Journal of Musculoskeletal and Neuronal Interactions JMNI

Original Article

Forearm muscle quality as a better indicator of physical performance than handgrip strength in older male ground golf players aged 70 to 89

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Abstract

Objectives: To examine the associations between absolute and relative handgrip strength (HGS) and physical performance. **Methods:** A total of 135 old men aged 70-89 years had muscle thickness (MT) measured by ultrasound at anterior forearm (MT-ulna). Maximum voluntary HGS was measured for the dominant hand. Relative HGS was calculated as ratios of HGS to MT-ulna (HGS/MT-ulna, kg/cm), HGS to forearm girth (HGS/forearm-girth, kg/cm), and HGS to body mass (HGS/body mass, kg/kg). Physical performance was also assessed using the short physical performance battery (SPPB). **Results:** Age was significantly correlated with absolute and relative HGS (r=-0.479 and r=-0.315 to -0.427, respectively all $p<0.001$) and physical performance (walking speed, r=-0.218, p=0.011; chair stand, r=0.348, $p<0.001$), but not with SPPB score (r=-0.083). Absolute HGS was positively correlated with usual-walking speed (r=0.354, $p<0.001$) and was inversely correlated with chair-stand time (r=-0.386, $p<0.001$). The strongest correlations were seen between HGS/MT-ulna and usual-walking speed (r=0.426, $p<0.001$) or chair-stand (r=-0.461, $p<0.001$). Stepwise regression analysis revealed that HGS/MT-ulna was a significant predictor for U-walk speed (R^2=0.205) and chair-stand time (R^2=0.241) while absolute HGS was not a significant predictor of either one. **Conclusion:** Thus, we suggest that forearm muscle quality (HGS/MT-ulna) may be a stronger predictor of physical performance than absolute HGS in active old men.

Keywords: Forearm Muscle Quality, B-Mode Ultrasound, Ground Golf Players, Elderly Men

Introduction

Decline in handgrip strength (HGS) in the aging process is associated with several adverse outcomes, including future disability[1,2], hospitalization[3], and mortality[4,5]. For instance, a recent study investigated the association between HGS, cause-specific mortality, and incident disease using a large sample (approximately 140 thousand participants) from 17 different countries[6]. The study found that HGS predicted not only all-cause mortality but also cardiovascular mortality, non-cardiovascular mortality, myocardial infarction, and stroke. More recently, a study reported significant associations between relative HGS (HGS divided by body mass index) and cardiovascular disease biomarkers in men and women[7]. However, the mechanisms behind the inverse association between HGS and morbidity and mortality are only speculated[6]. Recently, our study investigating the relationships between age-related decline in HGS and loss of forearm muscle size and/or muscle quality reported that lower forearm muscle quality (HGS divided by forearm ulna muscle thickness) is a major contributing factor to the age-related decline in HGS[8].

In previously reported cross-sectional and longitudinal studies[2,9,10], physical disability and functional limitation were defined using several questionnaires, e.g., Katz activity of daily living (ADL) and Rosow-Breslau instrumental activity of daily living (IADL). In many cases, the relationships between HGS and functional limitation or ADL/IADL have not been di-

The authors have no conflict of interest.

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Edited by: S. Warden
Accepted 8 June 2016

rectly assessed. Hairi and colleagues[11] reported that number of subjects who classified functional limitation was different when using a method of self-reported evaluation and a method of performance-based evaluation. Previous studies reported a strong association between HGS and lower extremity muscular strength and power[12,13]. In this case, HGS may be a potential parameter for predicting upper body as well as lower body functional ability in older adults. However, a limited number of studies have examined the direct evaluation of the relationships between HGS and physical functional performance such as 6-minute walking test[14,15], timed up & go test[16], chair stand[17], and usual walking speed[18]. In the present study, we aimed to examine the age-associated changes in HGS and physical performance and the associations between absolute and relative HGS and physical performance in apparently healthy older adults.

Methods

Subjects

One hundred and thirty-five men between the age of 70 and 89 were recruited through printed advertisement and by word of mouth from the members of the Kanoya Ground Golf association. All volunteers were training actively with ground golf (three to five times per week, about 120 minutes per session) for, on average, 10 years (range 2-25 years). Ground golf is a popular sport for older populations in Japan, and players compete to make the fewest total number of strokes over eight holes (15, 25, 30, 50 m distance between the hole and start mat, 2 times each). The holes and start mats are set up on a park or square. The time it takes to complete eight holes is approximately 30 minutes. All players were free of overt chronic disease (e.g., myocardial infarction, cancer, stroke and neuromuscular disorders). The study was conducted according to the World Medical Association Declaration of Helsinki and was approved by the institutional review board of the National Institute of Fitness and Sports in Kanoya. Written informed consent was obtained from all subjects before participation.

Forearm muscle thickness measurement

Forearm muscle thickness and girth measurements were taken while the subjects stood quietly with feet shoulder width apart and their arms relaxed down along the side of their bodies with supination of the forearm. The site used for measurements was located on the anterior forearm (at 30% proximal of the forearm length, defined as the distance from the distal end of the radial styloid process to the lateral border of the head of the radius) on the dominant side of the body as described previously[19,20]. The measurement site was marked with a marker pen and then the forearm girth was measured at the marked site. B-mode ultrasound (Aloka SSD 500, Tokyo, Japan) was used to measure forearm muscle thickness. A 7.5-MHz linear scanning transducer with water-soluble transmission gel was placed on the skin surface of the anterior forearm using the minimum pressure required, and cross-sections of each muscle were imaged. Three images were printed (Toshiba Super Sonoprinter TP-8010, Tokyo, Japan), and mean values were used for data analysis.

Forearm muscle thickness was measured as the distance between the subcutaneous adipose tissue-muscle interface and muscle-bone interface of the ulna (MT-ulna). Test-retest reliability of MT-ulna measurements using the intra-class correlation coefficient ($ICC_{3,1}$), standard error of measurement (SEM) and minimal difference was previously determined for data from Japanese adults (13 men and 10 women) scanned twice 24 h apart: 0.994, 0.06 cm, 0.17 cm, respectively[8]. A sonographer with over 30 years of research experience made all the ultrasound measurements.

Body mass and standing height were measured to the nearest 0.1 kg and 0.1 cm, respectively, by using an electronic weight scale (Tanita WB-260A, Tokyo, Japan) and a stadiometer (Yagami YG-200, Tokyo, Japan). Body mass index (BMI) was defined as body mass/height^2 (in kilogram per square meter).

Handgrip strength measurement

Maximum voluntary HGS was measured for the dominant hand with a factory-calibrated Smedley hand dynamometer (TKK 5401 Grip-D, Takei Scientific Instruments, Tokyo, Japan). All subjects were instructed to maintain an upright standing position, arms down by the side, holding the dynamometer in the hand without squeezing. The width of the dynamometer's handle was adjusted to the hand size of the subjects (the middle phalanx rested on the inner handle). Hand dominance was ascertained by asking each subject which hand they used to perform well-learned skills such as writing, throwing a ball and grasping a racket. Subjects were allowed to perform one test trial, followed by two maximum trials with a 60-second rest between trials, and the highest value was used for analysis. Test-retest reliability of HGS measurements using $ICC^{3,1}$, SEM and minimal difference was previously determined for data from the same 23 young and middle-aged adults described earlier, tested twice 24 h apart: 0.975, 2.5 kg, 7.0 kg, respectively[8].

Definition of forearm muscle quality

Muscle quality is typically defined as muscle strength or power per unit of muscle mass or muscle cross-sectional area[21]. In the present study, forearm muscle quality was defined as a ratio of HGS to MT-ulna (HGS/MT-ulna) as described previously[8]. A previous study revealed that HGS is strongly associated with MT-ulna in young men and women[20]. Relative HGS (index of forearm muscle quality) was also calculated as a ratio of HGS to forearm girth (HGS/forearm girth) and a ratio of HGS to body mass (HGS/body mass).

Physical performance tests

Physical performance was assessed using the short physical performance battery (SPPB) as described previously[22]. Briefly, the SPPB consists of three components: balance,

Table 1. Ultrasound measured forearm muscle thickness, physical performance, handgrip strength, and forearm muscle quality in active old men.

Variables	Overall	70-74	75-79	80+	p value
N	135	42	53	40	
Age (yrs)	77 (4)	72 (2) [bc]	77 (1) [ac]	82 (2) [ab]	p<0.001
Height (m)	1.61 (0.05)	1.62 (0.06)	1.61 (0.06)	1.60 (0.05)	p=0.501
Body mass (kg)	62.2 (8.6)	62.3 (9.0)	62.5 (8.1)	61.7 (9.2)	p=0.900
BMI (kg/m²)	23.9 (3.0)	23.7 (2.8)	24.0 (3.0)	23.9 (3.3)	p=0.909
FA girth (cm)	25.3 (1.5)	25.6 (1.3)	25.1 (1.5)	25.1 (1.6)	p=0.257
MT-ulna (cm)	3.62 (0.29)	3.69 (0.27)	3.57 (0.28)	3.63 (0.32)	p=0.144
U-walk speed (m/s)	1.29 (0.22)	1.33 (0.21)	1.31 (0.22)	1.21 (0.22)	p=0.051
Chair Stand (s)	7.1 (1.8)	6.3 (1.5) [c]	7.0 (1.8) [c]	8.0 (1.7) [ab]	p<0.001
SPPB (score)	10.9 (1.2)	11.3 (1.0)	10.7 (1.3)	10.9 (1.2)	p=0.099
HGS (kg)	36.7 (5.3)	39.9 (4.5) [bc]	36.3 (5.0) [ac]	33.8 (4.5) [ab]	p<0.001
HGS/MT-ulna (kg/cm)	10.2 (1.4)	10.9 (1.3) [bc]	10.2 (1.4) [ac]	9.3 (1.0) [ab]	p<0.001
HGS/FA girth (kg/cm)	1.45 (0.20)	1.56 (0.17) [bc]	1.45 (0.19) [ac]	1.35 (0.17) [ab]	p<0.001
HGS/Body mass (kg/kg)	0.60 (0.10)	0.65 (0.09) [bc]	0.59 (0.10) [a]	0.56 (0.09) [a]	p<0.001

BMI, body mass index; FA, forearm; MT, muscle thickness; U-walk, usual walk; HGS, handgrip strength; SPPB, short physical performance battery. [a] difference from 70-74. [b] difference from 75-79. [c] difference from 80+

timed 4-m walk, and chair stand. The balance test required subjects to maintain side-by-side, semi-tandem, and tandem stances for a maximum of 10 seconds. Usual walking time was measured using a 4-meter straight course. Subjects started at one end of the course and were asked to walk to the end at their usual (normal) pace. The elapsed time from the subject passing the start and finish point was recorded using a digital stopwatch. The chair stand test required subjects to rise from a chair a total of 5 times as quickly as they could, with arms across their chest. The elapsed time required to complete all 5 repetitions was recorded using a stopwatch.

Statistical analysis

Results are expressed as mean and standard deviation (SD). The differences between age groups (ages 70-74, 75-79, and 80+) for age, height, body mass, BMI, forearm girth, MT-ulna, usual walk speed, chair stand, SPPB score, HGS and forearm muscle quality were tested for significance by one-way analysis of variance, followed by pairwise comparisons using Tukey's multiple comparison procedure if a significant *F* test was obtained. If variances were unequal, Dunnett's C procedure was performed. Pearson product correlations were performed to determine the relationships between physical performance and absolute and relative HGS. Partial correlations of physical performance with selected variables adjusted for age and height were also statistically quantified. Stepwise multiple linear regression was also performed for the criterion variables of U-walk speed and chair stand time. Predictor variables included in the model were HGS, HGS/

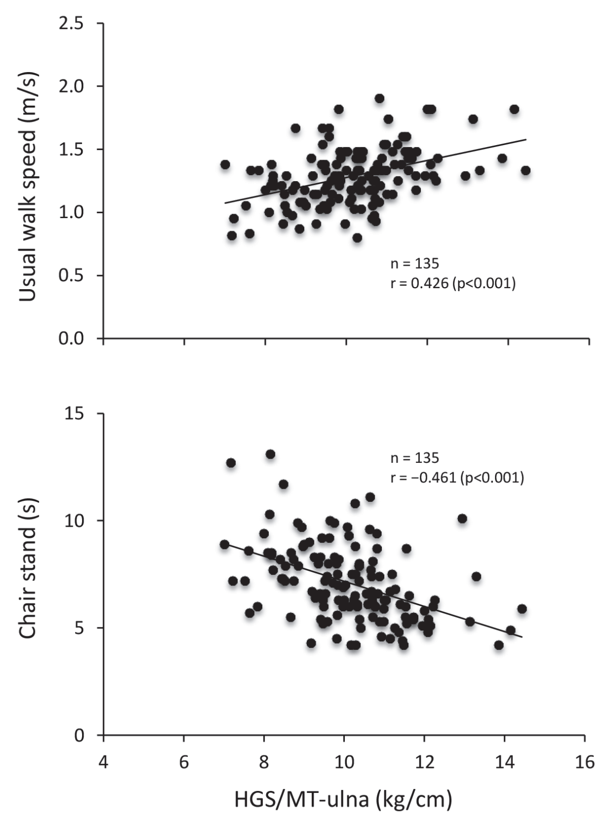

Figure 1. Relationships between a ratio of handgrip strength to forearm ulna muscle thickness (HGS/MT-ulna) and usual walking speed (upper panel) or chair stand (lower panel) in active old men.

Table 2. Partial correlation coefficients between forearm muscle quality and physical performance adjusting for age and body height (n=135).

	U-walk speed	Chair stand	SPPB
HGS	0.199*	-0.269†	0.099
HGS/MT-ulna	0.323‡	-0.370‡	0.135
HGS/forearm girth	0.267†	-0.330‡	0.094
HGS/body mass	0.238†	-0.316‡	0.195*

U-walk, usual walk; HGS, handgrip strength; MT, muscle thickness; SPPB, short physical performance battery.
**P<0.05, †P<0.01, ‡P<0.001.*

MT-ulna, HGS/forearm girth, HGS/body mass, age, height and body mass. Significance was set at *P*<0.05.

Results

Comparison among three age groups

Height, body mass and BMI were similar among ages 70-74, 75-79 and 80+ groups (Table 1). Forearm girth and MT-ulna were also similar among the three age groups. There were no significant differences in usual walk speed or SPPB score among the three groups. Compared with ages 70-74 and 75-79, ages 80+ had higher chair stand time. HGS as well as all three indices of relative HGS were progressively lower from ages 70-74 to 80+ (Table 1).

Relationship between age and absolute and relative HGS

Age was inversely correlated with absolute HGS (r=-0.479, p<0.001) as well as relative HGS such as HGS/MT-ulna (r= -0.423, p<0.001), HGS/forearm girth (r=-0.427, p<0.001), and HGS/body mass (r=-0.315, p<0.001).

Relationship between age and physical performance

Age was inversely correlated with usual walking speed (r= -0.218, p=0.011) and was positively correlated with chair stand (r=0.348, p<0.001). There were no significant correlations between age and SPPB score (r=-0.083, p=0.336).

Relationship between absolute and relative HGS and physical performance

Absolute and relative HGS were positively correlated with usual walking speed (range between r=0.266, p=0.002 and r=0.426, p<0.001) and were inversely correlated with chair stand time (range between r=-0.386 and r=0.461, all p<0.001). The strongest correlations were seen between HGS/MT-ulna and usual walking speed (r=0.426, p<0.001) and between HGS/MT-ulna and chair stand (r=-0.461, p<0.001) (Figure 1). There were no significant correlations between HGS and SPPB score (r=0.093, p=0.284), between HGS/MT-ulna and SPPB score (r=0.135, p=0.120), and between HGS/forearm girth and SPPB score (r=0.139, p=0.108). Only a weak correlation was observed between HGS/body mass and SPPB (r=0.214, p=0.013). After adjusting for age and height, the correlation coefficients were still significant between absolute and relative HGS and usual walking speed and chair stand and between HGS/body mass and SPPB (Table 2).

After stepwise multiple linear regression analysis, only HGS/MT-ulna and height were significant predictors of U-walk speed (R^2=0.205; Walk speed=0.059*(HGS/MT-ulna) + 0.007 * (Height)−0.398). HGS/MT-ulna had a standardized beta coefficient of 0.374 while height had a standardized beta coefficient of 0.003. In the analysis of predictors for chair stand, only HGS/MT-ulna and age were significant predictors (R^2= 0.241, Chair stand= -0.486*(HGS/MT-ulna) + 0.080 * (age) + 5.858). HGS/MT-ulna had a standardized beta coefficient of -0.383 and age had a standardized beta coefficient of 0.186.

Discussion

Previous studies report that higher absolute HGS may accompany better physical performance[2,9]. However, the correlation coefficients are relatively low (r=-0.147 for Timed Up & Go and r=0.231 for 6-min walking test) between the two variables[14-16]. The purpose of the current study was to examine the relationships between absolute and relative HGS and physical functional performance in older male ground golf players aged 70 to 89. The strongest correlations were observed between HGS/MT-ulna and physical performance (i.e., r=0.323 for usual walking speed and r=-0.370 for chair stand).

The primary findings in this study suggest that forearm muscle quality evaluated by a ratio of HGS to MT-ulna might be a better indicator of physical performance than absolute HGS in active old men. Ultrasound measured MT-ulna was the single best predictor (r=0.936) for estimating DXA-derived appendicular lean soft tissue mass from the previously developed equations[23]. From the results of the previous study[23], the MT-ulna may be a surrogate parameter for predicting limb muscle mass. Although age-related muscle mass loss is site-specific[24,25], a relatively strong association (r=0.68-0.83) was observed between HGS and lower extremity muscular strength and power[12,13]. In addition, the age-related decline in muscle quality may be similar between upper and lower extremities in men[26]. Therefore, further research is needed to clarify that HGS/MT-ulna is a variable indicator of lower body physical function in older adults.

Martien and colleagues[15] investigated whether knee extension strength is a better predictor of physical performance than handgrip strength among older adults in three different settings (community-dwelling, assisted living facilities, and nursing homes). They used relative HGS and knee extension strength as a ratio of strength to body mass and found that HGS and knee extension strength are both important predictors of physical performance in older adults, although combined data for men and women were analyzed. Recently, a study investigating the relationship between relative HGS and cardiovascular disease biomarkers reported that the relative HGS (divided by BMI) may be a useful public health measure of muscle strength[7]. In the present study, body mass and BMI were similar among three age groups, and age was not correlated (p>0.05) to body mass and BMI. Only HGS/MT-ulna was a significant predictor for both U-walking speed and chair stand time. However, HGS alone was not a significant predictor of U-walking speed and chair stand time. Thus, HGS/MT-ulna is a new index and may be a useful indicator of physical function and health outcomes in older adults.

Our results showed that the only variable significantly correlated with SPPB score was HGS/body mass. On the other hand, HGS/MT-ulna and other absolute and relative HGS measures were not significantly correlated with SPPB. The reasons for the discrepancy are not clear, but the balance component of the SPPB may be a potentially influential factor. For instance, as described above, MT-ulna is an index for predicting appendicular muscle mass[23], while body mass includes whole body muscle mass and body fatness. The individual differences in body composition, especially percentage of body fatness, may produce those discrepancies observed between relative HGS and balance ability.

In 2010, the European Working Group on Sarcopenia in Older People recommended an algorithm for identifying sarcopenia in older individuals based on measurements of walking speed, HGS and muscle mass[27]. Compared to other measures of relative HGS, HGS/MT-ulna was a significant predictor of walking speed and chair stand time. Ultrasound measured MT-ulna in the forearm is an excellent predictor (r=0.936) to estimate appendicular lean soft tissue mass[22]. The results from the present and previous studies suggest that a combination of measuring HGS and MT-ulna and calculating a ratio of HGS/MT-ulna for physical performance as well as calculating appendicular lean mass from MT-ulna may be a simplified screening strategy for sarcopenia. This may be especially pertinent for individuals who have had an injury in the lower body (including osteoarthritis of the knee), because they cannot perform a standard walking test. However, this is a possibility that needs to be more rigorously explored.

A number of limitations of the present study should be mentioned. First, because only three types of physical performance – usual walking speed, chair stand, and balance – were measured, we cannot infer similar results for other types of physical performance. Second, because our subjects were active older men, it is uncertain if the results pertain to inactive or sarcopenic individuals and women subjects. Lastly, for persons with arthritic pain in their hand and wrists, testing of HGS may be inappropriate and different tools should be considered for predicting physical function in these types of patients. Since a close relationship between muscle size and strength was reported in the forearm[20,28], predicting physical function using forearm muscle size may be advantageous in older adults who may have arthritic hands. In the present study, there were only weak correlations between MT-ulna and physical performance (data not shown) in active older men. Additional research into these issues is needed.

Conclusion

Our results indicated that the HGS/MT-ulna was a significant predictor of physical performance (i.e., usual walking speed and chair stand). Forearm muscle quality evaluated by a ratio of HGS to MT-ulna might be a better indicator of physical performance than absolute and other relative HGS in older male ground golf players.

Acknowledgements

Our appreciation is extended to the volunteers who participated in this study. We also thank board members of Kanoya Ground Golf Association, especially executive director Mr. Tetsuya Okumura, for their help in recruiting the participants and Ms. Akemi Abe for her assistance with the data collection in this study.

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