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Allometrically Scaled Grip Strength and the Mature Adult: Brief Report III

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Abstract- Grip strength has been shown to be closely associated to body strength and functional body movement ability among mature aged adults. However the aforementioned associations were based on absolute grip strength. What may be of greater importance is the relationship between allometrically scaled grip strength and body strength as well as functional body movement ability among mature aged adults. Purpose: This study examined the relationship between allometrically scaled grip strength and body strength as well as functional body movement ability among mature aged adults. Methods: This study examined previously reported data that was collected as follows. Female (n=12, 71.2±3.8 yrs, 66.3±9.2 kg) and male (n=16, 72.9±4.7 yrs, 85.5±9.4 kg) participants completed functional body movements including: vertical jump (VJ), medicine ball (MB) throws (1.5, 3.0, & 5.0 kgs), and a stair climb (SC) test. The participants also completed 1 RM tests with the leg press (LP), biceps curl (BC), triceps extension (TE), lat pull down (LPD), and machine bench press (BP). An aggregate strength score was also calculated as the sum of the individual 1 RM tests and was considered a total body strength score (TS). Likewise, all participants performed maximal hand grip (MG) with the Jamar hand grip dynamometer. MG scores were allometrically scaled to body height^2 (AMG: kg/m^2). Pearson correlation coefficients (PCC) were then calculated to determine the relationship between AMG and the 1 RM strength scores as well as the functional body movement scores. Results: PCC's between the AMG and the functional body measures ranged from r=0.70-0.78 ($p<0.01$), considered as high. PCC's between the AMG and 1 RM strength scores ranged from r=0.68-0.88 ($p<0.01$), considered as high to very high. The relationship between AMG and functional body measures as well 1 RM strength measures were reasonably consistent with those previously reported for MG and functional body measures as well 1 RM strength measures. Conclusions: Within the parameters of this study, both MG and AMG appear to be strongly reflective of functional body movements and 1 RM strength measures. In this regard, assessing grip strength may be beneficial to clinicians interested in assessing functional body movement ability and body strength among aging adults.

Keywords- *Grip, Grip Strength, Allowmetric, ADL's, Mature Adult*

I. INTRODUCTION

Muscle and strength loss associated with aging is referred to as sarcopenia (1). Sarcopenia loss of muscle strength and muscle function leads to decrements in the ability to perform activities of daily living (ADLs) (2) along with an increased risk of falls (3, 4). Injuries related to falls frequently present as permanent disability resulting in loss of independence (5, 6) and increased health care use and cost (7).

Noting the association between age related muscle loss/strength and mortality/injuries as well as the loss in the ability to perform ADLs, our previous work(s) focused on the relationship between grip strength and body strength measures as well as functional body movements (8,9). Our goal was to determine if grip strength (maximal grip strength: MG) could serve as a practical clinical test that could provide insight into an aging individual's ability to perform ADLs. Our prior work suggested that:

1. MG exhibited a high to very high significant relationship with regional and total body strength (8),
2. MG demonstrated a high to very high significant association with functional body movements that are muscular power oriented for both the upper and lower body (9), and
3. Given the aforementioned, clinicians might be well advised to collect MG as part of a mature adult's annual exam.

Since completing our earlier work (8,9) evidence supporting MG as an indice of health continues to evolve (10). In a recent umbrella review (10), which is a meta-analysis of systematic reviews, it was concluded that: "handgrip strength is a useful indicator for general health status and specifically for early all-cause and cardiovascular mortality, as well as disability". However, to our knowledge all of the papers cited in the Umbrella Review relied upon raw MG scores (i.e. not allometrically scaled). Likewise, our prior work relied upon raw MG scores for analysis (8,9).

Recent research (11) suggests that MG scores should be normalized to body size or allometrically scaled (11). The authors suggested that allometrically scaled MG would be “a more sensitive indication of strength capacity of an individual within a population” (11).

Given that MG is a useful indicator for general health (10) and that it is suggested that allometric scaling of MG leads to a more sensitive indication of physical strength (11), we decided to revisit our previous work regarding the relationship between MG and body strength as well as functional body movements among older adults (8,9).

As such, the purpose of this investigation was to: allometrically scale MG (AMG), compare AMG to measures of body strength measures, and compare AMG to functional body movement assessments among aging adults. This brief report is a continuation of our earlier work (8,9), which also allows us to also see if AMG is more sensitive than MG in establishing relationships between MG, body strength, and functional movements.

II. Methods

A. Participants

Participants (n=28) included mature males and females (68-88 years). Recruitment included public announcements, flyers, and word of mouth. The subjects were community-dwelling and independent with no prior background in resistance training (RT). Participants were approved for participation in the study by their personal physician. Prior to engaging in the study, participants were informed of the requirements of the study. The participants then read and signed an informed consent document approved by a University Institutional Review Board for the use of Human Subjects in research.

B. Procedures

As mentioned earlier, the focus of this paper is to re-evaluate previously published data regarding absolute MG and body strength and functional body movement ability among mature aged adults. To that end, the following assessment descriptions were initially reported elsewhere (8,9) and are reproduced here for the convenience of the readers. It should be noted that the body strength measures and functional body movement assessments were recorded on separate days separated by at least 72 hours.

C. Grip Strength Assessment

Maximal grip strength (MG) was assessed with a Jamar hand dynamometer. Participants completed two trials of maximal grip with both the dominant and non-dominant hand. Participants were seated with the shoulder at 0° abduction and flexion with the elbow at 90° flexion, as recommended by American Society of Hand Therapists (12). Participants were instructed to familiarize themselves with the Jamar by holding and squeezing the device prior to performing the maximal grip trials. Participants were then instructed to squeeze the device with a maximal effort for three seconds. The trials were separated by approximately 1 minute rest periods. The greatest MG score from the two trials was used for analysis.

D. Functional Body Movement Assessments

Vertical jump (VJ) measures were collected with the Vertec vertical jump measuring device in a manner previously described (13). The participants were given three VJ attempts with a self-selected rest period between trials ranging from 1-3 minutes. The best score (centimeters) was recorded and used for subsequent analysis. Vertical jump measures collected in this manner have been reported as reliable with intra class correlations (ICC’s) ranging from 0.87-0.89 (13). VJ height was then used to calculate peak power output as suggested by Sayers et al. (14). VJ peak power was used for subsequent analysis (VJ_{PP}).

$$\text{VJ Peak Power (watts)} = 60.7 * \text{VJ height (cms)} + 45.3 * \text{body mass (kg)} - 2055$$

Equation 1. Peak power output per Sayers et al. (14).

Medicine ball (MB) throws were collected for three different MB masses: 1.5, 3.0, and 5.0 Kgs. The MB throws were collected (meters) with the participants in a seated position as previously described (15). The participants were given three trials at each of the three MBs. The participants were allowed a self-selected rest period between trials ranging from 1-3 minutes. Medicine ball measures collected in this manner have been reported as reliable with ICC’s ≥0.98 (15).

Stair climb (SC) measures were collected for each participant as previously described (16). The best score of two trials separated by a 3 minute rest period was used for subsequent analysis. There were 12 stairs at 15.24 cm in height for a total of 1.83 meters. The SC climb times were then used to calculate power output (watts), equation 2. SC power output was used for subsequent analysis (SC_{PO}).

$$\text{SC Power Output (watts)} = \{9.81(\text{m/s}^2) * \text{body mass (kg)} * 1.83 \text{ (meters)}\} / \text{SC time (secs)}$$

Equation 2. Power output ascending a 1.81 meter stair case.

E. 1 RM Strength Assessments

Maximal strength measures (one repetition maximum-1 RM) were collected for the leg press (LP), biceps curl (BC), triceps extension (TE), lat pull down (LPD), and machine bench press (BP). Prior to study initiation, participants were instructed in proper execution of each exercise and appropriate breathing patterns in order to minimize cardiovascular stress (17). The participants performed multiple exercise sessions prior to the maximal strength test session assuring that they were familiar with the body mechanics of each movement. Following the familiarization exercise sessions, a 1 RM was then assessed and recorded for each exercise using established methods described previously (18). An aggregate strength score was also calculated as the sum of the individual 1 RM tests and was considered a total body strength score (TS).

Strength measures collected as those described during the current study have all been previously reported as reliable (19).

F. Analysis

Standard descriptive statistics (mean and standard deviation) for age, height, and body mass were calculated. PCCs were calculated between MG and: LP, BC, LPD, TE, BP, TS, VJ_{PP}, $MB^{1.5}$, $MB^{3.0}$, $MB^{5.0}$, and $SC_{PO.}$ Those same PCCs were then calculated for AMG and the aforementioned 1 RM strength measures and functional body movements. ($\alpha \leq 0.05$). Microsoft Excel 2013 software was utilized for data management and statistical analysis. The spread sheet and data were peer reviewed as suggested by AlTarawneh at al. (20).

III. Results

All of the participants were able to complete: the MG assessment, the 1 RM strength assessments (LP, BC, LPD, TE, and BP) and functional body movement assessments (VJ, $MB^{1.5}$, $MB^{3.0}$, $MB^{5.0}$, and SC). Table 1 provides the subject descriptive statistics for age, height and body mass (mean± standard deviation).

TABLE I. Participant descriptive characteristics (mean±SD).

Participants	N	Age (yrs)	Height (m)	Body Mass (kg)
Female	12	71.2±3.8	1.62±0.07	66.3±9.2
Male	16	72.9±4.7	1.77±0.06	85.5±9.4

Table 2 provides the MG and AMG grip scores. Table 3 provides the PCCs (r) between MG and the 1 RM strength scores as previously reported (8). Likewise, Table 3 provides the PCCs (r) between AMG and the 1 RM strength scores.

Table 4 provides the Pearson correlation coefficients (r) between MG and the functional body movement scores as previously reported (9) noting two exceptions. The MG comparisons to the VJ and the SC are based on power output assessments (watts). Previously (9) the MG comparisons with VJ and SC were based on units of centimeters of vertical jump height and seconds taken to complete the SC.

TABLE II. MG-maximal grip, AMG- allometric maximal grip (mean±SD).

Strength Measure	Male (n=16)	Female (n=12)
MG (kg)	30.3±5.6	10.6±3.3
AMG (kg/m^2)	9.6±1.7	4.0±1.0

TABLE III. Pearson Correlation Coefficients (r) between grip strength assessments and 1 RM strength measures, MG-maximal grip, AMG- allometric maximal grip, *p<0.01.

	Leg Press	Biceps Curl	Lat Pull	Triceps Extension	Bench Press	Total Body
MG	0.61*	0.85*	0.87*	0.80*	0.77*	0.83*
AMG	0.68*	0.87*	0.88*	0.82*	0.82*	0.87*

TABLE IV. Pearson Correlation Coefficients (r) between grip strength and functional body movement assessments, MG-maximal grip, AMG- allometric maximal grip, *p<0.01.

	Vertical Jump PP	Medicine Ball 1.5 kg	Medicine Ball 3.0 kg	Medicine Ball 5.0 kg	Stair Climb PO
MG	0.79*	0.86*	0.87*	0.91*	0.72*
AMG	0.78*	0.70*	0.73*	0.78*	0.75*

IV. Discussion

A recent umbrella review has strongly suggested the utility of MG as an “indicator of general health status and specifically for early all-cause and cardiovascular mortality, as well as disability” (10). Additional contemporary research suggests that allometrically scaling of MG may provide a more sensitive indicator of physical strength and “normalize strength for population-based research” (11). Science dictates that as new information develops, researchers are obligated to revisit their previous conclusions. With that said, we decided to re-examine the results of our earlier work regarding the relationship between MG and body strength as well as functional body movements among older adults (8,9). Our earlier work relied upon raw MG scores (non-allometrically scaled).

The current investigation unarchived the data from our earlier works (8,9): allometrically scaled MG (AMG), compared AMG to body strength measures, and compared AMG to functional body movement assessments. We suspected that if allometrically scaling MG provided a more sensitive indicator of physical strength, then the relationships between grip strength and body strength measures as well as functional body movement assessments would be stronger.

The MG scores were positively associated with regional and total body 1 RMs ranging from r=0.61 (high) to r=0.87 (very high). The AMG scores were also positively associated with regional and total body 1 RMs ranging from r=0.68 (high) to r=0.88 (very high). It is worth noting that the relationship between AMG and each strength indice was slightly higher than those for MG. These results support what we had anticipated. The strength of the relationships (high and very high) are as described by Miller (21).

The MG scores were positively associated with functional body movement assessments ranging from r=0.72 (high) to r=0.91 (very high). The AMG scores were also positively associated with functional body movement assessments ranging from r=0.70 (high) to r=0.78 (high). It is worth noting that the relationship between AMG and each functional body movement assessment were slightly lower than those for MG, with the exception of SC_{PO}. These results were mixed regarding what we had anticipated.

Consistent with our previous work (8,9), the results of our current investigation suggest that both indices of grip strength (MG and AMG) are essentially equally effective with regards to estimating body strength measures as well as functional body movement assessments. Likewise, the results of the current investigation support the results of the umbrella review

(10), which strongly suggests that grip strength is an indicator of general health status as well as disability.

As with our earlier work (8), we would like to note the impact of a potential outlier score on the PCCs calculated between AMG and the 1 RM strength measures. If one participant's scores were removed from the calculations, all of the PCCs reported would increase. The PCC between AMG and: LP=0.71, BC=0.92, LPD=0.94, TE=0.90, BP=0.88, and TS=0.93; which suggests an even greater relationship between AMG and body strength.

Our prior work discussed the importance of exercise prescription for targeting both muscular strength and power with the concept of specificity in mind towards performing ADLs (8.9). The ADLs we were referring to at the time were primarily ambulatory in nature, for example: chair-rising speed, stair-climbing speed, walking speed, etc. An example of a resistance training (RT) modality that is specific and transferable to the aforementioned ambulatory movements would be a dumbbell lunge. The dumbbell lunge requires the hand to be coupled to a dumbbell during the execution of the lunging movement. Hence, in addition to developing the musculature required for ambulation, it is likely that grip ability is indirectly (or secondarily) enhanced. However, not all RT modalities require a hand implement coupling, and hence, no indirect exercising of grip ability. With that said, there are many ADLs that require a hand-object coupling, for example: carrying a bag of groceries, opening a jar, using a manual can opener, using a broom or a yard rake, shoveling snow, taking out the trash, pouring laundry detergent, etc. As such, there is inherent value in targeting grip strength development (or maintenance) as part of any exercise prescription for members of an aging population.

Regarding future research, we agree with the authors of the aforementioned umbrella review (10). There is rather strong evidence supporting the notion that hand grip strength is an indice of health, mortality, and disability (10). Future research should focus on the underpinning factors responsible for the association between grip strength and health outcomes (10).

V. CONCLUSIONS

Given the high PCCs between both grip strength indices (MG and AMG) and body strength measures as well as functional body movement assessments, it appears that grip strength evaluation may serve as a practical and simple clinically meaningful screening assessment of body strength and functional body movements (i.e. ADLs). Grip strength assessment could be easily included as part of an annual physical exam. As such, providing practitioners a datum regarding exercise prescription for their patients, which is of particular value to aging patients experiencing sarcopenia and a reduced ability to perform ADLs.

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