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Sit-to-stand test: Performance and determinants across the age-span

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Abstract

Although the validity of the sit-to-stand (STS) test as a measure of lower limb strength has been questioned, it is widely used as such among older adults. The purposes of this study were: 1) to describe five-repetition STS test (FRSTST) performance (time) by adolescents and adults and 2) to determine the relationship of isometric knee extension strength (force and torque), age, gender, weight, and stature with that performance. Participants were 111 female and 70 male (14–85 years) community-dwelling enrollees in the NIH Toolbox Assessment of Neurological and Behavioral Function. The FRSTST was conducted using a standard armless chair. Knee extension force was measured using a belt-stabilized hand-held dynamometer; knee extension torque was measured using a Biodex dynamometer. The mean times for the FRSTST ranged from 6.0 sec (20–29 years) to 10.8 sec (80–85 years). For both the entire sample and a sub-sample of participants 50–85 years, knee extension strength ($r = -0.388$ to -0.634), age ($r = 0.561$ and 0.466), and gender ($r = 0.182$ and 0.276) were correlated significantly with FRSTST times. In all multiple regression models, knee extension strength provided the best explanation of FRSTST performance, but age contributed as well. Bodyweight and stature were less consistent in explaining FRSTST performance. Gender did not add to the explanation of FRSTST performance. Our findings suggest, therefore, that FRSTST time reflects lower limb strength, but that performance should be interpreted in light of age and other factors.

Keywords

Muscle strength; measurement; mobility; aging

1. Introduction

Performance of the sit-to-stand (STS) maneuver involves activation of multiple muscles of the lower limb, most notably the knee extensor (quadriceps femoris) muscles [9,15]. It is not surprising therefore that the STS maneuver is used extensively as a measure of lower limb strength. While numerous investigators have demonstrated a relationship between lower limb strength and STS performance [1,2,4,6,8,10–12,14], other researchers have questioned use of the STS test as a measure of lower extremity muscle strength [13]. They have demonstrated that STS performance is dependent, at least in part, on factors other than strength (eg, balance) [11,14]. Consequently, we considered further investigation necessary before advocating the STS test as a measure of lower limb strength. Additionally, much of the research on the STS test has focused on older adults and has not accounted for the possible contribution of anthropometric factors. As the STS test requires muscles to generate forces to accelerate/decelerate the body's mass through a distance against the pull of gravity, we thought it important to address anthropometric factors (body weight and stature) as well.

Several variations of the STS test exist. This study, however, focused on the five-repetition STS test (FRSTST) as it is the most often employed [3] and less likely to reflect endurance than a 10 repetition [5] or 30 second test [10]. The purposes of this study, therefore, were: 1) to describe performance on the FRSTST across ages spanning from adolescence to older adulthood and 2) to determine the relationship between that performance and knee extension strength, body weight, stature, age, and gender. We hypothesized that FRSTST performance would be related to knee extension strength, bodyweight, stature, age, and gender.

2. Method

This investigation was part of the validation phase of the National Institutes of Health (NIH) Toolbox study, an investigation designed to develop a brief but comprehensive battery of portable and low-cost measures of cognitive, motor, sensory, and emotional health and function that lay administrators could employ in large cohort studies [7]. The present study was limited to motor domain data gathered by trained testers at 2 participating sites (University of Connecticut and Rehabilitation Institute of Chicago) whose institutional review boards approved the study.

2.1. Participants

All participants provided written informed consent before testing. Inclusion required that participants were fluent in English, were between 14 and 85 years of age, were able to walk without use of an assistive device, and had no heart, vascular, lung, or bone/joint problems that precluded their standing from a chair or climbing steps. Sampling was by age stratum, with a higher proportion of participants aged 65 and older to ensure feasibility with those most likely to be frail.

2.2. Procedures

Basic demographic (age, gender) and anthropometric (body weight and stature) data were obtained first. Thereafter, measures of endurance, dexterity, and strength were obtained.

Among the strength measures were the FRSTST and isometric knee extension strength, which were measured in varying order.

The FRSTST required participants to stand up from and sit down on a slightly padded 43 cm high armless chair (Fig. 1) as quickly as possible 5 times. Participants folded their arms across their chests and were instructed to stand-up completely and make firm contact when sitting. Timing began on the command “go” and ceased when the participants sat after the fifth stand-up. Participants were allowed a practice trial of 2 repetitions before the timing of 2 test trials of 5 repetitions. The fastest of the 2 test trials was used in subsequent analysis.

Isometric knee extension strength was determined using 2 different procedures; a MicroFET hand-held dynamometer was used to measure knee extension force (Fig. 2) whereas a Biodex isokinetic dynamometer was used to measure knee extension torque. For both procedures participants sat with stabilization provided by straps, with their knees at about 90 degrees of flexion, and with the dynamometer input pads positioned just proximal to the malleoli. Both procedures involved 3 trials with each lower limb. The first trial was submaximal and served as practice. The following 2 test trials were at maximal effort. Regardless, participants were requested to come to the requested effort over a second or 2 and to continue making such effort until requested to stop (ie, after a total of 5 seconds). For each procedure, the greatest of the 2 test trials of each side was used in subsequent analysis.

2.3. Data Analysis

All analysis was conducted using the Statistical Package for Social Sciences (SPSS) version 14.0. Transformations were first conducted. These involved summing the force and torque measurements of the 2 lower limbs and dividing by (normalizing against) body weight [2]. Standard descriptive statistics were then calculated for relevant demographic and anthropometric factors and for FRSTST times, and knee extension force and torque (both untransformed and transformed). The relationship of knee extension strength, demographic (age, gender), and anthropometric (bodyweight, stature) with FRSTST times was examined using Pearson correlations. Multiple regression analysis (forward method) was used to determine the relative contribution of knee extension strength and other variables (age, gender, body weight, stature) to the explanation of FRSTST times. As the FRSTST is typically used with older adults, the Pearson correlations and multiple regression analysis were performed on both the entire sample and a sub-sample of participants (50–85 years).

3. Results

For the two sites contributing data to this study, 181 of 184 participants were able to perform the FRSTST. Of these 111 were female and 70 were male. Their ages ranged from 14 to 85 years (46.5 ± 22.7 years). Their body weight (mass) ranged from 42.6 to 135.8 kg (72.9 ± 16.8 kg). Their stature ranged from 1.51 to 2.09 meters (1.69 ± 0.11 meters). The time required to complete the FRSTST ranged from 3.9 to 17.7 sec (7.5 ± 2.4 sec). Table 1 provides age-band specific descriptive statistics for FRSTST times. Isometric knee extension forces and torques of the left and right sides combined (both non-normalized and normalized against body weight) are summarized in Table 2.

Correlations of the independent variables with FRSTST times are reported in Table 3. The correlations between FRSTST times and the strength measures were all negative, moderate in magnitude, and significant ($p < 0.001$) for both the sample as a whole ($r = -0.388$ to -0.634) and for the older sub-sample ($r = -0.476$ to -0.568). The magnitude of the correlations was higher, but not significantly so, for force measures than for torque measures and for body weight normalized measures. The FRSTST times had a significant ($p < 0.001$), negative, and moderate correlation with age, both for the entire sample and the sub-sample of older adults. The correlations between FRSTST times and gender were significant but low in magnitude for both the sample as a whole and the sub-sample. Neither body weight nor stature was correlated significantly with FRSTST performance in either the full sample or the subsample.

Multiple regression analysis (Table 4) for the complete sample showed knee extension strength measures to provide the strongest explanation of FRSTST time. This was true for each strength measure ($\beta > -1.5$) and each strength measure squared ($\beta > 1.04$), suggesting a curvilinear relationship that is confirmed by examination of the scatterplots (Fig. 3). The regression analysis also revealed that age, body weight, and stature added to the explanation of FRSTST time provided by knee extension force and torque. Age and stature added to the explanation of FRSTST time provided by bodyweight normalized knee extension force or torque. Gender did not add to the explanation of FRSTST time. Overall, regression models including strength, weight (as either a separate variable or normalizing factor), age, and stature explained a minimum of 46.6 percent of the variance in FRSTST time.

Multiple regression analysis (Table 5) for the sub-sample of older adults also showed knee extension strength measures to be the strongest determinants of FRSTST time. This was true for each strength measure ($\beta = -0.367$ to -1.563). The regression analysis also revealed that age added to the explanation of FRSTST time, regardless of the knee extension strength measure. Stature added to the explanation of FRSTST time provided by knee extension force or torque. Gender did not add to the explanation of FRSTST time. Overall, regression models including strength, age, and in two cases stature explained 33.4 to 50.4 percent of the variance in FRSTST time.

4. Discussion

The FRSTST is probably the most often employed functional test of lower limb strength. However, unlike the 10-repetition STS test [5], the FRSTST has been used almost exclusively for older adults [3]. The present study expands information on FRSTST performance to encompass adolescents as well as young and middle-aged adults. Compared to FRSTST times previously summarized for older adults in the 60–69 year, 70–79 year, and 80–89 year age bands [3], the mean times in the present study were somewhat faster. This could be the result of our study's relatively small convenience sample of generally healthy participants.

Based on what is known about lower limb muscle performance during the STS maneuver [9,15], and the results of the present study, we are confident that FRSTST times are reflective of knee extension strength across the age span. That said, much of the variance in

FRSTST times is left unexplained by knee extension force and torque. Across the age span, age, stature, and bodyweight added to the explanation of FRSTST times in regression analysis of the entire sample. Taken together, these findings mean that lower (better) FRSTST times are demonstrated by patients who are stronger, younger, shorter, and lighter. When analysis was limited to the older sub-sample, age remained an explanatory factor as did stature if strength was not normalized against bodyweight. As we did not measure balance, sensation, or psychological status, their potential contribution to the explanation of STS performance is not known for the present study [11,14]. We are uncertain as to why Netz et al. failed to find a relationship between knee extension strength and STS performance [13], but several differences in our studies may be relevant. The sample studied by Netz et al. involved 49 women 61 to 87 years of age, whereas ours included 181 women and men 14 to 85 years of age [13]. Netz et al. used a 10 repetition STS test, which may be more likely to reflect muscular endurance than the FRSTST. Netz et al. normalized both knee extension torque and STS time to bodyweight [13]. We only normalized knee extension strength values against bodyweight. Finally, Netz et al. did not account for the possible curvilinear nature of the relationship between strength and STS performance or address stature as a mitigating factor as was done in our study.

In conclusion, the FRSTST is a functional strength measure that approximates the way the body works in everyday life. The significant relationship between knee extension strength and FRSTST performance among 14–85 year olds and 50–85 year olds provides support for the test as a utilitarian strength measure. Nevertheless, knee extension strength alone provides an insufficient explanation of FRSTST performance. Age, body weight, and stature also influence FRSTST performance and should be considered when interpreting FRSTST performance.

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Fig. 1.
Timing of participant performing the five-repetition sit to stand test.

Fig. 2.
Measurement of a participant's knee extension force using a hand-held dynamometer augmented with belt stabilization.

Fig. 3.

Scatterplot showing the curvilinear relationship between a knee extension strength measure and five repetition sit to stand (FRSTS) time.

Table 1

Descriptive statistics for five-repetition sit to stand test times by age category

Age (n)	Mean $\pm$ SD (95% CI)	Min-Max
14–19 (25)	6.5 $\pm$ 1.2 (6.0–7.0)	4.7–9.7
20–29 (36)	6.0 $\pm$ 1.4 (5.6–6.5)	3.9–11.2
30–39 (22)	6.1 $\pm$ 1.4 (5.5–6.8)	4.1–10.4
40–49 (15)	7.6 $\pm$ 1.8 (6.6–8.6)	5.6–13.2
50–59 (20)	7.7 $\pm$ 2.6 (6.5–8.9)	4.2–12.1
60–69 (25)	7.8 $\pm$ 2.4 (6.8–8.7)	4.7–15.1
70–79 (24)	9.3 $\pm$ 2.1 (8.4–10.1)	5.5–13.3
80–85 (14)	10.8 $\pm$ 2.6 (9.3–12.3)	5.8–17.6
14–85 (181)	7.5 $\pm$ 2.4 (7.1–7.8)	3.9–17.6
50–85 (83)	8.7 $\pm$ 2.6 (8.1–9.3)	4.2–17.6

Table 2

Descriptive statistics for knee extension strength measures

Measure	14–85 years Mean $\pm$ SD	50–85 years Mean $\pm$ SD
Knee extension force (N)	790.8 $\pm$ 315.8	658.0 $\pm$ 272.3
Bodyweight normalized knee extension force (N/N)	1.13 $\pm$ 0.42	0.91 $\pm$ 0.31
Knee extension torque (Nm)	346.3 $\pm$ 141.4	290.3 $\pm$ 116.4
Bodyweight normalized knee extension torque (Nm/N)	0.49 $\pm$ 0.17	0.40 $\pm$ 0.13

Table 3

Pearson correlations (r) of strength and other variables with five-repetition sit-to-stand test (FRSTST) performance

Independent variable	FRSTST (14–85 yr) r (p)	FRSTST (50–85 yr) r (p)
Knee extension force	−0.534 (0.000)	−0.563 (0.000)
Bodyweight normalized knee extension force	−0.634 (0.000)	−0.568 (0.000)
Knee extension torque	−0.388 (0.000)	−0.476 (0.000)
Bodyweight normalized knee extension torque	−0.542 (0.000)	−0.490 (0.000)
Age	0.561 (0.000)	0.466 (0.000)
Gender	0.182 (0.014)	0.276 (0.012)
Body weight	0.093 (0.214)	−0.152 (0.169)
Stature	−0.139 (0.062)	−0.086 (0.438)

Table 4

Summary of regression analysis examining the effects of four knee extension strength measures and other variables on five-repetition sit to stand time (Age 14–85 years, $n = 181$)

Variables in final model	Standard- ized β	p	R/R ²
Knee extension force	−1.643	0.000	0.748/0.559
Knee extension force squared	1.055	0.000	
Age	0.304	0.000	
Bodyweight	0.243	0.000	
Stature	0.209	0.002	
Bodyweight normalized knee extension force	−1.786	0.000	0.751/0.564
Bodyweight normalized knee extension force squared	1.283	0.000	
Age	0.283	0.000	
Stature	0.128	0.017	
Knee extension torque	−1.527	0.000	0.683/0.466
Knee extension force squared	1.042	0.000	
Age	0.371	0.000	
Bodyweight	0.276	0.000	
Stature	0.188	0.014	
Bodyweight normalized knee extension torque	−1.516	0.000	0.686/0.471
Bodyweight normalized knee extension torque squared	1.101	0.000	
Age	0.352	0.000	
Stature	0.166	0.008	

Table 5

Summary of regression analysis examining the effects of four knee extension strength measures and other variables on five-repetition sit to stand time (Age = 50–85 years, $n = 83$)

Variables in final model	Standard- ized β	p	R/R ²
Knee extension force	–1.563	0.000	0.710/0.504
Knee extension force squared	0.953	0.002	
Stature	0.364	0.000	
Age	0.240	0.010	
Bodyweight normalized knee extension force	–1.278	0.000	0.682/0.466
Bodyweight normalized knee extension force squared	0.848	0.003	
Age	0.274	0.003	
Knee extension torque	–0.558	0.000	0.616/0.380
Stature	0.353	0.003	
Age	0.310	0.003	
Bodyweight normalized knee extension torque	–0.367	0.000	0.578/0.334
Age	0.329	0.001	