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Relative Handgrip Strength as a Simple Tool to Evaluate Impaired Heart Rate Recovery and a Low Chronotropic Index in Obese Older Women

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ABSTRACT

International Journal of Exercise Science 11(2): 844-855, 2018. The aim of the present study was to compare differences in heart rate response following a treadmill exercise test in elderly obese women categorized into groups based on relative handgrip strength. Eighty-eight obese elderly women who were between the ages of 60 and 87 participated in the study and were categorized and enrolled to one of two groups based on lower (< 1.51 m^2) or higher (≥ 1.51 m^2) relative handgrip strength, respectively. The heart rate recovery in the first and second minutes following the treadmill exercise test and the chronotropic index were compared between groups. The higher relative handgrip strength group presented a significantly higher peak heart rate during exercise and a quicker heart rate recovery following exercise versus the lower relative handgrip strength group ($p<0.05$). Furthermore, there was a tendency ($p=0.059$) toward a significantly greater chronotropic index in the higher versus the lower relative handgrip strength group. In conclusion, elderly women with greater relative handgrip strength also demonstrated a better heart rate response during and following exercise, possibly indicating better autonomic balance. The relative handgrip strength might be an important and inexpensive tool for the elderly obese women to indirect assess cardiovascular health.

KEY WORDS: handgrip strength, heart rate recovery, exercise stress test, aging

INTRODUCTION

Deficits in strength and power can be used as a determinant for disability and mortality risk in old age (9). In addition, field-based assessments are key tools to delineate the relationship between physical function and muscle quality in older adults. Handgrip strength is a common field-based assessment to evaluate physical function in community-dwelling older women (39).

Handgrip strength is a simple, reliable and inexpensive assessment tool that has demonstrated prognostic utility (7), and is considered a powerful variable that provides useful information for an increased risk of mortality in older women with cardiovascular and respiratory disease (33). However, the use of absolute Handgrip strength might introduce bias as compared with relative handgrip strength. When muscle strength was compared without correcting for body mass, obese women presented a higher level of absolute muscle strength (8, 25), when compared with overweight and normal weight participants. Furthermore, when adjusted for body mass index (BMI), obese older women presented lower relative handgrip strength (RHGS). Thus, RHGS might be an interesting and convenient tool to use in clinical practice to classify older participants with reduced physical function or loss of independent daily living ability (12), and cardiometabolic disease risk factors (10).

A study including 4,221 participants aged ≥ 20 years showed that RHGS adjusted for BMI was significantly associated with more-favourable cardiovascular health biomarkers (lower systolic blood pressure, triglycerides, and plasma insulin, glucose, higher high-density lipoprotein cholesterol in male and female participants) compared to absolute handgrip strength (25). These findings are in line with a positive effect of higher RHGS (adjusted for BMI) on cardiometabolic disease risk in 927 Taiwanese aged 53 years and older (24). Thus, using BMI to correct muscle strength scores has been recommended in the research of muscle quality in the older population (39, 10).

As mentioned earlier, studies have documented a link between impaired relative muscle strength and risk factors for cardiovascular disease and physical function in older adults. However, the correlation between RHGS with autonomic function and delayed decrease in the heart rate during the first minute following treadmill exercise testing has not been investigated. A slower heart rate recovery following exercise might reflect decreased vagal activity (20), and represents an increased risk for overall mortality (11). To note, low isometric handgrip strength is associated with autonomic damage in people with diabetes and older individuals (30), and a lower heart rate variability is associated with lower handgrip strength, and a higher risk of mortality independent of age, sex and cardiovascular risk factors (22). Research to assess the utility of relative grip strength as an indicator of impaired heart rate recovery following a treadmill exercise test is needed in the older population.

Moreover, obese very old women have a lower RHGS presented a higher BMI or obesity compared to their normal weight and overweight counterparts (12), and might present a lower chronotropic index. This is confirmed by the fact that obese individuals have a lower activity of renin-angiotensin and sympathetic nervous system during a standardized treadmill protocol versus lean participants, independent of hypertension status (41).

The aim of this study was to compare the heart rate recovery following a treadmill exercise test and the chronotropic index between obese older women with high and low RHGS. Considering that aging and lower RHGS are associated with a higher systolic blood pressure, triglycerides, plasma insulin and parasympathetic dysfunction (9, 30, 36), the initial hypothesis was that older women with a lower RHGS would present an impaired heart rate recovery following a treadmill exercise test and a lower chronotropic index versus older women with higher RHGS.

METHODS

Participants

Community-dwelling obese older women from the Centro de Convivência do Idoso located at Catholic University of Brasilia were recruited for participation in the present study. Participants were recruited by guest lectures. To be eligible for participation in this study, obese older women needed to be aged ≥ 60 years. A total of eighty-eight older women were categorized based on RHGS. Participants were divided into two groups: < 1.51 m² (lower relative handgrip strength—LRHGS, n= 27) and ≥ 1.51 m² (higher relative handgrip strength—HRHGS, n= 61). The RHGS was used as a proxy for overall strength (31, 34, 38). The overall hand-grip strength cut-points for increased likelihood for mobility limitation was 21 kg for women aged 55 years and older (6).

Obesity was determined according to the recommendations of the National Institute of Diabetes and Digestive and Kidney Diseases, considering a cut-off point of 30% for women (28). Dual-energy X-ray absorptiometry (DEXA) is based on the comparison of X-ray attenuations of two different energies measuring total body composition and fat content with a high degree of accuracy, comparable to hydrostatic weighing (2,23). DEXA is thus considered a valid, reliable, safe, and noninvasive technique for assessment of body adiposity and obesity classification (14, 13). BMI was not used to hierarchical multiple regression analysis because it may be limited due to the loss of fat-free mass and height, while the relative adiposity, and specifically the intra-abdominal fat, continues to increase (19).

The present study was approved by the Institutional Research Ethic Committee of Catholic University of Brasília (protocol 45648115.8.0000.5650/2016). The study design and employed procedures were in accordance with ethical standards and the Declaration of Helsinki (37). Each participant was fully informed about the risks associated with study participation and signed an Informed Consent.

Protocol

During the first visit, participants were interviewed and responded to anamnesis, and were excluded if they had a history of heart failure, valvular or congenital disease, or had pacemaker implantation, and osteo-articular disorders. During the second visit, participants underwent anthropometric measures, and completed a questionnaire about lifestyle, use of medications, and leisure type physical activity. After that, participants were given a body composition assessment via DEXA and a treadmill exercise test. During the third visit, participants underwent a battery of functional tests that included the handgrip strength assessment.

The older women were classified as hypertensive by diagnostic criteria used in previous studies, such as questions, use of antihypertensive medications and self-report (27, 3). Diabetes was defined as documented prescription of insulin or other hypoglycemic medications (29). Anthropometric measures included: height (to the nearest 0.1cm) and body mass (to the nearest 0.1 kg), that were used to calculate body mass index (BMI) (body weight/height^2). All circumferences were obtained using a non-elastic tape measure and followed the same procedures as a previous study (32).

Percent body fat and fat-free mass were determined via DEXA (General Electric-GE model 8548 BX1L, year 2005, Lunar DPX type, Software Encore 2005; Rommelsdorf, Germany) and the procedures were in accordance with our previous research (28).

The functional tests included a 30-s chair stand, timed-up-and-go, handgrip strength (21, 35) and a 6-min walk test that was administered according to the guidelines of the American Thoracic Society (4).

Handgrip strength was determined using a Handgrip Hydraulic dynamometer (Saehan Corp®, SH5001, S. Korea). Three measures on the right and left hand were obtained and the highest value was recorded. The second position was used for all the participants; with the forearm in a neutral position, elbow fully extended; standing position; and verbal encouragement was used for all participants with one-minute rest intervals between measurements. To calculate the RHGS, the highest reading from each hand was divided by the subject's BMI. In addition, previous research supported strength corrected for BMI over the absolute strength measures (25, 10, 26, 31).

Exercise testing procedures in the laboratory have been described in detail elsewhere (40). Participants underwent a symptom-limited treadmill exercise test using a ramp-treadmill protocol. The protocol used velocity increments (between 0.004 and 0.005 km/h each second) and grade (between 0.015 and 0.021% each second), adjusted for participants to reach maximal exercise capacity within the recommended range of 8 to 12 minutes. The initial and final velocity was 3.0 km/h and 6.0 km/h, respectively, while the initial and final grade was 1.0 and 14.0 %. Participants were encouraged to exercise till voluntary-exhaustion, and the achievement of 85% of maximum predicted HR and/or respiratory exchange ratio > 1.02 were used for the termination of testing (40). During each exercise stage and recovery stage, symptoms (chest discomfort, rate of perceived exertion, and dizziness), blood pressure, and heart rate were monitored. Following peak exercise (maximum time spent in the test), participants walked for a 2-minute cool-down period at 2.0 km/h and 2.5 % grade (11). Heart rate recovery was measured by an electrocardiogram during the 1- and 2-minute cool-down period and was defined as the difference between heart rate at peak exercise and 1 minute and 2 minutes following exercise. For safety, participants were permitted to lean on handrails during exercise.

Chronotropic incompetence was assessed as failure to achieve 85% of the age-predicted heart rate. A chronotropic index less than 0.80 was also considered by the following equation [(HRstage – HRrest)/(220 – age in years – HRrest)] x 100 (22). For the maximal metabolic equivalent (MET) level of participants from the treadmill time, the following equation was used: maximal MET level = (treadmill time in minutes X 1.750) + 10.5/3.5 (14).

Leisure type physical activity was evaluated based on a previous publication (42). Participants were asked to classify the type, frequency and duration of leisure type physical activity during the previous month, with several examples of exercise modalities. On the basis of Ainsworth et al. (1), compendium of physical activities, a metabolic equivalent value of 3.5 METs for a conditioning exercise, 3.0 METs for a resistance training exercise, 3.0 METs for walking, 4.0 METs for water activities, 5.0 METs for dancing and 2.5 METs for stretching was used.

Statistical Analyses

All statistical analyses were conducted using SPSS software version 18.0 (Chicago, USA). Normality was verified by Shapiro-Wilk test. Independent t-tests was used for comparison between groups. For non-parametric variables (disease, medications, and chronotropic incompetence), a Chi square for proportions was used (Fisher exact test when cells with expected values were less than five as essential hypertension and calcium channel antagonist's variables) and Cramer's V test of association was applied, where the medium effect is > 0.3.

The hierarchical multiple regression used a continuous dependent variable Cole et al., 1999 (1 minute HR recovery) based on multiple independent variables and controlling for the effects of covariates based or previous research (5,18). For effect size calculations, the following formula was applied. d = (mean of the experimental group, < 1.51 m^2 – mean of the relative handgrip strength of the control group, ≥ 1.51 m^2)/standard deviation of the control group. For determination of the magnitude of effect sizes we considered the following values. Trivial (0 - 0.2), small (0.2 - 0.6), moderate (0.6 – 1.2), large (1.2 – 2.0), and very large (> 2.0) (Flanagan et al., 2013).

A post-hoc power analyses was analyzed for heart rate recovery during 1 minute (14) and a power of 89% with effect size of 0.74 was verified. Therefore, 86 participants were needed for this experiment in order to assures an adequate sample size and power to detect statistical significance. The power was calculated by the software G*Power 3.1.6 (Faul et al., 2007). An alpha level of $p \leq 0.05$ was considered significant.

RESULTS

The coefficient of variation for the percent body fat estimated by DEXA was 10.10 and 6.27 % for the < 1.51 m^2 (lower) and ≥ 1.51 m^2 (higher) relative handgrip groups, respectively.

No difference between groups for the presence of essential hypertension, diabetes, angiotensin receptor blockers, diuretics, beta blockers, calcium channel antagonists, angiotensin converting enzyme inhibiters, statins, hypoglycemic medications, chronotropic incompetence, and chronotropic index were observed ($p > 0.05$) (see Table 1).

Table 1. Diseases, medications and chronotropic incompetence characteristics of the participants.

	LRHGS (n = 27)		HRHGS (n = 61)		X^2
Diseases	Yes	No	Yes	No	
Essential hypertension	23 (85.2)	4 (14.8)	41 (67.2)	20 (32.2)	0.119
Diabetes mellitus type 2	6 (22.2)	21 (77.8)	10 (16.4)	51 (83.6)	0.556
Daily Medications					
Angiotensin receptor blockers	14 (51.9)	13 (48.1)	22 (36.1)	39 (63.9)	0.165
Diuretics	13 (48.1)	14 (51.9)	25 (41.0)	36 (59.0)	0.531
β-blockers	6 (22.2)	21 (77.8)	9 (14.8)	52 (85.2)	0.390
Calcium channel antagonists	2 (7.4)	25 (92.6)	7 (11.5)	54 (88.5)	0.561
Angiotensin-converting enzyme inhibiters	7 (25.9)	20 (74.1)	9 (14.8)	52 (85.2)	0.210
Statins	6 (22.2)	21 (77.8)	18 (29.5)	43 (70.5)	0.479
Hypoglycemic Medications	7 (25.9)	20 (74.1)	9 (14.8)	52 (85.2)	0.210
Chronotropic evaluation					
Chronotropic incompetence	11 (40.7)	16 (59.3)	20 (32.8)	41 (67.2)	0.471
Chronotropic index	11 (40.7)	16 (59.3)	20 (32.8)	41 (67.2)	0.471

Data are presented as frequencies and percentage values.
**p* <.05, X^2 = qui-square, HRHGS = high relative handgrip strength, LRHGS = low relative handgrip strength.

The LRHGS group presented a lower height (*p* =.001), but a higher body mass (*p* =.020), BMI (*p* =.001), percent body fat (*p*=.001), body fat (*p*=.001), waist circumference (*p*=.003), and hip circumference (*p*=.001) versus the higher relative handgrip strength group (HRHGS). Furthermore, the HRHGS group presented a higher leisure time physical activity (MET/h per week) (*p* =.030), absolute right (*p*=.001) and left handgrip strength (*p*=.001), relative handgrip strength (*P*=.001), 6 minutes walking test (*p*=.001), and a lower timed up and go test versus the LRHGS group (*p*=.001). (Table 2).

For the exercise test variables, the HRHGS group presented a higher Peak O_2 consumption (*p* =.001), a trend toward a statistically significant difference in a higher chronotropic index (*p* =.096), a superior peak heart rate (*p*=.019) and a better heart rate recovery in the first (*p*=.003) and second minutes (*p*=.002) post-treadmill exercise testing. In addition, a trend toward statistical significance for a higher maximal metabolic equivalent level (MET) and treadmill exercise time for the HRHGS group versus the LRHGS group (*p* =.059).

The hierarchical multiple regression model presented a good fit for the data, F (3,87) = 5.72, *p* =.001, adj. R^2 =.14. Only age and BMI added significantly to the model (*p* < 0.05) (Model 1). The addition of relative handgrip strength (Model 2) did not significantly increase R^2 at 0.17, F (3,87) = 0.07, *p* =.783. The regression coefficients and standard errors can be found in Table 3.

Table 2. Subject characteristics.

	LRHGS (n = 27)	HRHGS (n = 61)	*P*	ES	Magnitude
Anthropometrics					
Age, years	68.63 ± 5.52 (66.44 – 70.82)	67.98 ± 6.34 (66.36 – 66.91)	0.649	0.11	Trivial
Height, m	1.51 ± 0.05 (1.48 – 1.53)	1.55 ± 0.05 (1.54 – 1.57)*	0.001	0.81	Moderate
Body weight, kg	72.67 ± 9.80 (68.79 – 76.55)	66.58 ± 1.63 (63.60 – 69.56)*	0.020	0.62	Moderate
BMI, kg/m²	31.82 ± 3.61 (30.40 – 32.25)	27.42 ± 3.99 (26.40 – 28.44)*	0.001	1.21	Large
Body fat, %	43.56 ± 4.31 (41.86 – 45.27)	38.07 ± 6.07 (36.51 – 39.62)*	0.001	1.27	Large
Body fat, kg	31.16 ± 6.56 (28.56 – 33.76)	25.23 ± 7.65 (23.27 – 27.19)*	0.001	0.90	Moderate
Neck circunference, cm	36.23 ± 2.05 (35.42 – 37.01)	35.23 ± 2.93 (34.48 – 35.98)	0.113	0.48	Small
Waist circunference, cm	94.49 ± 7.74 (91.43 – 97.56)	88.12 ± 9.69 (85.63 – 90.60)*	0.003	0.82	Moderate
Hip circunference, cm	110.85 ± 12.71 (105.82 – 115.88)	101.59 ± 7.68 (99.63 – 103.56)*	0.001	0.72	Moderate
Waist/hip ratio	0.85 ± 0.81 (0.82 – 0.89)	0.86 ± 0.07 (0.84 – 0.88)	0.615	0.10	Trivial
Functional Capacity					
MET/h per week	6.78 ± 5.82 (4.47 – 9.08)	10.04 ± 6.61 (8.35 – 11.74)*	0.030	0.56	Small
HGS right arm, kg	21.85 ± 3.08 (20.63 – 23.07)	27.33 ± 4.78 (26.10 – 28.55)*	0.001	1.77	Large
HGS left arm, kg	20.22 ± 3.65 (18.78 – 21.67)	25.07 ± 4.31 (23.96 – 26.17)*	0.001	1.32	Large
Relative HGS (kg/BMI), m²	1.32 ± 0.16 (1.26 – 1.39)	1.93 ± 0.35 (1.84 – 2.02)*	0.001	3.78	Very large
Time up and go, seconds	7.31 ± 0.94 (6.94 – 7.68)	6.64 ± 0.72 (6.46 – 6.83)*	0.001	0.70	Moderate
Chair stand, reps	13.67 ± 2.01 (12.87 – 14.47)	14.11 ± 2.62 (13.44 – 14.79)	0.433	0.22	Small
6-MWT, m	458.77 ± 54.40 (437.25 – 480.29)	496.75 ± 45.28 (485.15 – 508.35)*	0.001	0.69	Moderate
Exercise test variables					
Treadmill exercise time, minute	6.92 ± 2.08 (6.09 – 7.74)	7.82 ± 2.01 (7.30 – 8.33)	0.059	0.43	Small
Peak O_2 consumption, ml/kg per minute	16.42 ± 2.42 (15.44 – 17.40)	19.02 ± 2.97 (18.25 – 19.80)*	0.001	1.07	Moderate
Chronotropic index	0.86 ± 0.26 (0.73 – 0.93)	0.92 ± 0.21 (0.87 – 0.97)	0.096	0.32	Small
Systolic blood pressure, mmHg	126.33 ± 11.00 (121.97 – 130.68)	125.79 ± 16.65 (121.52 – 130.05)	0.878	0.04	Trivial
Diastolic blood pressure, mmHg	72.93 ± 8.92 (69.40 – 76.46)	72.13 ± 8.50 (69.40 – 76.46)	0.689	0.08	Trivial
Basal heart rate, bpm	72.58 ± 11.86 (67.88 – 77.27)	74.86 ± 9.99 (72.30 – 77.42)	0.353	0.19	Trivial
Peak heart rate, bpm	136.22 ± 17.99 (129.10 – 143.34)	145.38 ± 15.90 (141.30 – 149.45)*	0.019	0.50	Small
1 minute HR recovery, bpm	17.52 ± 7.30 (14.63 – 20.41)	23.87 ± 9.54 (21.43 – 26.31)*	0.003	0.86	Moderate
2 minutes HR recovery, bpm	27.40 ± 9.17 (23.61 – 31.19)	35.29 ± 10.85 (32.27 – 38.31)*	0.002	0.85	Moderate
MET	15.11 ± 3.64 (13.67 – 16.55)	16.68 ± 3.52 (15.78 – 17.59)	0.059	0.43	Small

Values are expressed as mean (standard deviation) and confidence interval (CI), BMI = body mass index, HGS = hand grip strength, 6-MWT = 6-min walking test, LRHGS = lower relative hand grip strength, HRHGS = higher relative hand grip strength group, MET = metabolic equivalent, * $P < 0.05$ LRHGS vs. HRHGS.

Table 3. Hierarchical multiple regression predicting one minute heart rate recovery from, age, BMI and relative handgrip strength.

	Relative handgrip strength			
	Model 1		Model 2	
Variable	B	β	B	β
Constant	73.68*		70.90	
Age, years	- 0.43*	- 0.28	- 0.42*	- 0.27
BMI, kg/m²	- 0.77*	- 0.36	- 0.73*	- 0.34
Relative handgrip strength			0.78	0.35
R^2	0.16		0.17	
F	8.63*		5.72*	
ΔR^2	0.16		0.00	
ΔF	8.63*		0.07	

Note. N = 88. * p <.05. BMI= Body Mass Index

DISCUSSION

The findings of this study suggest that in obese older women, a handgrip test can be an effective indicator of impaired heart rate recovery at one and two minutes' following a treadmill exercise test. Furthermore, the results also support that lower relative handgrip strength adjusted for BMI had similar value as laboratory-based assessments in physical performance in community-dwelling older women (39). The older women in the present study, with lower relative handgrip strength, presented inferior agility in the timed-up-and-go test and inferior 6-minute walking test distance versus the higher relative handgrip strength group.

A previous study (12) aimed to investigate whether RHGS was associated with physical function in 83 women (mean age 88 yrs.), and the results demonstrated that a higher RHGS strength was significantly associated with better physical function and independent daily living (12). Although all participants were obese in our study, the group with a lower RHGS had a higher percent body fat, BMI, waist circumference, and hip circumference versus the higher RHGS group. It is reasonable to suggest that muscle strength deteriorates more in older women with a higher percent body fat than their lower percent body fat counterparts. This can be inferred by a higher pro-inflammatory status in obese older women that might impair relative muscle strength and negatively affect fat-free mass (14).

The major finding in the present study was that lower RHGS in a group of older women was significantly associated with an impaired heart rate recovery following a treadmill exercise test. Furthermore, a lower RHGS is considered a simple determinant for increased cardiometabolic risk factors, including: blood pressure, triglycerides, total cholesterol to high density cholesterol, fasting glucose and glycated hemoglobin (25,26). Having a lower RHGS is also associated with autonomic damage in people with diabetes (30) and a lower heart rate variability, which increases the risk of mortality independent of age, sex and cardiovascular risk factors (22). It is possible that in older women with lower RHGS, the sympathetic withdrawal occurs in a slower fashion versus those with higher RHGS. Moreover, parasympathetic reactivation might be prolonged in those with lower RHGS, which may contribute to impaired heart rate recovery (20).

A generalized impairment in vagal activity is known to be a risk factor for death (11). During six years' follow-up with 2,428 adults that underwent a symptom-limited exercise test, an impaired value for heart rate recovery was strongly associated with death in older women. Thus, confirming that an impaired heart rate recovery is a marker of impaired vagal activity and is associated with increased mortality risk factor.

Moreover, after adjusting for covariates using hierarchical multiple regression, only age and BMI were negative determinants of 1-minute heart rate recovery, while relative handgrip strength was not. These results were consistent with two previous studies (5,18), showing that a higher BMI was associated with an impaired heart rate recovery at 1-minute post-treadmill exercise testing. In addition, RHGS should be considered a feasible measure to use in future studies with older obese women because it is simple, reliable, and inexpensive to use (39,25,26).

Another key finding was that older women with lower RHGS demonstrated a significantly lower peak heart rate and a trend toward a significantly lower chronotropic index. This might indicate that older women with a lower handgrip strength might present diminished □-adrenergic responsiveness that appears to contribute to an attenuated left ventricular contractile response to exercise (36). In addition, considering that the group of lower handgrip strength had a higher percent body fat; the activity of renin-angiotensin and sympathetic nervous systems may also be impaired in obese versus leaner individuals, irrespective of whether hypertension is present (41), but this hypothesis must be confirmed with further studies.

The present study had some limitations that should be considered, such as the small sample population and distribution of body fat percentages between the groups promoted by study design. In addition, our cross-sectional analysis did not uncover any causation. Thus, the hypothesis that an autonomic imbalance is the main determinant of heart rate behavior needs to be confirmed in prospective studies.

In conclusion, older women with lower relative hand-grip strength presented an impaired heart rate recovery following a treadmill exercise test versus older women with a higher relative hand-grip strength. Thus, relative hand-grip strength might be a promising and simple measure for practical use in the evaluated population.

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