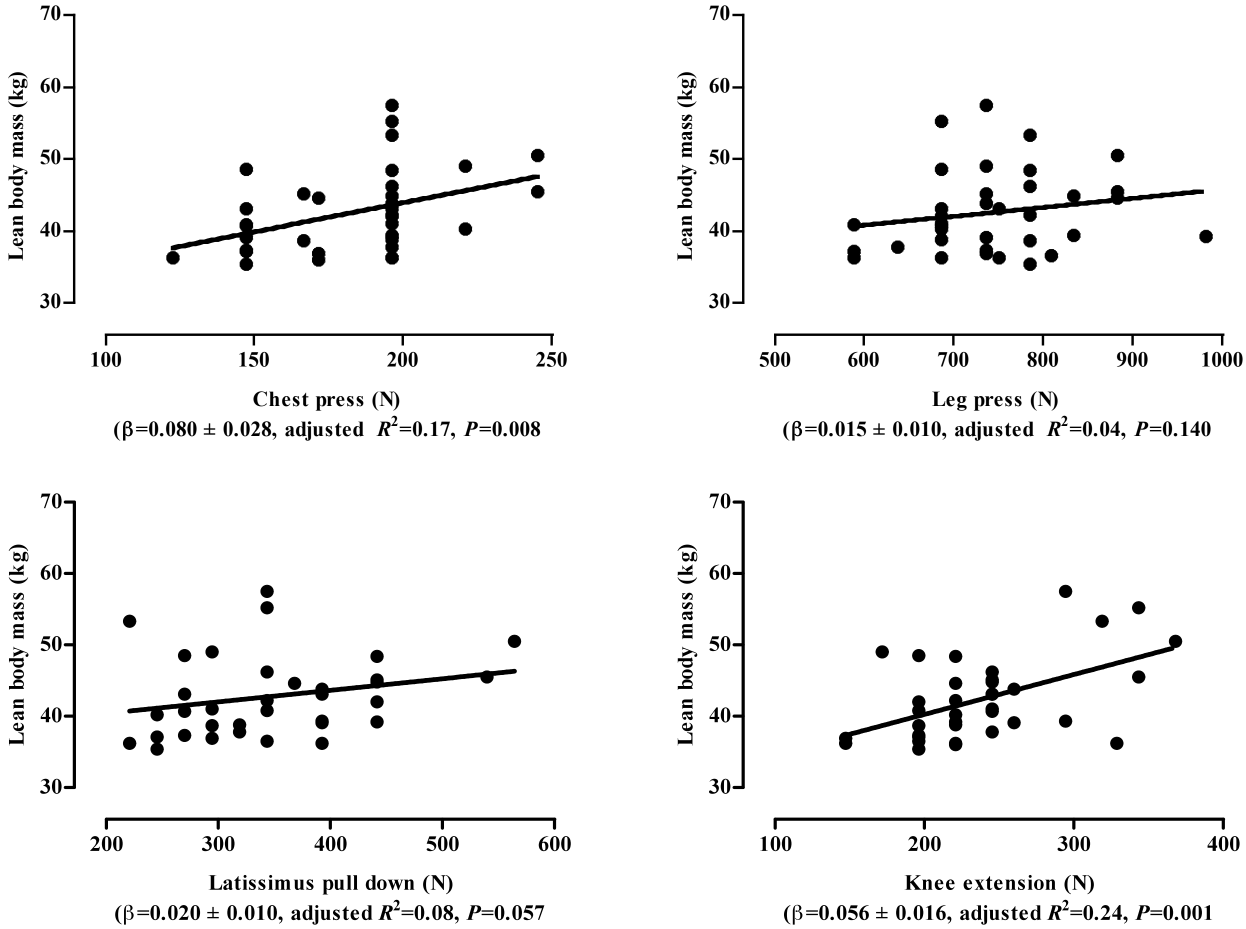
A. Chest press exercise.



r=0.01 (adjusted r^2=0.01, β=.016 ± .374, p=0.966)

B. Leg press exercise.

Figure 2: Scatterplot showing ability to predict lean body mass from measures of muscularity (chest press, leg press, latissimus pull-down, and knee extension).



The first component of the PCA, accounting for 55.1% of the total variance, can be tentatively identified as "general muscularity." All of our measurements loaded relatively equally upon this factor (Table 3). The second component accounted for a further 13.6% of variance, and given the positive loading of handgrip, but the negative loading of seated rowing and leg press, presumably reflects differences between upper and lower body muscularity.

Multivariate prediction models

We assessed the possibility of enhancing the handgrip predictions of lean body mass by adding data from 1RM measurements, but none of the variables that we examined added significantly to the prediction based on handgrip alone.

Table 2: Univariate correlations of lean body mass with the one repetition maximum muscle force developed in selected exercises (the shading indicates the location of significant correlation coefficients).

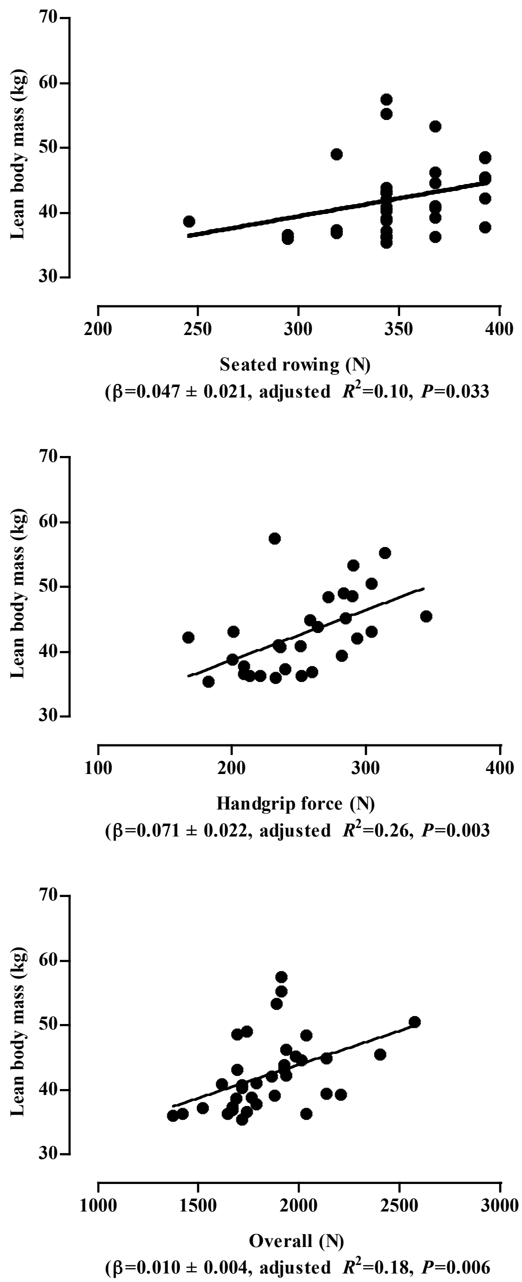
	LBM	HG	CP	LP	LPD	KE	SR	OMS	SEE of LBM prediction (kg)
LBM	1.00								———
Handgrip	0.54 (0.003)	1.00							4.86
CP	0.44 (0.008)	0.49 (0.005)	1.00						5.17
LP	0.25 (0.140)	0.35 (0.053)	0.35 (0.029)	1.00					5.56
LPD	0.32 (0.057)	0.58 (0.001)	0.48 (0.003)	0.64 (0.0005)	1.00				5.44
KE	0.52 (0.001)	0.48 (0.007)	0.56 (0.0005)	0.36 (0.027)	0.51 (0.001)	1.00			4.92
SR	0.36 (0.033)	0.34 (0.057)	0.47 (0.003)	0.38 (0.017)	0.58 (0.0005)	0.55 (0.0005)	1.00		5.37
OMS	0.45 (0.006)	0.56 (0.001)	0.64 (0.0005)	0.81 (0.0005)	0.89 (0.0005)	0.71 (0.0005)	0.72 (0.0005)	1.00	5.14

BM: body mass; LBM: lean body mass; HG: handgrip; CP: chest press; LP: leg press; LPD: latissimus pull down; KE: knee extension; SR: seated rowing; OMS: overall muscle strength (the sum of scores for the five 1RM tests).

Table 3: Vectors for principal component analysis of data including lean body mass, handgrip force, latissimus pull-down, knee extension, chest press, seated rowing and leg press.

% variance	First component 55.1	Second component 13.6	Third component 9.0
Lean body mass	0.647	0.569	———
Handgrip force	0.702	0.431	0.465
Latissimus pull-down	0.817	———	0.323
Knee-extension	0.791	———	-0.383
Chest press	0.776	———	———
Seated rowing	0.753	-0.377	———
Leg press	0.702	-0.453	———

Figure 3: Scatter-plot showing ability to predict lean body mass from measures of muscularity (seated rowing, handgrip force, and overall strength).



Discussion and Conclusions

Handgrip force has been widely used as a means of predicting overall muscle strength (Bohannon, 2012; Bohannon, 2009), health outcomes (García-Peña et al., 2013; Wahba et al., 2013; Bohannon, 2008), mortality (Xue et al., 2010; Syddall et al., 2003), and disability, functional decline and loss of independence (Bohannon, 2008). A low grip strength has been related to the phenotype of frailty (Fried et al., 2001) and a poor quality of life (Sayer et al., 1998). In individuals living with HIV/aids, handgrip data has also been used to assess the deterioration in immediate muscular function (Raso et al., 2013). Investigators have used such statistical techniques as Pearson and Spearman correlations, Cronbach's alpha, factor and principal component analyzes, linear and logistic regression analyzes, as well as Kaplan-Meier survival curves (Felicio et al., 2014; García-Peña et al., 2013; Wahba et al., 2013; Samuel et al., 2012; Bohannon, 2009; Xue et al., 2010). However, the question remains as to how closely the handgrip measurement predicts more sophisticated measures of lean tissue, and how well the handgrip data rates relative to other simple tests of an individual's muscularity.

Our principal component analysis demonstrates that both the handgrip force and all five of the 1RM measurements have as their main inter-individual source of variance the overall muscularity of the subject, as summarized by both a determination of lean body mass and the first component of our PCA. Further, our findings show that the measurement of handgrip force in this group of healthy elderly women offers a better prediction of lean body mass than any of the 1RM measurements, although even for handgrip, the correlation is not particularly close (the correlation accounts for only 29% of the total variance, with a standard error of prediction of 11.5% for the prediction of lean tissue mass). Nevertheless, the handgrip dynamometer appears to offer the best simple field procedure for evaluating the muscularity of older individuals.

Future research could usefully make similar analyses in both men and women, including individuals of a younger age. In the frail elderly, it would also be useful to compare the predictive power of handgrip and 1RM tests relative to measures of the individual's ability to perform activities of daily living (such as rising from a chair or walking at a specified speed). It would also be helpful to assess the relative predictions of handgrip and IRM evaluations in individuals with differing levels of habitual physical activity, physical fitness and health status, with particular reference to the accuracy of predictions following the development of conditions that lead to a specific weakening of the arms or the legs.

Conclusions

We conclude that our study supports the use of the handgrip dynamometer as the best simple field measure of overall muscle strength in healthy elderly women, although estimates have a substantial (10%) standard error. Scores obtained using this device show the closest correlation with both overall muscularity, as seen in a principal component analysis and with lean body mass. Moreover, predictions of these criteria are not enhanced if the handgrip measurement is supplemented by other simple I RM measures of muscular strength.

Authors' Qualifications

The authors' qualifications are as follows: Vagner Raso, Ph.D, Roy J. Shephard, M.B.B.S., M.D. [Lond.]. Ph.D., D.P.E., LL.D., D.Sc., and Valéria Maria Natale, M.D., Ph.D.

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