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Repeated Chair Stands as a Measure of Lower Limb Strength in Sexagenarian Women

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Background. Despite inadequate empirical validation, sit-to-stand (STS) performance is often used as a proxy measure of lower limb strength among older adults. Furthermore, the relationships between bilateral isokinetic hip, knee, and ankle joint strength and their contributions to STS performances among older adults have not been established. The authors evaluated these relationships on 2 STS tests (5-chair STS test and 30-second chair STS test) in sexagenarian women.

Methods. 47 women (mean age, 64.50 years) performed both STS tests on the same day and bilateral isokinetic (60°/second) hip extensor, hip flexor, knee extensor, knee flexor, ankle plantar flexor, and ankle dorsiflexor strength testing within 7 days after STS testing. Regression analyses were performed using the average weight-adjusted isokinetic hip, knee, and ankle joint strength scores as the independent variables and both STS test scores as the dependent variables.

Results. Regression analyses including all 6 leg strength variables explained 48% ($p = .0001$) and 35% ($p = .007$) of the variance in 5-chair STS test scores and 30-second chair STS scores, respectively. Ankle plantar flexor, hip flexor, and knee extensor strength were the strongest predictors for both STS tests.

Conclusions. Although ankle plantar flexor, hip flexor, and knee extensor strength play essential roles in performing the STS movement, most STS variance was unexplained, suggesting that important additional variables are also involved in completing the movement.

ONE of the most common activities of daily living, and a precursor to walking, is rising from a seated to a standing position. The ability to perform the sit-to-stand (STS) movement is important to maintaining physical independence and may be one of the most important functional measures of physical capacity (1,2). Age-related decreases in lower limb strength, speed, and power are considered major contributing factors to the diminishing capacity to perform basic activities of daily living (e.g., rising from a chair, walking unassisted, and climbing stairs) and to increasing morbidity and ultimately leading to death (3–9).

The accepted method used to assess lower limb strength is isokinetic knee extensor strength (10–14). Because it is not feasible to administer this test to most older adults, researchers have often used STS performance measures as proxy indicators of lower limb strength (15,16). The continued face validity justification for relying on STS performance as proxy measures of lower limb strength has been questioned (17–19). Studies of the biomechanics of standing up (17), and preliminary explorations of the STS performance by other investigators (18,19), have found that the STS movement represents a complex functional movement that is not entirely accounted for by measures of lower limb strength but is also influenced by a range of balance, sensorimotor, and psychological factors. In addition, recent studies have shown that changes in the muscle power of the lower (20) and upper limbs (21) may help predict functional decline.

Biomechanical analyses of the STS movement using hip, knee, and ankle joint kinematic parameters have proved useful in studying the lower limb strength-to-physical function relationship in older adults. For example, a kinematic study of the STS movement (17) suggests that the movement can be divided into four phases. Within each phase of the STS movement, the following lower limb strength contributions have been suggested. 1) A sufficient level of hip flexor and ankle dorsiflexor strength is essential during the flexion-momentum phase (phase I), when the body weight is shifted from the buttocks to the feet. 2) Knee extensor strength is essential during the momentum transfer phase (phase II), when the body weight is moved off the chair and over the feet. 3) Both knee extensor and hip extensor strength are essential during the extension phase (phase III), when maximum knee and hip extensor velocities are achieved. 4) Ankle plantar flexor strength is essential during the stabilization phase (phase IV), after the STS movement has been completed and maintenance of postural stability and balance are important. Complicating matters further is the recognition that the hip, knee, and ankle joints differentially contribute to the amount of lower limb strength, speed, and power required for a successful STS movement. For these reasons, the relationships between hip, knee, and ankle joint strength and the functional ability to stand up from a seated position warrant greater empirical study.

Two STS tests (5-chair STS test and 30-second chair STS test) have been most often used in older adults (15,16). Although the movements required by each test are identical, the two tests differ in at least one important aspect. The 5-chair STS test measures the time required to complete five movements, whereas the other test measures the number of movements that can be completed in 30 seconds. We theorize that the 5-chair STS test may serve as more of a proxy indicator of lower limb speed and power, whereas the 30-second STS test may serve as more of a proxy indicator of lower limb endurance. For these reasons, the STS tests are not considered interchangeable.

The aim of this study was to combine both STS tests in one experimental design and systematically evaluate the importance of overall lower limb strength and the relative contributions of hip, knee, and ankle joint strength with performance on each of the STS tests in a sample of community-residing sexagenarian women. At issue in this study is not the validity of the STS test as a proxy measure of lower limb strength but rather the relationships among and between hip, knee, and ankle joint strength and the 5-chair STS test and 30-second chair STS test performance. Given the latest research findings that the STS movement is multidimensional (with both physiologic and psychological determinants, for example), and recognizing that our study focuses solely on the dimension of strength, we hypothesized that lower limb strength (i.e., hip, knee, and ankle joint strength) is a strong predictor (R^2 value) of STS performance.

Methods

Participants

After we received approval from The University of Georgia Institutional Review Board, a convenience sample of 47 community-residing sexagenarian women from the Athens, Georgia area were recruited from women's clubs, wellness centers, and churches. Physicians' clearances were obtained for all participants. Physical characteristics included (a) age (64.51 $\pm$ 3.08 years), (b) height (163.03 $\pm$ 4.34 cm.), and (c) weight (67.73 $\pm$ 10.08 kg). Participant results showed that 94% (44 of 47) of the sample scored $\geq$ 50th percentile for the 5-chair STS test performance, and 66% (31 of 47) of the sample scored $\geq$ 50th percentile for the 30-second chair STS test performance, indicating that most participants would be classified with average to high physical function when compared with normative chair STS performance data (15,16).

Procedures

Participants completed 2 testing sessions, with 3 to 7 days between each. Session 1 required 60 minutes and involved a laboratory orientation, collection of demographic data, and completion of both STS test protocols. Session 2 required 90 minutes and involved bilateral isokinetic hip, knee, and ankle joint strength testing (60°/s) using a Cybex NORM Isokinetic Dynamometer (Henley Health, Sugar Land, TX). The right and left legs were tested separately to determine the possibility of bilateral hip, knee, or ankle joint strength asymmetry or a unilateral symptomatic joint in either the right or left leg (22).

Chair Sit-To-Stand Testing

The 5-chair STS test and 30-second chair STS test were completed using a standard padded chair (43.20 cm) without armrests (23). Participants followed identical STS techniques for both STS tests (16), with both arms crossed against the chest, starting from the seated position and standing up (legs straight) and sitting down (full weight on the chair). The 5-chair STS test calculates the time required (in seconds) to complete 5 repeated chair stands. The 30-second chair STS test calculates the number of chair stands completed in 30 seconds. Participants completed two trials of each STS test interspersed by a 5-minute rest interval. The scores from both trials were averaged for each STS test for data analyses. The order of STS tests was counterbalanced by randomly assigning participants to 1 of 5 STS testing sequences (e.g., 5-5-30-30, 30-30-5-5, 5-30-5-30, or 30-5-30-5).

Isokinetic Leg Strength Testing

For each isokinetic strength test (60°/s), participants were instructed to push and pull as hard and fast as possible until test completion (5 repetitions per muscle group). The peak torque repetition for each muscle group was adjusted by body weight (kilograms) and used in the data analyses. Participants were familiarized with the testing procedures by completing 3 submaximal warm-up repetitions at 60°/second, followed by actual testing (24). A 5-minute rest interval was interspersed between each leg movement. To maximize equipment set-up efficiency, strength testing was administered in the following sequence: right knee extensor/flexors, left knee extensor/flexors, left hip extensor/flexors, right hip extensor/flexors, right ankle plantar/dorsiflexors, and left ankle plantar/dorsiflexors.

Statistical Analysis

Regression analyses were conducted using the 5-chair STS test and 30-second chair STS test scores as the dependent variables and average weight-adjusted isokinetic hip, knee, and ankle joint strength scores as the independent variables. To account for individual differences in body weight, average weight-adjusted strength scores were calculated by dividing the mean bilateral strength score (mean bilateral strength score = right + left scores of corresponding muscle groups, divided by 2) by body weight (kilograms) (25). Statistical regression was applied to determine what proportion of variance in the dependent variables could be explained by the independent variables, and which lower limb muscle group(s) may have the highest relative importance (e.g., highest standardized regression coefficients) in estimating STS test performance. Of the 50 participants who completed testing, 3 contained an outlier variable (e.g., height, STS performance, or isokinetic hip strength) using the criterion $\pm$ 3 *SD* (standard deviations) from the mean and were not included in the final analyses. Average weight-adjusted lower limb strength scores were used as independent variables to account for any non-linearities between lower limb strength and STS performance (dependent variable). All analyses were conducted using SPSS version 10.0 software (SPSS, Chicago, IL). An alpha level of .05 was considered significant for all analyses.

Results

Chair Sit-To-Stand Testing

Table 1 shows descriptive statistics (e.g., means and standard deviations) both STS tests. Based on Pearson test–retest correlation coefficient analyses, both the 5-chair STS test ($r = .95$, $p = .0001$) and 30-second chair STS test ($r = .93$, $p = .0001$) demonstrated high degrees of stability when performed on the same day. In addition, Table 2 shows that the performance scores on both STS tests were highly correlated ($r = -.83$, $p \leq .01$).

Isokinetic Leg Strength

Table 1 shows right, left, and average isokinetic hip, knee, and ankle joint strength results. Based on Pearson correlation coefficient analyses for right and left hip, knee, and ankle joint strength scores, a moderately high correlation was indicated for all muscle groups, except ankle dorsiflexor strength. Right and left hip extensor ($r = .79$, $p = .0001$), hip flexor ($r = .80$, $p = .0001$), knee extensor ($r = .71$, $p = .0001$), knee flexor ($r = .67$, $p = .0001$), and ankle plantar flexor strength scores ($r = .72$, $p = .0001$) all displayed acceptable levels of bilateral strength symmetry (26). Right and left ankle dorsiflexor strength scores showed low correlation ($r = .33$, $p = .023$), indicating the possible presence of bilateral strength asymmetry in this muscle group. The issue of strength asymmetry was not a factor in the analyses because an average bilateral (right and left) strength score was calculated.

Table 2 shows Pearson correlation coefficients for lower limb strength scores. All lower limb strength scores (range $r = -.58$ to .64) had either weak-negative associations (e.g., $r = -.70$ to $-.30$), little or no associations (e.g., $r = -.30$ to $+.30$), or weak-positive associations (e.g., $r = +.30$ to $+.70$).

Chair Sit-To-Stand Test Regression Results

Table 3 shows results of regression analyses using 5-chair STS test and 30-second chair STS test scores as the dependent variables and all lower limb strength scores as the independent variables. Regression results using all 6 lower limb strength variables explained 48% ($p = .0001$) and 35% ($p = .007$) of the variance in 5-chair STS test and 30-second chair STS test scores, respectively. These results, as anticipated, suggest that variables other than hip, knee, and ankle joint strength influenced STS test performance.

Within the regression model using 5-chair STS test scores as the dependent variable, ankle plantar flexor ($\beta = -.450$, $p = .014$), hip flexor ($\beta = -.337$, $p = .045$), and knee extensor ($\beta = -.301$, $p = .053$) strength scores had the highest standardized regression coefficients, and each variable was significant in explaining 5-chair STS test performance. Within the regression model using 30-second chair STS test scores as the dependent variable, ankle plantar flexor ($\beta = .358$, $p = .074$) strength had the highest standardized regression coefficient and was the only lower limb strength variable approaching significance in explaining 30-second chair STS test scores.

The inclusion of participant height to the regression model with all lower limb strength variables was not significant ($p = .122$) in explaining 5-chair STS test performance but was significant ($p = .029$) in explaining 30-second chair STS test performance (Table 3). In both models, height showed

Table 1. Chair STS Test and Isokinetic Lower Limb Strength Results (60°/s) ($N = 47$)

Variable	Mean	*SD*
Five-chair STS test	11.34 s	2.44 s
30-second chair STS test	13.97 stands	3.07 stands
Hip extensors		
Right	124.91	21.87
Left	122.18	27.08
Average	123.55	23.20
Hip flexors		
Right	40.69	15.25
Left	41.09	10.56
Average	40.89	12.26
Knee extensors		
Right	89.52	16.13
Left	92.73	13.72
Average	91.13	13.80
Knee flexors		
Right	52.21	10.79
Left	51.22	12.99
Average	51.72	10.87
Ankle plantar flexors		
Right	33.28	9.02
Left	32.12	9.19
Average	33.20	8.44
Ankle dorsiflexors		
Right	7.86	2.43
Left	10.46	2.45
Average	9.16	1.99

Notes: All isokinetic strength scores are in Newton-Meters.
SD = standard deviation; STS = sit-to-stand.

Table 2. Pearson Correlation Coefficients for Lower Limb Strength and STS Test Results

	HE	HF	KE	KF	AP	AD	5Ch	30Ch
HE	—	0.44**	0.44**	0.58**	0.57**	0.03	−0.29*	0.33*
HF	0.44**	—	0.49**	0.59**	0.64**	0.24	−0.58**	0.47**
KE	0.44**	0.49**	—	0.58**	0.46**	0.37**	−0.46**	0.44**
KF	0.58**	0.59**	0.58**	—	0.57**	0.31*	−0.35*	0.33*
AP	0.57**	0.64**	0.46**	0.57**	—	0.35*	−0.58**	0.52**
AD	0.03	0.24	0.37**	0.31*	0.35*	—	−0.14	0.21
5Ch	−0.29*	−0.58**	−0.46**	−0.35*	−0.58**	−0.14	—	−0.83**
30Ch	0.33*	0.47**	0.44**	0.33*	0.52**	0.21	−0.83**	—

Notes: *$p < .05$; **$p < .01$.

HE = Hip extensors; HF = hip flexors; KE = knee extensors; KF = knee flexors; AP = ankle plantar flexors; AD = ankle dorsiflexors; 5Ch = five-chair STS test; 30Ch = 30-second chair STS test; STS = sit-to-stand.

Table 3. Regression Analyses Using 5-Chair STS Test and 30-Second Chair STS Test Scores as the Dependent Variables and All Lower Limb Strength Scores as the Independent Variables

Class of Independent Variables	R^2 (R^2_{adj})	Model Significance (p Value)	Standardized Regression Coefficients	Individual Significance (p Value)
Five-chair STS				
Average	.48 (.40)	.0001	HE = .158	.331
Isokinetic			HF = −.337	.045*
Leg Strength			KE = −.301	.053
			KF = .146	.398
			AP = −.450	.014*
			AD = .158	.244
Average	.51 (.42)	.0001	HE = .094	.566
Isokinetic			HF = −.331	.045*
Leg Strength			KE = −.280	.067
And Height			KF = .093	.587
			AP = −.340	.074
			AD = .122	.366
			HT = .198	.122
30-Second chair STS				
Average	.35 (.25)	.007	HE = −.004	.984
Isokinetic			HF = .204	.270
Leg Strength			KE = .257	.135
			KF = −.136	.481
			AP = .358	.074
			AD = −.017	.908
Average	.42 (.32)	.002	HE = .095	.591
Isokinetic			HF = .193	.272
Leg Strength			KE = .225	.170
And Height			KF = .193	.272
			AP = .187	.357
			AD = .039	.789
			HT = −.308	.029*

Notes: *$p < .05$.

HE = hip extensors; HF = hip flexors; KE = knee extensors; KF = knee flexors; AP = ankle plantar flexors; AD = ankle dorsiflexors; HT = participant height; STS = sit-to-stand.

a negligible incremental change in explaining 5-chair STS test scores ($R^2 = .51$ with height, $R^2 = .48$ without height) and 30-second chair STS test performance ($R^2 = .42$ with height, $R^2 = .35$ without height). These results suggest that height provided a low level of relative importance in explaining STS performance, but further study may be warranted on the effect that height may have on 30-second chair STS test performance based on the significance of adding height to the regression model.

Subsequent regression analyses using 5-chair STS test and 30-second chair STS test scores as the dependent variables and all lower limb muscle power scores as the independent variables (not shown) explained 43% ($p = .001$) and 33% ($p = .01$) of the variance in 5-chair STS test and 30-second chair STS test scores, respectively. These results suggest that lower limb strength and power are comparable independent predictors of STS performance in the sample studied.

Discussion

Researchers have used the STS movement as a proxy indicator of lower limb strength in older adults (15,16,27–29). Our current findings contribute to the emerging body of literature (18,20) that highlights the STS task as a multidimensional functional movement involving more than just lower limb strength. When R^2 values were calculated through multiple regression, only a moderate proportion of variance in STS performance on either STS test could be explained using hip, knee, and ankle joint strength scores as independent variables. This finding is important given the reliance by researchers on these two STS tests as a primary indicator of lower limb strength.

Our research extends the work of Lord and colleagues (18), who found that in addition to lower limb strength (knee extensor/flexor and ankle dorsiflexor strength), STS performance in older community-residing adults is also influenced by a range of balance, sensorimotor, and psychological factors. Because the current study included only a unidimensional assessment of the STS test (e.g., lower limb strength measures), it is not surprising that only moderate R^2 values were realized in regression analyses for the 5-chair STS test ($R^2 = .48$, $p < .0001$) and 30-second chair STS test ($R^2 = .35$, $p < .007$). What is intriguing is that Lord and colleagues (18), also reported only moderate R^2 values for the 5-chair STS test ($R^2 = .35$, $p < .01$) when they used a multidimensional assessment of the STS test (e.g., lower limb strength, balance, sensorimotor, and psychological factors). That result may have been a result of the heterogeneous sample of participants (e.g., men and women aged 75–93 years with various levels of mobility limitation), whereas the current study included only women aged 60 to 70 years who had no mobility limitations. In retrospect, although lower limb strength variables have been shown to be important in relation to the STS movement, additional independent variables that may further address the multidimensional nature of the STS movement (e.g., leg speed, leg power, leg endurance, posture, injury history, and psychological variables such as fear of falling, self-efficacy, and mood) may also explain what specific combination of independent variables contributes to the variance in STS test performance. In other words, the current study shows that ankle plantar flexor, hip flexor, and knee extensor strength are important and necessary indicators, but only moderate predictors, of STS performance in the sample of sexagenarian women we examined.

Of the six muscle groups we tested, ankle plantar flexor strength contributed the most to predicting STS test performance, followed by hip flexor and knee extensor strength. In addition, the ankle plantar flexors undoubtedly contribute to successful STS performance in ways not measured by strength alone. For example, because each STS test involves repeated sitting and standing, where each successive STS repetition requires an adequate level of static balance, the essential role the ankle plantar flexors contribute in stabilizing the body in the upright standing position after each chair rise becomes apparent.

Conclusions and Recommendations

When paired with the findings of Lord and colleagues (18), our results suggest that the STS test is multidimensional, given that more variance in STS performance was left unaccounted for than could be explained by the conjoint contributions of six bilateral lower limb muscle groups in a well-controlled sample of community-residing sexagenarian women. We agree with the conclusions stated by Lord and colleagues (18) that the STS is a multidimensional test not only of lower limb strength but also of variables such as sensorimotor, balance, and psychological parameters.

Clearly, more research is needed in a diverse sampling of older adults to determine the fundamental assessment differences between the 5-chair STS test (e.g., more of a test of lower limb speed and/or power) and the 30-second chair STS test (e.g., more of a test of lower limb endurance). Based on the amount of time needed to complete 5 successive chair-stands (sample mean = 11.34 s), the 5-chair STS test may be a more appropriate functional lower limb strength, speed, and power assessment instrument for older adults who have lower physical functional abilities (e.g., assisted living and nursing home residents and persons with joint replacement or hip, knee, or ankle joint involvement). In contrast, the 30-second chair STS test may be a more appropriate functional lower limb endurance assessment instrument for older adults categorized with higher physical functional abilities (e.g., persons residing in the community who are independent, physically active, and experiencing no hip, knee, or ankle joint involvement). Our ability to apply our results to the general elderly population is limited by the homogeneity of the sample (i.e., community-residing, sexagenarian women with no medical, orthopedic, or musculoskeletal conditions), the sample size ($n = 47$), the level of significance in data analyses ($\alpha = .05$), the isokinetic strength and physical function tests performed, and the specific equipment used for data collection.

Future research on the STS test should investigate the effects bilateral hip, knee, and ankle joint strength asymmetries and the effect participant height may have on STS test performance (especially the 30-second chair STS test). In addition, interventions other than hip, knee, and ankle joint strength training that may improve STS performance in older adults, including balance, posture, and flexibility training, need to be investigated.

Finally, many persons are living into and well beyond their eighties in the United States, and the numbers who will survive long enough to experience frailty is expected to increase. Continued research on the relationship hip, knee, and ankle joint strength have on performance of basic activities of daily living (e.g., standing up unaided from a chair, bed, or toilet; walking; and stair climbing) has merit not only for gerontologists and health care professionals but also for persons experiencing declines in their function and independence associated with advanced aging, and their family members who eventually serve as their caregivers. Outcomes from future research on the STS movement might not only identify which physiologic and psychological variables explain the greatest amount of variance in STS performance but also determine whether seat height manipulation (e.g., placing firm pillows on the seat or attaching chair-leg extenders) can improve either single chair-stand or repeated chair-stand performance.

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