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Muscle Strength, Muscle Mass, and Physical Disability in Women with Systemic Lupus Erythematosus

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Abstract

Objective—Limited data exist describing relationships between muscle strength, muscle mass, and physical disability among individuals with systemic lupus erythematosus (SLE). The present study examines the relationship of muscle strength and muscle mass with physical disability among adult women with SLE.

Methods—One hundred forty-six women from a longitudinal SLE cohort participated in the study. All measures were collected during an in-person research visit. Lower extremity muscle strength was assessed by peak knee torque of extension and flexion and by chair-stand time. Total lean body mass, appendicular lean mass, and fat mass (kg/m²) were measured by whole-body dual energy absorptiometry. Self-reported physical disability was assessed using the SF-36 Physical Functioning subscale and Valued Life Activities (VLA) Disability scale. Spearman's rank correlation coefficients tested the correlations between muscle strength, muscle mass, and disability scores. Regression analyses modeled the effect of lower extremity muscle strength and mass on SF-36 and VLA disability scores controlling for age, SLE duration, SLE disease activity measured with the Systemic Lupus Activity Questionnaire (SLAQ), physical activity level, prednisone use, body composition, and depression.

Results—On all measures, reduced lower extremity muscle strength was associated with poorer SF-36 and VLA disability scores. Trends persisted after adjustment for covariates. Muscle mass was moderately correlated with muscle strength, but did not contribute significantly to adjusted regression models.

Conclusions—Lower extremity muscle strength, but not muscle mass, was strongly associated with physical disability scores. While further studies are needed, these findings suggest that improving muscle strength may reduce physical disability among women with SLE.

INTRODUCTION

Associations between reduced muscle strength and increased physical disability have been observed in various study populations, including elders and individuals with osteoarthritis (1–10). In these populations, both total body and regional measures of muscle mass, such as total body lean mass and appendicular lean mass, were also associated with the degree of physical disability (4, 9, 11, 12). Interestingly, muscle density, which is felt to reflect muscle integrity and contractility, was found to be more closely related to the degree of disability than was muscle mass among elders (1–4). These observations from elderly populations suggest that muscle function may better explain changes in physical disability than does muscle quantity.

Among individuals with rheumatoid arthritis (RA), similar trends have been observed between muscle mass, muscle function, and physical disability. Rheumatoid arthritis predisposes to changes in regional muscle and fat distribution, with increased fat mass and decreased lean mass (13–15). Thus individuals with RA are likely at increased risk of muscle-related disability. Indeed, similar to observations from elderly populations, other groups have observed strong associations between total body muscle mass, appendicular muscle mass, muscle density, and physical disability among individuals with RA (16–18). However, muscle density, which is closely related to muscle function, was a stronger indicator of physical disability than was muscle mass (18).

In SLE, only limited data exist describing the relationships between muscle strength and physical disability (19, 20), and to our knowledge no data have been published that examine the role of regional muscle mass and physical disability in SLE. Similar to RA, SLE predisposes to increased fat mass and decreased lean mass (21–23), and there is a high burden of physical disability among individuals with SLE (24–26). In contrast to RA, SLE is more frequently associated with certain musculoskeletal manifestations, such as myalgia and myositis, which may put individuals with SLE at particular risk of muscle-related disability (27–29). Therefore, the goal of the present study was to address this gap in the literature by examining the relationships between muscle strength, muscle distribution, and physical disability among women with SLE; and testing whether muscle strength and muscle mass are associated with self-reported disability.

SUBJECTS AND METHODS

Subjects

The sample for the present study was drawn from participants in the University of California, San Francisco (UCSF) Lupus Outcomes Study (LOS). Participants in the LOS had formerly participated in a study of genetic risk factors for SLE outcomes (30, 31); were recruited from both clinical and community-based sources, including UCSF-affiliated clinics (22%), non-UCSF rheumatology offices (11%), lupus support groups and conferences (26%), and newsletters, web sites, and other forms of publicity (41%); and participate in annual structured telephone interviews. SLE diagnoses using the American College of Rheumatology (ACR) criteria (32) were verified by medical record review. Additional details regarding the LOS are reported by Yelin *et al.*(33). LOS participants who lived in the

greater San Francisco Bay area were recruited for an in-person assessment in the UCSF Clinical and Translational Science Institute's Clinical Research Center (CRC) that included measurement of lower extremity muscle strength. Exclusion criteria were non-English speaking, age <18 years, current daily oral prednisone dose of 50 mg or greater, current pregnancy, uncorrected vision problems that would interfere with reading ability, and joint replacement within 1 year.

Three hundred twenty-five individuals appeared to be eligible for the CRC study and were asked to participate during one of their annual telephone interviews; 81 (24.9%) were ineligible (35 were actually outside the recruitment area, 25 were too ill, 9 had had recent surgery, 7 were unable to complete the study procedures, 2 were pregnant, 2 had poor English skills, and 1 had severe cognitive problems and was unable to complete the telephone interview). Of the 251 eligible individuals, 84 (33.5%) declined participation. The most common reasons for declining were primarily related to transportation (n = 12) and scheduling difficulties (n = 39). One hundred fifty-seven individuals completed study visits. Eleven men were excluded because there were too few for separate analysis. One hundred and forty-six women were included in the present analysis. Sociodemographic and health-related characteristics of the study sample are shown in Table 1. This study was approved by the UCSF Committee on Human Research.

Measures

Muscle strength—Lower extremity muscle strength was assessed by knee torque and chair-stand time. A Biodex® unit was used to measure peak isokinetic torques of knee extension and flexion at 120 degrees/second adjusted for body weight (34). Participants completed two reproducible and acceptable trials. Average maximal knee strength for extension and flexion were analyzed. Chair-stand time was measured as the time to complete 5 chair-stands from a standard chair without using one's arms (35). Peak isokinetic knee torque and chair-stand time were chosen because these are commonly used proxy measures for muscle strength among rheumatologic and non-rheumatologic populations (3, 4, 9, 11, 19, 35–37).

Muscle mass—Body composition and regional body muscle distribution were assessed in the CRC using a Lunar Prodigy whole-body dual energy absorptiometry (DXA) system (GE Healthcare). The DXA technique is able to differentiate bone, muscle, and fat and calculates total body mass (kg), fat mass (gm), percent fat, and lean body mass (gm), as well as the regional distribution of these components (left arm, leg, and trunk; right arm, leg, and trunk; and total arm, leg, and trunk). DXA has been used previously in determination of soft tissue mass and has been validated (38–40) as a method of assessing body composition in both younger and older individuals. It has good reported reproducibility and is sensitive to small changes in body composition (41). The precision errors ± 1 SD for percent fat are 1.4% in soft tissue, 1.0 kg for fat mass, and 0.8 kg for lean tissue mass (39). DXA has previously been used successfully to assess body composition among individuals with SLE (22, 23). Height-adjusted indices were created for total lean body mass (LMI, kg/m^2), appendicular lean mass, and fat mass (FMI, kg/m^2).

Physical Disability—Two measures that assess different aspects of physical disability were examined. The first measure was the Short Form 36 (SF-36) Health Survey physical function subscale (42), which includes 10 items assessing actions such as lifting and carrying, bending or kneeling, walking, and climbing stairs. Scores are standardized to range from 0–100, with a mean \pm SD of 50 ± 10 , and higher scores reflecting better function. The second measure was the Valued Life Activities (VLA) disability scale (25), which consists of 21 items, for which respondents rate difficulty in performance on a 4-point scale (where 0 = no difficulty and 3 = unable to perform). Activities that individuals deem unimportant to them or that they do not perform for reasons unrelated to lupus are not rated and are not included in scoring. The mean difficulty score (range 0–3) is calculated based on items rated, with higher scores reflecting greater disability.

Other Variables—Sociodemographic characteristics (e.g., age, race/ethnicity, education, income, and smoking status) were obtained from the baseline LOS telephone interview. Disease activity was assessed using the Systemic Lupus Activity Questionnaire (SLAQ) a validated, self-report measure of disease activity in SLE (43, 44). The SLAQ was taken from the LOS interview that most closely preceded the CRC visit. Glucocorticoid use was assessed at the time of the visit. Physical activity was assessed by self-report with the long form of the International Physical Activity Questionnaire (IPAQ) (45). The IPAQ has been used and validated in a number of populations (46, 47). The scoring protocol provides a cut point by which individuals' weekly energy expenditure can be categorized as low, moderate, or high. Individuals who expended fewer than 600 metabolic equivalent (MET) minutes per week were classified as inactive for these analyses (45, 46). To simplify reporting, individuals who reported 600 MET minutes per week or more were referred to as "active." Depressive symptoms were assessed using the Center for Epidemiologic Studies Depression Scale (CES-D). The CES-D is a commonly used 20-item scale to evaluate depressive symptom severity, with a score range of 0–60 (48).

Statistical Analysis

Differences in baseline characteristics between women who did and did not complete strength measures were tested with chi-squared and *t*-test analyses. Correlations between measures of muscle mass and muscle strength were tested using Spearman's rank correlation coefficient. Linear regression analyses were used to model the effects of lower extremity muscle strength and regional body muscle composition (lean mass index to fat mass index ratio (LMI/FMI)) on SF-36 Physical Functioning and VLA Disability scores with and without adjusting for covariates (age, SLAQ score, disease duration, prednisone use, physical activity level, and depressive symptom score). To test whether the observed effect of muscle strength on disability was sensitive to missing muscle strength data, individuals with missing muscle strength data were assigned the weakest recorded value for missing measures (i.e., the lowest knee torque values and highest chair-stand times) and regression models were repeated. Statistical analyses were conducted using Stata software, version 13.1 (StataCorp, College Station, TX).

RESULTS

Subject characteristics

The overall mean age, SLAQ SLE disease activity score, SLE disease duration, daily prednisone dose, and LMI/FMI are reported in Table 1. The overall mean \pm SD peak knee torque of extension and flexion was 44.1 ± 15.7 and 29.7 ± 11.2 N-m, respectively. The overall mean \pm SD chair-stand time was 14.3 ± 4.0 seconds. The overall mean \pm SD SF-36 Physical Functioning and VLA difficulty scores were 43.8 ± 10.4 and 0.7 ± 0.5 , respectively.

Of the 146 women, 21 (14%) did not complete the knee torque assessment, and 32 (22%) did not complete the chair-stand assessment. The most common reasons for non-completion were pain or other health-related contraindications to the procedures (e.g., high or low blood pressure). Compared to women with complete strength data available, women missing either Biodex® or chair-stand data, had greater mean age, SLAQ score, depressive symptoms (CES-D Depression score), and disability (SF-36 and VLA Difficulty scores); and lower relative mean muscle mass (LMI/FMI) and peak knee torque. Mean daily prednisone dose and chair-stand time did not differ between women with complete and partial strength data.

Muscle strength and muscle mass

Neither total body lean mass index (LMI) nor appendicular LMI were highly correlated with strength measures (Table 2). However, LMI corrected for fat mass index (LMI/FMI) was significantly, though moderately, correlated with all measures of lower extremity muscle strength.

Muscle strength, muscle mass, and disability associations

In unadjusted models, muscle mass (LMI/FMI) and all three measures of muscle strength (knee extension, knee flexion, and chair-stand time) were highly associated with SF-36 and VLA disability scores (Tables 3 and 4). Greater muscle mass and greater muscle strength were associated with better SF-36 scores and VLA scores. In adjusted models, however, LMI/FMI was not significantly associated with disability scores ($p < 0.05$ in all models). In contrast, increased muscle strength was still associated with better SF-36 and VLA disability scores when adjusting for covariates (age, SLAQ score, SLE disease duration, prednisone use, LMI/FMI, physical activity level, and depression score). For example, an increase of 10 N-m in peak torque of knee extension was associated with an average 1.87 point (0.94, 2.81; $p < 0.001$) improvement in SF-36 Physical Functioning score and a 0.06 point (0.10, 0.02; $p < 0.01$) improvement in VLA score, when the effects of all covariates are held constant. In the adjusted model, the association between chair-stand time and SF-36 score approached but did not attain statistical significance ($p = 0.12$).

Sensitivity analyses

When individuals with missing strength data were assigned the weakest recorded value for missing measures, the overall effects of muscle strength on disability scores were equivalent (Table 5). Reduced lower extremity strength was still associated with increased disability scores on the SF-36 and VLA assessments, while muscle mass was not.

DISCUSSION

We observed that, among adult women with SLE, reduced lower extremity muscle strength was associated with increased self-reported physical disability on the SF-36 Physical Functioning and VLA Disability assessments even when adjusting for covariates. In addition, while muscle mass correlated with muscle strength, only muscle strength was significantly associated with disability in adjusted models. These findings make a unique contribution to the current literature on physical disability in SLE. To our knowledge, this is one of the first studies to examine the relationship between objective measures of muscle strength, muscle mass, and physical disability in SLE.

Although healthy women were not included in this study, the cohort of women with SLE appeared to demonstrate decreased lower extremity muscle strength compared to healthy women. Prior studies of healthy women ranging in age from approximately 20 to 70 years old using similar methodologies to assess peak isokinetic knee torque reported average peak torques for knee extension that ranged from approximately 60 to 120 N-m (55, 56), compared to 44 N-m found in our study. Among women in their eighth decade of life, Newman et. al observed an average peak isokinetic knee torque of 82 N-m (57). Thus, even when accounting for minor differences in methodology, the women with SLE in our cohort demonstrated decreased lower extremity strength compared to healthy women. This burden of decreased muscle strength in our cohort supports the potential role for interventions to improve muscle strength and decrease physical disability among women with SLE.

Prior studies of body composition and disability in rheumatoid arthritis noted that appendicular lean muscle mass and thigh muscle density were associated with various disability measures (17, 18). Kramer *et al.* used computed tomography (CT) to measure thigh muscle density, which is argued to reflect muscle function and quality of contractile units (18). They observed that muscle density was more strongly associated with disability measures than muscle mass. In our cohort of women with SLE, we quantified muscle function by measuring muscle strength. As would be anticipated from the observations of Kramer *et al.*, we demonstrated that muscle strength and not muscle mass was highly associated with disability measures. Thus we corroborate muscle-related mechanisms of physical disability previously observed in individuals with RA. We demonstrate that similar muscle-related mechanisms of disability affect individuals with SLE. Our findings build upon prior observations and suggest that muscle strength likely plays a greater role than muscle mass in contributing to physical disability in SLE.

Our observation that lower extremity muscle strength, but not muscle mass, is associated with self-reported physical disability could be explained by various potential mechanisms. First, muscle strength may be more closely related than muscle mass to the relatively complex, higher-order physical activities measured by the SF-36 Physical Functioning and VLA Difficulty assessments, such as climbing stairs and doing housework. It is conceivable that these activities, which require dexterity and coordination, depend more closely on muscle function than on muscle quantity compared to simpler activities, such as transferring or toileting. Similarly, muscle strength may be more closely related than muscle mass to an individual's aerobic fitness and therefore may be more closely related to self-reported

disability among these women (49). Lastly, pro-inflammatory cytokines, such as interleukin-6 and tumor necrosis factor, distinct from their ability to induce muscle fiber atrophy, have been observed to interfere with muscle fiber contraction (50, 51). Individuals with SLE, a condition in which these cytokines are often elevated, may be at increased risk for this type of insult to muscle fiber function. Each of these potential explanations for the particular importance of muscle function to physical disability requires further direct study.

In our cohort with mean disease duration of 15.5 years and mean SLAQ disease activity score of 12.9, the overall mean reported SF-36 Physical Functioning score was 40.7 and the mean reported VLA Difficulty score of 0.8. A mean SF-36 Physical Functioning score of 40.7 is approximately one standard deviation below the overall population mean of 50. There are no data on the mean VLA Difficulty score in the overall population. However, the mean VLA Difficulty score among individuals with rheumatoid arthritis and chronic obstructive pulmonary disease (COPD) have been reported as 0.76 and 0.75, respectively (52, 53). Thus the mean disability scores observed in our cohort suggest a significant degree of physical disability. This burden of disability highlights both the clinical importance of this topic and the unmet need for interventions to improve or prevent physical disability among individuals with SLE.

In our analyses, differences in strength of 10 N-m yielded statistically significant but small differences in disability measures, so it may be helpful to put these results into context. The minimum clinically important difference (MCID) for health-related quality of life measures can be estimated as a one-half standard deviation (SD) difference (54). On the SF-36 Physical Functioning assessment, with mean 50 and SD 10, the MCID would then correspond to a change of 5 units; and on the VLA Difficulty assessment, with mean 0.8 and SD 0.6 among individuals with SLE, the MCID corresponds to 0.3 (25, 42). In adjusted analyses, we observed that 10 N-m increments in peak torque of knee extension were associated with an average 1.87 point (0.94, 2.81) differences in SF-36 Physical Functioning score and a 0.06 point (0.10, 0.02) difference in VLA score. Therefore, an increase of approximately 30 N-m or 50 N-m of knee extension would be associated with a MCID in SF-36 Physical Functioning and VLA Disability score, respectively, when adjusting for covariates. While increases of 30 to 50 N-m in lower extremity strength may not be achievable, perhaps smaller increases in strength in conjunction with other interventions to improve physical functioning among women with SLE, such as total body strength training or aerobic exercise, may be beneficial. Moreover, regardless of the origin, muscle weakness is unlikely to develop in isolation among individuals with SLE, and therefore is likely to be one of many factors leading to an individual's physical disability. Thus, muscle strength, is perhaps best viewed as one important factor among the various determinants of physical disability in individuals with SLE.

This study also highlights the difficulty inherent in objectively measuring muscle weakness among individuals at-risk for weakness. Compared to women with complete muscle strength data, those with no or only partial strength data because they declined to perform the assessment (most commonly due to pain or health-related conditions) had significantly worse mean SF-36 Physical Functioning scores and mean VLA Difficulty scores. Women who did not complete the strength assessments were also on average older, had greater

SLAQ disease activity scores, trended towards greater disease duration, reported greater depressive symptoms, and had lower muscle mass (LMI/FMI). Thus, women who are likely at the greatest risk for muscle weakness are unfortunately also those most likely to decline the assessment of muscle strength. As a result of this trend, our estimate of the effect of muscle strength on physical disability is likely biased towards the null hypothesis of no effect. The true association between reduced muscle strength and increased disability is likely to be even greater than that which we observed.

Our study has potential limitations. This is an observational, cross-sectional study. Thus, we must be cautious in attempting to extrapolate causal or temporal effects from our data. As discussed above, the power of our study was limited by missing data and the tendency of women with greater disability to decline the muscle strength assessments. The lack of a healthy control comparison group is also a potential limitation.

There are also strengths of our study. This is one of the first studies of SLE to incorporate objective measures of muscle strength and muscle mass indetermining the effects muscle characteristics on self-reported disability. We used two standardized, objective assessments to quantify muscle strength, and its relationship to muscle mass and physical disability.

This study has potential implications for the prevention or treatment of physical disability among women with SLE. Our findings suggest that interventions focused specifically on improving muscle strength may have a role in improving physical functioning in individuals with SLE. Many factors in addition to muscle strength, such as pain and aerobic fitness, likely contribute to physical disability among individuals with SLE (49). However, interventions focused on muscle strength may be beneficial in improving physical functioning among women with SLE when used as an adjunct to or a component of other interventions to improve physical functioning.

In summary, we observed that among women with SLE, having reduced lower extremity muscle strength was strongly associated with increased physical disability. Moreover, muscle strength and not muscle mass was associated with disability. These results suggest that interventions focusing on muscle strength may be beneficial in improving physical functioning for women with SLE. Future studies will be needed to examine the longitudinal effect of reduced muscle strength and muscle strengthening interventions on physical disability in SLE.

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SIGNIFICANCE AND INNOVATIONS

- Among adult women with systemic lupus erythematosus (SLE), reduced lower extremity muscle strength was associated with greater self-reported physical disability on the SF-36 Physical Performance and VLA Difficulty assessments in adjusted models.
- Muscle mass correlated with muscle strength, but it was not associated with physical disability in adjusted models.
- These results highlight a need for additional studies to evaluate whether interventions to increase muscle strength improve physical functioning for women with SLE.
- Future studies should explore mechanisms by which muscle strength, independent of muscle mass, relates to physical disability.

Table 1Participant Baseline Characteristics[#]

	Analysis Set			p ^{###}
	Overall (n=146)	Complete Strength Data (n=102)	Partial Strength Data (n=44)	
Age, years	47.8 ± 12.3	46.91 ± 12.7	51.5 ± 10.3	0.014
Disease Duration, years	15.5 ± 9.1	14.6 ± 12.8	17.5 ± 8.7	0.081
SLAQ Score	12.9 ± 7.4	11.6 ± 7.5	15.8 ± 6.5	0.0016
CES-D Depression Score	15.8 ± 12.4	13.7 ± 12.0	19.8 ± 12.3	0.004
Prednisone use, mg/day % (n)				0.82
0	51.6 (79)	53.9 (55)	47.1 (24)	
1–4.5	6.5 (10)	4.9 (5)	9.8 (5)	
5–9.5	19.0 (29)	20.6 (21)	15.7 (8)	
10–14.5	11.8 (18)	11.8 (12)	11.8 (6)	
15–19.5	3.3 (5)	3.9 (4)	2.0 (1)	
20	2.0 (3)	2.0 (2)	2.0 (1)	
LMI/FMI ^{###}	1.6 ± 0.7	1.7 ± 0.6	1.3 ± 0.7	0.002
Biodex®, N-m				
Knee Extension	44.1 ± 15.7 (n=125)	46.1 ± 14.8 (n=102)	35.2 ± 16.7 (n=23)	0.0022
Knee Flexion	29.7 ± 11.2 (n=125)	30.9 ± 11.1 (n=102)	24.7 ± 10.4 (n=23)	0.016
Chair-stand Time, seconds	14.3 ± 4.0 (n=114)	14.2 ± 4.0 (n=102)	15.2 ± 3.5 (n=12)	0.42
SF-36 Physical Functioning Score	40.7 ± 11.5	43.8 ± 10.4	33.7 ± 10.7	<0.0001
VLA Difficulty Score	0.8 ± 0.6	0.7 ± 0.5	1.1 ± 0.5	<0.0001

[#] Values are mean ± standard deviation unless otherwise indicated. Complete strength data refers to subjects for whom all Biodex® and Chair-stand measures were available. Partial strength data refers to subjects for who were missing either Biodex® or Chair-stand data.

^{##} From *t*-tests and chi-squared analyses comparing complete vs. partial.

^{###} LMI = lean mass index and FMI = fat mass index.

Table 2Correlations Between Measures of Muscle Mass and Muscle Strength (n=102)[#]

	Knee Extension, N-m	Knee Flexion, N-m	Chair-stand Time, seconds
LMI, kg/m ²	-0.21 *	-0.18	-0.05
Appendicular LMI, kg/m ²	-0.17	-0.17	-0.08
LMI/FMI	0.36**	0.48***	-0.25*

[#] Values represent the spearman rank correlation coefficient.

LMI = lean mass index. FMI = fat mass index.

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

Table 3Associations between Muscle Strength, Muscle Mass, and SF-36 Physical Functioning Score[#]

Model		Unadjusted	Adjusted ^{##}
1 (n=119)	Knee Extension, N-m	3.78 (2.70, 4.86)***	1.87 (0.94, 2.81)***
	LMI/FMI	n/a	0.66 (-1.22, 2.54)
2 (n=119)	Knee Flexion, N-m	4.74 (3.18, 6.31)***	2.55 (1.32, 3.79)***
	LMI/FMI	n/a	0.39 (-1.52, 2.30)
3 (n=111)	Chair-stand Time, seconds	-1.11 (-1.54, -0.67)***	-0.27 (-0.63, 0.08)
	LMI/FMI	n/a	0.23 (-1.72, 2.19)
4 (n=146)	LMI/FMI	4.68 (2.10, 7.27)***	n/a

[#] Values are the regression beta coefficient (95% confidence interval) for the mean change in SF-36 Physical Functioning Score for the given predictor variable. For ease of interpretation, knee extension and flexion values are scaled in units of 10 N-m. Higher SF-36 (range 0–100) and lower Chair-stand Time indicate better functioning.

^{##} Model is adjusted for the following covariates: age, SLAQ score, disease duration, prednisone use, LMI/FMI (LMI = lean mass index and FMI = fat mass index), physical activity level (active vs inactive), and CES-D Depression score.

N/A = not applicable

p<0.001

Table 4Associations between Muscle Strength, Muscle Mass, and Valued Life Activities Difficulty Score[#]

Model		Unadjusted	Adjusted ^{##}
1 (n=119)	Knee Extension, N-m	-0.16 (-0.22, -0.10)***	-0.06 (-0.10, -0.02)**
	LMI/FMI	n/a	-0.0005 (-0.09, 0.09)
2 (n=119)	Knee Flexion, N-m	-0.20 (-0.29, -0.12)***	-0.10 (-0.15, -0.04)**
	LMI/FMI	n/a	0.02 (-0.07, 0.10)
3 (n=111)	Chair-stand Time, seconds	0.06 (0.04, 0.08)***	0.02 (0.002, 0.04)*
	LMI/FMI	n/a	0.02 (-0.07, 0.12)
4 (n=146)	LMI/FMI	-0.17 (-0.30, -0.044)**	n/a

[#] Values are the regression beta coefficient (95% confidence interval) for the mean change in Valued Life Activities Disability (VLA) score for the given predictor variable. For ease of interpretation, knee extension and flexion values are scaled in units of 10 N-m. Lower VLA (range 0–3) and lower Chair-stand Time indicate better functioning.

^{##} Model is adjusted for the following covariates: age, SLAQ score, disease duration, prednisone use, LMI/FMI (LMI = lean mass index and FMI = fat mass index), physical activity level (active vs inactive), and CES-D Depression score.

N/A = not applicable

*
 $p < 0.05$

**
 $p < 0.01$

 $p < 0.001$

Table 5Sensitivity Analysis for Missing Muscle Strength Data (n=146)[#]

Model		SF-36 Physical Functioning	Valued Life Activities Difficulty
1	Knee Extension, N-m	1.17 (0.53, 1.80)***	-0.03 (-0.06, 0.002)
2	Knee Flexion, N-m	1.93 (1.00, 2.86)***	-0.06 (-0.10, -0.01)*
3	Chair-stand Time, seconds	-0.32 (-0.48, -0.17)***	0.01 (0.005, 0.02)**

[#] Missing muscle strength data were assigned the weakest observed value for each measure. Values are the regression beta coefficient (95% confidence interval) for the mean change in SF-36 Physical Functioning Score and VLA Difficulty Score for the given predictor variable. For ease of interpretation, knee extension and flexion values are scaled in units of 10 N-m. Higher SF-36 (range 0–100), lower VLA Difficulty (range 0–3), and lower Chair-stand Time indicate better functioning. Models are adjusted for the following covariates: age, SLAQ score, disease duration, prednisone use, LMI/FMI (LMI = lean mass index and FMI = fat mass index), physical activity level (active vs inactive) and CES-D Depression score.

*
p<0.05

**
p<0.01

p<0.001