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COMPARISON OF LABORATORY- AND FIELD-BASED ESTIMATES OF MUSCLE QUALITY FOR PREDICTING PHYSICAL FUNCTION IN OLDER WOMEN

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Abstract: *Background:* Muscle quality is related to physical function in older adults, however no study has investigated the utility of a field-based estimate for use in clinical settings. *Objectives:* This study investigated laboratory- and field-based measurements of muscle quality for predicting physical function in community-dwelling older women. *Design:* Cross-sectional. *Setting:* University research laboratory. *Participants:* Community-dwelling older women (n = 97, 73.9 ± 5.6 y). *Measurements:* Leg extension power using the Nottingham power rig, handgrip strength, body composition via dual-energy X-ray absorptiometry, and physical function (6-minute walk, 8-foot up-and-go, 30-second chair stand). Laboratory-based muscle quality (MQ-LAB) was defined as leg power (watts) normalized for lower-body mineral-free lean mass (kg) and field-based muscle quality (MQ-FIELD) was measured as handgrip strength normalized for body mass index. *Results:* MQ-LAB (r range = 0.42 to -0.63, all p < 0.01) and MQ-FIELD (r range = 0.37 to -0.50, all p < 0.01) had similar associations with measures of physical function. Using linear regression analysis, the percent improvement in physical function that could be expected from a 10% increase in muscle quality was similar for laboratory- and field-based estimates (2.7-4.4% vs. 2.6-3.8%, respectively). *Conclusions:* A field-based estimate of muscle quality provides a similar prediction of physical function to a laboratory-based approach in community-dwelling older women, and may be feasible for use in a clinical setting by practitioners.

Key words: Muscle quality, aging, physical function, sarcopenia.

Introduction

Muscle quality has traditionally been defined as the ratio of muscle strength to muscle mass or cross-sectional area (1, 2). Age-related reductions in muscle strength and power occur at a greater rate than the loss of muscle mass (sarcopenia), which suggests a decrement in muscle quality of older adults (1-3). Consequently, there is growing interest in muscle quality as it has been associated with measures of physical function (chair rise time and gait speed) (4) and physical frailty (5) in older adults. Other studies have identified muscle quality as an independent predictor of lower-extremity physical function (6) and gait variability (7) in community-dwelling older adults. Muscle quality can be broadly defined as a capacity measure (strength or power) in relation to a quantity measure (muscle mass/size). However, a universal definition for muscle quality has not been established, and consequently, the literature is replete with a myriad of definitions. As a result, it is difficult to ascertain the utility of different indices in older adults because there is a paucity of empirical evidence comparing them.

While studies have reported the impact of muscle quality on physical function, they have been conducted in research laboratories, and generally measured muscle function via isometric or isokinetic dynamometry and used a sophisticated imaging technique to quantify skeletal muscle mass. No known studies have attempted to delineate the relationship between physical function and muscle quality in older adults using field-based methods. Development of a field-based estimate of muscle quality is valuable as it would provide a more accessible and feasible measurement for use in community-based and clinical settings, and may allow for a relatively quick and simple prediction of physical function in older adults by practitioners. One common field-based method of assessing muscle function is handgrip strength, which has been correlated with total body strength (3) and has been shown to be predictive of incident disability in community-dwelling older adults (8). Likewise, body mass index (BMI) can provide an indication of overall body size and is a cost-effective

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alternative to measurement techniques such as magnetic resonance imaging and dual-energy X-ray absorptiometry (DXA) scanning. Thus, an index of muscle quality that measures handgrip strength normalized for BMI may be a viable field-based approach to quantifying muscle quality in older adults. However, comparison with a laboratory-based method is necessary to determine the potential utility of a field-based approach to defining muscle quality.

Therefore, the aim of the present study was to compare laboratory- and field-based estimates of muscle quality and determine their capacity for predicting performance on objective measurements of physical function in a cohort of community-dwelling older women.

Methods

Participants

Community-dwelling older women aged 65-89 years were recruited for participation in this study. This study employed a cross-sectional design and participants completed all testing measures during a single session. All participants provided written informed consent prior to enrollment and this study was approved by the Institutional Review Board at the University of Georgia.

Leg Power and Handgrip Strength

Leg extension power was measured using the Nottingham power rig (University of Nottingham Medical School, Model NG7 2UH, Nottingham, UK). The participant was seated in an adjustable seat and instructed to push against a foot pedal until their knee was extended. The peak power value (watts) for each leg was used for analysis and lower-body muscle power was determined by summing the peak power values of the left and right legs. Handgrip strength was measured using handheld dynamometry (JAMAR Hydraulic Hand Dynamometer, Model 5030J1, Bolingbrook, IL) and all participants completed the test with both their dominant and non-dominant hand. Values were measured to the nearest kg and maximum handgrip strength was determined by summing the peak values for the dominant and non-dominant hands.

Body Composition and Muscle Quality

Whole-body and regional soft tissue composition was measured via DXA scanning (iDXA, GE Healthcare-Luna, Madison, WI). Mineral-free lean mass of the lower-extremities was quantified as total lean mass below the top of the iliac crest. The laboratory-based estimate of muscle quality (MQ-LAB) was defined as leg extension power (watts) normalized for mineral-free lean mass of the lower-body (kg). The field-based estimate of muscle quality (MQ-FIELD) was calculated as handgrip strength normalized for BMI.

Physical Function

Physical function was measured via the 6-minute walk, 8-foot up-and-go, and the 30-second chair stand. The 6-minute walk measures the greatest distance that an individual can walk in 6 minutes, and is a valid and reliable test of physical endurance in community-residing older adults (9). The 8-foot up-and-go requires participants to stand up from a chair, walk around a cone located 8 feet away, and return to the chair as quickly as possible (10). This assessment was included as it provides a measurement of dynamic balance and agility in older adults (10). Each participant completed two trials and the shortest time was recorded for analysis. Physical function was also assessed via the 30-second chair stand, which measures the number of times that an individual can rise to a full stand from a seated position without using their arms in 30 seconds (10). This test provides an index of lower-extremity muscle strength and has been associated with maximum leg press strength in older adults (11).

Statistical Analysis

Data were examined for normality using histograms and distribution statistics (skewness and kurtosis). Because some data were not normally distributed, both muscle quality and physical function variables were natural log transformed. This was done to induce normality in positively skewed variables and to facilitate interpretation of linear regression coefficients as percent change in the physical function measure for a given percent change in muscle quality (see below). Prior to performing regression analyses, Pearson correlations were performed to examine the bivariate associations between measures of body composition and physical function, and scatterplots were examined to assess the linearity of these relationships. Linear regression analyses were then conducted to quantify and compare the relative contributions of MQ-LAB and MQ-FIELD to measures of physical function. Because four participants were identified as outliers for the 30-second chair stand (total score of 0) and were found to have excessive influence on the regression model, they were excluded from all analyses (n=93 for 30-second chair stand). Age and self-reported number of medical conditions were controlled for, as they were significantly associated with muscle quality and all measures of physical function. All analyses were conducted using SPSS for Windows version 20.0 (SPSS, Inc., Chicago, IL) and statistical significance was set at $p < 0.05$.

Results

Descriptive characteristics are presented in Table 1. The study sample was 94% white, 5% black, and 1% Asian. The most common medical conditions were arthritis (n = 66, 68%), other comorbidities including cancer, sleep apnea, and epilepsy (n=66, 68%), and hypertension (n=43, 44%).

Table 1
Participant characteristics (n=97)

Characteristic	Mean ± SD	Min-Max	Median	25th-75th %
Age (y)	73.9 ± 5.6	65.0-89.0	73.0	69.0-78.0
Height (m)	1.67 ± 0.09	1.46-1.93	1.67	1.61-1.74
Weight (kg)	69.2 ± 12.8	38.5-106.5	69.0	61.1-77.3
Body Mass Index (kg/m^2)	26.6 ± 4.7	16.1-45.3	26.2	23.3-29.4
Medical Conditions (total)	2.1 ± 1.2	0-6	2	1-3
Percent Body Fat (%)	41.6 ± 6.8	21.0-55.8	42.4	37.4-46.7
Lower-Body MFLM (kg)	20.2 ± 2.6	14.0-28.2	20.0	18.6-22.0
Leg Power (watts)	184.1 ± 58.4	73.6-333.1	182.8	140.7-214.8
Handgrip Strength (kg)	45.4 ± 11.0	22.0-78.0	46.0	36.0-52.5
MQ-LAB (watts/kg)	9.1 ± 2.8	4.2-16.2	9.1	7.0-10.8
MQ-FIELD	1.8 ± 0.5	0.9-3.1	1.7	1.3-2.1
6-Minute Walk (m)	484.3 ± 88.0	243.2-735.6	485.0	430.7-551.1
8-Foot Up-and-Go (s)	6.99 ± 1.57	3.30-12.60	6.68	6.02-7.61
30-S Chair Stand (total)[a]	12.8 ± 3.6	2-23	13	11-14

[a]n=93; MFLM = mineral-free lean mass; MQ-LAB = leg power (watts) / lower-body MFLM (kg); MQ-FIELD = handgrip strength / BMI

Table 2 presents Pearson correlation coefficients for demographic, body composition, and physical function variables. As expected, MQ-LAB (r range = 0.42 to -0.63, all p < 0.01) had a stronger relation than MQ-FIELD (r range = 0.37 to -0.50, all p < 0.01) with all three measures of physical function, however the associations were similar. A comparison of the laboratory- and field-based estimates of muscle quality for predicting physical function is presented in Table 3. Using linear regression analyses, MQ-LAB and MQ-FIELD were both significant predictors of performance on all selected measures of physical function. Because muscle quality and physical function measures were natural log transformed, the β coefficients can be interpreted as the predicted percent change in each physical function test for a 1% change in the muscle quality measure. To make these results more clinically meaningful, the coefficients presented in Table 3 correspond to a 10% improvement in MQ-LAB and MQ-FIELD. The percent improvement in all physical function variables that could be expected from such an increase in muscle quality was similar across laboratory- and field-based estimates (2.7-4.4% vs. 2.6-3.8%, respectively).

Table 3
Predicted percent change in physical function associated with a 10% increase in laboratory- and field-based measures of muscle quality (n=97)

Muscle Quality	6-Minute Walk % change [95% CI]	8-Foot Up-And-Go % change [95% CI]	30-S Chair Stand % change [95% CI][a]
Laboratory-Based	2.7 [1.5, 3.8]	-3.6 [-4.9, -2.4]	4.4 [1.8, 7.1]
Field-Based	2.6 [1.6, 3.7]	-3.1 [-4.3, -1.9]	3.8 [1.5, 6.2]

[a]n=93; Analysis controlled for age and number of medical conditions

Discussion

The principal findings from this study suggest that both laboratory- and field-based estimates of muscle quality provide similar predictions of performance on widely used measures of physical function in community-dwelling older women. This study contributes to an emerging body of literature that underscores the importance of muscle quality for physical function in older adults, and provides preliminary evidence that a field-based estimate has the capacity to predict function similarly to a more sophisticated laboratory-based measurement.

To our knowledge, no study has compared the relative contributions of different measurements of muscle quality to physical function in community-dwelling older adults. As was described previously, muscle quality is generally defined as a measure of muscle function in relation to a measure of muscle quantity. As a result, prior studies that have defined muscle quality have

Table 2
Pearson correlation coefficients between demographic, body composition and physical function measures (n=97)

	BMI	Medical Conditions	Lower-body MFLM	Leg Power	Handgrip Strength	MQ-LAB	MQ-FIELD	6MWT	UPGO	CHR[a]
Age	-.21*	.20	-.15	-.51**	-.36**	-.48**	-.18	-.43**	.43**	-.21*
BMI		.13	.58**	.09	.03	-.10	-.53**	-.25*	.24*	-.22*
Medical Conditions			-.04	-.29**	-.13	-.28**	-.19	-.26*	.26**	-.27**
Lower-body MFLM				.31**	.35**	-.05	-.04	.08	.02	-.20
Leg Power					.46**	.91**	.36**	.56**	-.58**	.33**
Handgrip Strength						.38**	.81**	.41**	-.42**	.27**
MQ-LAB							.40**	.56**	-.63**	.42**
MQ-FIELD								.49**	-.50**	.37**

[a]n=93; *Significant correlation at p < 0.05; **Significant correlation at p < 0.01; MFLM = mineral-free lean mass; 6MWT = 6-minute walk; UPGO = 8-foot up-and-go; CHR = 30-second chair stand

assessed function using isometric (7, 12) and isokinetic (1, 2, 6, 13) dynamometry, one-repetition maximum strength (4, 12), handgrip strength (1), and leg power (14, 15). With regard to muscle quantity, studies have used DXA scanning to determine skeletal muscle mass (1, 4, 6, 7, 13), and computed tomography (2, 14) or magnetic resonance imaging (12) to quantify muscle volume. Our findings suggest a field-based index of muscle quality predicts function similarly to a laboratory-based method, which is beneficial as a field-based estimate of muscle quality is feasible for use in a clinical setting where practitioners' access to more sophisticated measurement instruments (dynamometry, power rig, DXA scanner) and assessment time is likely to be limited.

Another novel aspect of this study is the measurement of muscle quality using muscle power, which has been used in few previous studies (14, 15) and has not been assessed via the Nottingham power rig. Although fewer studies have defined muscle quality using leg power, there is emerging evidence that suggests muscle power is paramount for physical function in both community-dwelling older women (16), as well as those older adults with mobility limitations (17). Because the age-related decline in muscle power occurs faster than the reduction in muscle mass, muscle power represents a critical target for future intervention strategies designed to preserve functional abilities in older adults.

Our findings are in accordance with previous studies that have investigated the relationship between muscle quality and physical function (4-7). For example, Misic et al. (6) found that muscle quality was a stronger predictor of lower-extremity physical function than aerobic fitness and fat mass in community-dwelling older adults. In their study, muscle quality was reported to explain 29-42% of the variance in dynamic physical function. Likewise, our regression model indicated that muscle quality explained ~11-26% of the variance in physical function, even after adjustment for covariates. In contrast to our findings, Bouchard et al. (13) reported that muscle quality was not a significant predictor of a composite measure of physical function in a sample of community-dwelling older adults from the NHANES cohort. However, their composite measure of physical function was comprised of two objective measurements (20-foot walk test and Romberg test) and five questions that assessed self-reported physical function. The strength of the association between performance-based and self-perceived physical function varies considerably (18), and a stronger relationship with muscle quality may have been observed using additional objective measurements of physical function.

Although our findings highlight the potential utility of a field-based estimate of muscle quality, there are limitations to this study that should be addressed. First, because a consensus has not been established with regard to the optimal index of muscle quality, our field-based estimate was compared with a laboratory-based method that normalized leg power for mineral-free lean mass of the lower-body. However, incorporating muscle power provides a novel index of muscle quality and provides a foundation for future studies to investigate its importance when normalized for skeletal muscle mass. Likewise, while handgrip strength was included in our field-based index of muscle quality, we did not evaluate performance on any upper-extremity functional assessments and it is possible that stronger associations would have been evident during such tasks.

In summary, our findings suggest that a field-based estimate of muscle quality predicts physical function similarly to a laboratory-based approach in community-dwelling older women. These results highlight the importance of maintaining muscle function (power and strength) relative to muscle size (mass or cross-sectional area) with age. Additional research should attempt to corroborate the association between field-based measurements of muscle quality and different functional activities, as well as further characterize the potential role of muscle power as a salient determinant of physical function in both older men and women.

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