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Original Article

Effect of arm position and foot placement on the five times sit-to-stand test completion times of female adults older than 50 years of age

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Abstract. [Purpose] The five times-sit-to stand test (FTSTS) is a clinical test which is commonly used to assessed the functional muscle strength of the lower limbs of older adults. The aim of this study was to examine the effect of different arm positions and foot placements on the FTSTS completion times of older female adults. [Subjects and Methods] Twenty-nine healthy female subjects, aged 63.1±5.3 years participated in this cross-sectional study. The times required to complete the FTSTS with 3 different arm positions (hands on thighs, arms crossed over chest, and an augmented arm position with the arms extended forward) and 2 foot placements (neutral and posterior) were recorded. The interaction effect and main effect of arm positions and foot placements were examined using a 3 (arm position) × 2 (foot placement) two-way repeated measures analysis of variance (ANOVA). [Results] There was no interaction effect among the 3 arm positions in the 2 foot placements. A significant main effect was identified for foot placement, but not arm position. Posterior foot placement led to a shorter FTSTS time compared to that of normal foot placement. [Conclusion] With the same arm position, FTSTS completion times with posterior foot placement tended to be shorter. Therefore, the standard foot placement should be used for FTSTS administration.
Key words: Outcomes, Standing, Rehabilitation

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INTRODUCTION

The sit-to-stand test was first administered by Csuka and McCarty as a way of measuring the lower-extremity strength of non-disabled subjects[1)]. Over the years, variations of the sit-to-stand test have emerged, such as the 10 times sit-to-stand test[1)] and the 10- and 30-seconds sit-to-stand tests[2, 3)]. The five times sit-to-stand (FTSTS) test is the test which is most often used in clinical and research settings[4, 5)]. In the FTSTS, the subject is instructed to stand up and sit down 5 times as quickly as possible. The time required to complete the whole task is recorded with a stopwatch. In addition, as a useful indicator of the functional muscle strength of the lower limbs[1, 2)], the FTSTS has also been used to assess the balance performance of subjects with chronic stroke[5)], to assess disability in older adults[4, 6)], and to identify the fall risks of the elderly[7)] and people with Parkinsonism[8)].

The FTSTS has been found to have an excellent test-retest reliability for non-disabled older adults, with an intraclass correlation coefficient (ICC) of 0.89 to 1.00[9, 10)]. The FTSTS also demonstrates excellent intra-rater, inter-rater and test-retest reliability for subjects with chronic stroke (ICC = 0.97 to 0.99)[11)].

The FTSTS is an appropriate indicator of lower limb muscle strength and balance performance. FTSTS completion times are significantly associated with lower limb muscle strength ($r = -0.37$ to 0.43, $p \le 0.01$)[9)] and Berg Balance Scale scores ($r = -0.837$, $p \le 0.001$)[5)]. FTSTS completion times have been found to differentiate individuals with and without balance disorders[12)] and fall risks[13)], and to discriminate non-disabled older adults from stroke survivors[11)].

Although the FTSTS is an important functional assessment tool, the testing procedure is not standardized, and this may affect the results[14)]. Subjects' arm position and movement may affect the FTSTS completion times, as they affect movement of the body's center of mass (CoM) when rising and sitting. Indeed, restricting arm movement leads to a different strategy in rising from sitting[15)]. Although subjects are usually constrained from using their upper limbs during testing[5, 9, 11, 12, 16, 17)], reported arm positions when performing FTSTS have varied from study to study. Some studies have asked subjects to place their hands on their laps[11)], while others have instructed them to fold their arms across the chest[5, 9, 12, 16, 17)].

Foot placement is another factor known to affect FTSTS results, as it affects how far a subject's body mass moves

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forward in rising[18]. However, foot placement is not normally standardized during testing[12, 14, 15, 19, 20]. Only two studies have mentioned that subjects should put their feet in a comfortable position[12, 20].

Our hypothesis was that foot placement and arm position of subjects during FTSTS would lead to significant differences in the FTSTS completion times. This study was designed to test whether arm position and foot placement affect FTSTS completion times. Three arm positions and 2 foot placements were investigated using a sample of non-disabled older women. The choices of arm positions (hands on thighs, arms crossed over chest, and an augmented the arm position with arms extended forward) and foot placements (neutral and posterior) in this study were based on those used in studies which investigated the effects of arms position or movement[21], and foot position on the performance of sit-to-stand by non-disabled adults[18, 22] or patients with stroke[23].

SUBJECTS AND METHODS

Because no previous study has investigated the effects of arm position and foot placement on FTSTS completion times, we estimated our sample size based on the results of Khemlani's sit-to-stand biomechanics study[19] using G*Power software (version 3.1.6). Khemlani's results suggest there is a large effect size in the comparison of total movement durations with anterior and posterior foot placement. Assuming a type 1 error of 5%, a power of 80% and an effect size of 0.45, the analysis predicted that 26 subjects would be required to detect a statistically significant difference.

Our study was a cross-sectional clinical trial. Twenty-nine non-disabled women ≥ 50 years of age were recruited at community centers in Hong Kong where leisure activities were regularly arranged by the center. Subjects were included if they could complete the FTSTS protocol independently. Subjects were excluded if they had any medical, neurological or musculoskeletal condition that would have adversely affected study participation. Subjects with cognitive impairments (an abbreviated mental test score below 7) were also excluded[24].

The Ethics Committee of the Hong Kong Polytechnic University approved this study, which was conducted in accordance with the Helsinki Declaration of 1975 as revised in 1983. Written informed consent was obtained from all of the subjects prior to the study.

The test was conducted in a laboratory at the Hong Kong Polytechnic University. Demographic data including age and gender were recorded,while body weight and height were measured by an experienced research assistant on the assessment date. An armless chair with an adjustable seat height and seat depth of 28.5 cm was used in this study. Each subject was required to perform the FTSTS under 6 conditions which were performed in a random sequence determined by drawing lots:

Condition 1: Neutral foot placement, hands on thighs
Condition 2: Neutral foot placement, arms crossed on chest
Condition 3: Neutral foot placement, augmented arms position
Condition 4: Posterior foot placement, hands on thighs
Condition 5: Posterior foot placement, arms crossed on chest
Condition 6: Posterior foot placement, augmented arms position

The test was performed in a laboratory with a carpet floor. Subjects were required to wear their usual comfortable footwear for the test. Each subject was instructed to sit on the chair with her back touching the backrest. The seat height was adjusted to the subject's lower leg length by measuring the distance from the fibular head to the ground using a tape measure. the subjects' knees were flexed at 90° in the start position. Neutral foot placement was defined as the foot positioned vertically below the center of the knee joints at 0 degrees of dorsiflexion. Posterior foot placement was defined as the foot positioned 10 cm behind a line drawn vertically from the center of the knee joint to the ground. The augmented arm position was defined as both hands held together with the shoulders flexed at 90° and the elbows fully extended.

Standardized instructions were given as follows: "On the count of 3, please stand up and sit down 5 times as quickly as possible." The timing started when the subject's back first left the backrest and stopped when it touched the backrest after the 5th repetition. The times were taken with a digital stopwatch by a single investigator. A practice trial was given at the beginning of the test. Each subject performed 2 trials for each of the six conditions and the times were averaged for data analysis. Two minutes of rest were taken between each trial to avoid fatigue effects.

Descriptive statistics was used to describe the demographic characteristics of the subjects. Categorical data is expressed as frequency, while the ordinal data, including FTSTS completion times, is expressed as the mean and standard deviation.

The interaction effect and main effect of foot placement and arm position were examined using 2 (foot position) × 3 (arm position) two-way repeated measures analysis of variance (ANOVA). The outcome variable was the FTSTS completion times. If there was no significant interaction effect between arm position and foot placement, the main effect of arm position and foot placement was examined separately. Post hoc analysis using pair-wise comparison was used to compare the FTSTS completion times between the 3 arm positions and 2 foot placements. A significance level of 0.05 (two-tailed) was used. Bonferroni's adjustment was applied when appropriate in order to avoid inflation of type I errors. All statistical analyses were performed with the Statistical Package for the Social Sciences software (SPSS) version 17.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Twenty-nine female adults older than 50 years, with a mean age of 63.1±5.3 years, participated in this study. All of them were community ambulators, and none of them had trouble in completing the test. Table 1 summarizes the subjects' demographic characteristics. Their mean FTSTS completion times across the 6 conditions are shown in Table 2.

The result of two-way repeated measures ANOVA show

Table 1. Characteristics of the healthy subjects (n = 29)

Demographic characteristics	Mean (SD), range
Age, years	63.1 (5.3), 56 to 80
Weight, kg	57.3 (9.6), 37.5 to 79
Height, cm	154.3 (5.9), 143 to 164
BMI, kg/m^2	24.1 (3.8), 17.5 to 32.5
AMT	9.5 (0.7), 8 to 10
	Number of faller (%)
Faller (fall within 6 months)	1 (3.4)

SD: standard deviation; BMI: body mass index

Table 2. Average FTSTS times of the different combinations of foot placement and arm position (n = 29)

Arm position	FTSTS times (seconds) (SD)	
	Neutral foot placement	Posterior foot placement
On thighs	12.4 (4.1)	11.8 (4.8)
Crossed on chest	13.1 (5.5)	12.5 (5.5)
Augmented	12.8 (5.0)	12.0 (4.6)

FTSTS: five times sit to stand test; SD: standard deviation.
Significant main effect of foot placement (p < 0.001)

that there was no interaction effect between foot placement and arm position [F (1.479, 41.400) = 0.302, p = 0.674]. There was a significant main effect of foot placement [F (1, 28) = 22.79, p < 0.001], but not arm position [F (1.662, 44.32) = 2.582, p = 0.096]. With the same arm position, posterior foot placement yielded significantly shorter FTSTS completion times than the normal foot placement. Posterior foot placement with the hands on the thighs yielded the shortest FTSTS completion times, 11.8±4.8 seconds, while neutral foot placement with the arms crossed on the chest resulted in the longest completion times 13.1±5.5 seconds.

DISCUSSION

This study is the first to investigate the combined effect of arm position and foot placement on FTSTS completion times. The results show that foot placement affects FTSTS completion times but that arm position does not. The subjects took less time with the posterior foot placement than with the normal foot placement, which is described as “neutral” in this study. In daily life, of course, many individuals may adopt an even more posterior placement in preparation for rising, with their feet not flat on the floor.

The mean FTSTS completion times across the 6 conditions ranged from 11.8 to 13.1 seconds. The averages for women in their 60s, with a mean age of 63.1±5.3 years were longer than those reported by Mong’s group for non-disabled older adults in their 50s (mean age of 56.0 ±3.7 years; FTSTS completion times of 10.8±1.7 seconds)[11)], and those reported by Novy’s group for non-disabled women in their 30s (mean age of 34.2±10.1 years, and FTSTS completion times of 7.6±1.1 seconds)[25)]. This was to be expected, as physical function[26)] and muscle strength decrease with age[27, 28)]. A previous study demonstrated that the maximal muscle fiber conduction velocity of the vastus medialis was negatively correlates with age (r=−0.52, p<0.01 for female subjects)[29)]. Besides, Miyoshi et al. compared the normalized maximum isometric strength of knee extension between different age groups and found there was a decreasing trend with advancing of age[28)]. Also, a kinetic study showed that older elderly (mean age 81.9) had less postural stability than elderly (mean age 69.3) during sit-to-stand as reflected by a significantly longer center of force trajectory length (151.5±25.8 mm vs. 124.2±14.6 mm)[30)]. Deterioration of neuromuscular control, the ability to generate force in the quadriceps, and postural control due to aging may affect the performance of sit-to-stand and thus, the FTSTS completion time.

In order to eliminate the effect of gender on FTSTS completion times, only non-disabled female subjects were recruited for this study. The results of a previous study[25)] demonstrated that gender differences exist in the performance of tests in which speed is the objective: e.g. the repeated sit-to-stand, 5-minute-walk, and 50-foot-walk tests. Novy’s group showed that the mean FTSTS completion times of non-disabled men (7.1±1.7 seconds) were faster than those of non-disabled women (7.6±1.1 seconds)[25)]. This difference can be explained by the known gender differences in muscle strength, height and body weight.

As expected, the FTSTS completion times of our subjects were faster than those typical of subjects with neurological disorders, including patients with chronic stroke (17.9±9.6 seconds)[5)] and patients with Parkinson’s disease (20.3±14.1 seconds)[31)]. Stroke-specific impairments such as decreased muscle strength and impaired ability to shift the center of mass account for the longer FTSTS completion times of patients with stroke[5)]. Rigidity, reductions in generated muscle force, postural instability and hypokinesia are common symptoms of Parkinson’s disease patients[31)], and all of these symptoms are expected to lengthen FTSTS completion times.

Surprisingly, there were no significant differences among the FTSTS completion times of the different arm positions with either foot placement in our study. Carr and colleagues demonstrated that a forward arm position helps to generate the forward momentum needed to shift the center of mass more effectively when a subject rises[15)]. They also found that restricting the arms during rising significantly prolonged the time required to produce the maximum support moment (defined as the percentage of the extension phase during which the support moment equaled or exceeded three times the body weight) compared to the arms free position[15)].

Different arm positions did not affect the FTSTS completion times in our study because our subjects did not need to generate any additional momentum with their arms during standing up. All of subjects were healthy, and the majority of them were still working. Their lower limb strength was well above the threshold of muscle strength required in a sit-to-stand movement. A non-linear relationship exists between muscle and functional performance in older adults[32, 33)]. Minimum muscle strength is required to complete a specific task. Once that minimum strength is attained, any improvement in muscle strength should elicit substantial improvements in functional performance until some threshold is reached, above which further improvements in muscle strength do not elicit further improvements in performance.

Consistent with the findings published by Khemlani's group[19], our results demonstrate that placing the subjects' feet further back facilitated faster FTSTS completion times under all 6 conditions. In a biomechanical study involving electromyography and a sample of 10 young and non-disabled subjects, they demonstrated that movement duration, hip flexion amplitude and peak angular velocity of the hip joint while rising were all significantly greater when the subjects' heels were placed on a line 10 cm behind the forward position (corresponding to the posterior position of our present study)[19]. Khemlani's group further showed that the overall amplitude of the peak support moment (the algebraic sum of the support moments at the hip, knee and ankle joints) was significantly greater when the feet were placed further back[19]. This explains why posterior foot placement facilitates standing up, resulting in faster FTSTS completion times.

Moreover, previous biomechanical studies have shown that foot placement during the sit-to-stand movement significantly affects the total energy expenditure[34]. Kawagoe et al. showed that the hip extension moment significantly decreased from 148.8 Nm to 32.7 Nm during the seat-off phase when subjects' feet were placed 10 cm posterior to the neutral position[34]. This could further explain why posterior foot placement facilitates faster FTSTS completion times.

This study had several limitations. The quality of performance in the sit-to-stand task was disregarded because speed is the main focus of the FTSTS. Moreover, although factors such as weight-bearing asymmetry and seat height are known to influence sit-to-stand performance, they were not measured in this study. The generalizability of the study's findings is limited to female adults ≥ 50 years of age who meet similar inclusion criteria. It is necessary to generalize the results to other populations via a larger scale investigation.

As all subjects were required to perform FTSTS under 6 different conditions, learning and fatigue effects might have affected their performance. However, learning or fatigue effects should have been minimized by the randomization of the testing sequences, and the 2-minute rest periods provided in this study. Only 3 arms positions (hands on thighs, arms crossed over chest, and the augmented arms position) and 2 foot placements (neutral and posterior) were used in this study. Whether significant difference in FTSTS completion times would be found if different arm positions and foot placements were chosen remains unknown.

The study design did not allow the determination of optimal foot placement or arm position for the assessment of FTSTS completion times, but the results do show the effect of the selected foot placements and arm positions on the FTSTS completion times.

This was the first study to investigate the relationship between arm position, foot placement and FTSTS completion times using a sample of women ≥ 50 years of age. Arm position demonstrated no significant relationship with FTSTS completion times. However, posterior foot placement led to shorter FTSTS completion times compared to neutral foot placement.

Although no optimal foot placement for performing the FTSTS test was identified in this study, our recommendation is that a standard foot placement be used for the same patient when repeating the FTSTS in different clinical settings during rehabilitation in order to produce reliable measurements of change in functional muscle strength. Subjects should be free to adopt their preferred arm position, as it is not likely to be a confounding variable. Although the subjects of this study were healthy female adults ≥ 50 years of age, the findings may have general implications for applying the FTSTS in cardiac, pulmonary and neurological rehabilitation. Further studies are required to validate the results with different patient populations.

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REFERENCES

1) Csuka M, McCarty DJ: Simple method for measurement of lower extremity muscle strength. Am J Med, 1985, 78: 77–81. [Medline] [CrossRef]
2) Bohannon RW: Sit-to-stand test for measuring performance of lower extremity muscles. Percept Mot Skills, 1995, 80: 163–166. [Medline] [CrossRef]
3) McCarthy EK, Horvat MA, Holtsberg PA, et al.: Repeated chair stands as a measure of lower limb strength in sexagenarian women. J Gerontol A Biol Sci Med Sci, 2004, 59: 1207–1212. [Medline] [CrossRef]
4) Guralnik JM, Ferrucci L, Simonsick EM, et al.: Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. N Engl J Med, 1995, 332: 556–561. [Medline] [CrossRef]
5) Ng S: Balance ability, not muscle strength and exercise endurance, determines the performance of hemiparetic subjects on the timed-sit-to-stand test. Am J Phys Med Rehabil, 2010, 89: 497–504. [Medline] [CrossRef]
6) Gill TM, Williams CS, Tinetti ME: Assessing risk for the onset of functional dependence among older adults: the role of physical performance. J Am Geriatr Soc, 1995, 43: 603–609. [Medline]
7) Buatois S, Perret-Guillaume C, Gueguen R, et al.: A simple clinical scale to stratify risk of recurrent falls in community-dwelling adults aged 65 years and older. Phys Ther, 2010, 90: 550–560. [Medline] [CrossRef]
8) Duncan RP, Leddy AL, Earhart GM: Five times sit-to-stand test performance in Parkinson's disease. Arch Phys Med Rehabil, 2011, 92: 1431–1436. [Medline] [CrossRef]
9) Lord SR, Murray SM, Chapman K, et al.: Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people. J Gerontol A Biol Sci Med Sci, 2002, 57: M539–M543. [Medline] [CrossRef]
10) Bohannon RW, Shore ME, Barreca SR, et al.: Five repetition sit-to-stand test performance by community-dwelling adults: A preliminary investigation of times, determinants and relationship with self reported physical performance. Isokinet Exerc Sci, 2007, 15: 77–81.
11) Mong Y, Teo TW, Ng SS: 5-repetition sit-to-stand test in subjects with chronic stroke: reliability and validity. Arch Phys Med Rehabil, 2010, 91: 407–413. [Medline] [CrossRef]
12) Whitney SL, Wrisley DM, Marchetti GF, et al.: Clinical measurement of sit-to-stand performance in people with balance disorders: validity of data for the Five-Times-Sit-to-Stand Test. Phys Ther, 2005, 85: 1034–1045. [Medline]
13) Buatois S, Miljkovic D, Manckoundia P, et al.: Five times sit to stand test is a predictor of recurrent falls in healthy community-living subjects aged 65 and older. J Am Geriatr Soc, 2008, 56: 1575–1577. [Medline] [CrossRef]
14) Janssen WG, Bussmann HB, Stam HJ: Determinants of the sit-to-stand movement: a review. Phys Ther, 2002, 82: 866–879. [Medline]
15) Carr JH: Balancing the centre of body mass during standing up. Physiother Theory Pract, 1992, 8: 159–164. [CrossRef]
16) Annweiler C, Schott AM, Abellan van Kan G, et al.: The Five-Times-Sit-to-Stand test, a marker of global cognitive functioning among community-

dwelling older women. J Nutr Health Aging, 2011, 15: 271–276. [Medline] [CrossRef]
17) Guralnik JM, Simonsick EM, Ferrucci L, et al.: A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol, 1994, 49: M85–M94. [Medline] [CrossRef]
18) Shepherd RB, Koh HP: Some biomechanical consequences of varying foot placement in sit-to-stand in young women. Scand J Rehabil Med, 1996, 28: 79–88. [Medline]
19) Khemlani MM, Carr JH, Crosbie WJ: Muscle synergies and joint linkages in sit-to-stand under two initial foot positions. Clin Biomech (Bristol, Avon), 1999, 14: 236–246. [Medline] [CrossRef]
20) Meretta BM, Whitney SL, Marchetti GF, et al.: The five times sit to stand test: responsiveness to change and concurrent validity in adults undergoing vestibular rehabilitation. J Vestib Res, 2006, 16: 233–243. [Medline]
21) Carr JH, Gentile AM: The effect of arm movement on the biomechanics of standing up. Hum Mov Sci, 1994, 13: 175–193. [CrossRef]
22) Vander Linden DW, Brunt D, McCulloch MU: Variant and invariant characteristics of the sit-to-stand task in healthy elderly adults. Arch Phys Med Rehabil, 1994, 75: 653–660. [Medline] [CrossRef]
23) Camargos AC, Rodrigues-de-Paula-Goulart F, Teixeira-Salmela LF: The effects of foot position on the performance of the sit-to-stand movement with chronic stroke subjects. Arch Phys Med Rehabil, 2009, 90: 314–319. [Medline] [CrossRef]
24) Chu LW, Pei CK, Ho MH, et al.: Validation of the abbreviated mental test (Hong Kong version) in the elderly medical patient. Hong Kong Med J, 1995, 1: 207–211.
25) Novy DM, Simmonds MJ, Olson SL, et al.: Physical performance: differences in men and women with and without low back pain. Arch Phys Med Rehabil, 1999, 80: 195–198. [Medline] [CrossRef]
26) Nakano MM, Otonari TS, Takara KS, et al.: Physical performance, balance, mobility, and muscle strength decline at different rates in elderly people. J Phys Ther Sci, 2014, 26: 583–586. [Medline] [CrossRef]
27) Evans WJ, Campbell WW: Sarcopenia and age-related changes in body composition and functional capacity. J Nutr, 1993, 123: 465–468. [Medline]
28) Miyoshi K, Kimura T, Yokokawa Y, et al.: Effect of ageing on quadriceps muscle strength and on the forward shift of center of preddure during sit-to-stand movement from a chair. J Phys Ther Sci, 2005, 17: 23–28. [CrossRef]
29) Mase K, Kamimura H, Imura S, et al.: Effect of age and gender on muscle function—Analysis by muscle fiber conduction velocity. J Phys Ther Sci, 2006, 18: 81–87. [CrossRef]
30) Kim MH, Yoo WG: Comparison of center of force trajectory during sit-to-stand movements performed by elderly and old-old elderly subjects. J Phys Ther Sci, 2014, 26: 1403–1404. [Medline] [CrossRef]
31) Inkster LM, Eng JJ, MacIntyre DL, et al.: Leg muscle strength is reduced in Parkinson’s disease and relates to the ability to rise from a chair. Mov Disord, 2003, 18: 157–162. [Medline] [CrossRef]
32) Buchner DM, Beresford SA, Larson EB, et al.: Effects of physical activity on health status in older adults. II. Intervention studies. Annu Rev Public Health, 1992, 13: 469–488. [Medline] [CrossRef]
33) Buchner DM, Larson EB, Wagner EH, et al.: Evidence for a non-linear relationship between leg strength and gait speed. Age Ageing, 1996, 25: 386–391. [Medline] [CrossRef]
34) Kawagoe S, Tajima N, Chosa E: Biomechanical analysis of effects of foot placement with varying chair height on the motion of standing up. J Orthop Sci, 2000, 5: 124–133. [Medline] [CrossRef]