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The Effect of Various Foot Placement and Arm Position on Five Times Sit to Stand Test Time in Healthy Young Adults

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Abstract: ***Sit-to-stand transfer is defined as the moving mass center of the body upward from sitting to standing position without losing the balance. The capability to move from sitting to standing is important for mobility. Aim: This study aimed to investigate the effects of different foot placement and arm placement strategies on the five times sit-to-stand test using healthy participants to test the influence of foot and arm position during sit-to-stand movement. This was a cross-sectional study. Healthy young adults (N = 30) of both genders aged between 18 to 25 years with healthy lifestyles were selected based on inclusion and exclusion criteria. Methods: In a structured setting, participants were instructed to stand and sit five times in a standard chair that was 43 cm high and 28 cm deep. They were to do this with their arms crossed on their chest, thigh, and augmented manner, and their feet in a posterior, anterior, and neutral position in a random order. The time it took to finish each task was noted. The statistical significance of the changes between the test conditions was assessed using a one-way repeated measure ANOVA. Findings: When compared to other different arm and foot placement strategies, posterior foot placement with augmented arm posture (arms forward) resulted in considerably reduced FTSTS times ($P \leq 0.001$). Conclusion: This study showed that foot placement and arm position could influence the completion time of FTSTS test. Standardizing the foot placement and arm position in the test procedure is essential if this test is to be used repeatedly on the same participant or individuals with neurological dysfunction.***

Keywords: Five times sit-to-stand test, FTSTS, Lower limb mobility, Functional ability, Chair rising, Sit to stand, Foot placement, Arm position.

1. Introduction

The sit-to-stand (STS) movement is the most common functional activity, and it is important for the independent living of an individual [1]. The distribution of joint moments between the hip, knee, ankle, and limbs can be manipulated by different movement strategies and by varied techniques such as alternating the foot placements for sit-to-stand movement. Six muscles of the lower limb are commonly worked during STS movement Biceps femoris, Rectus femoris, Vastus lateralis, Medial soleus, Lateral gastrocnemius, Tibialis anterior. These muscles recruitment timing and different muscle patterns were used to complete sit-to-stand movement [2].

Standing from a sitting position can be done with four different phases; a sufficient level of hip flexion and ankle dorsiflexion during the flexion momentum phase when the body weight is transmitted from the buttock to the feet followed by knee extension during the transfer phase where the body weight is moved off the chair and shift to the feet. Thirdly in the extension phase maximal hip and knee extension is to be attained followed by ankle plantar flexion during the stabilization phase after the STS activity has been completed and postural stability to be maintained [3]. During STS transfer, the mass center of the body (MCB) moves forward mainly using the rotation of the upper body whereas the main contribution of the upper transition of MCB is from the leg extension position [4].

STS movement requires a peak joint moment more than other movements such as stair climbing and walking and also yields hip contact pressure between the acetabulum of the pelvis and femoral head during sit-to-stand more than other daily activities. The sum of peak hip and knee joint movement is an appropriate index to evaluate muscle strength [5]. Elements required for rising from a sitting position are forward flexion of the trunk followed by upward movement of the trunk and extension of the knee followed by backward movement of the trunk. Then, the elements required for the descending phase are forward lean of the trunk, downward movement towards the chair followed by knee flexion and backward movement of the pelvis [6].

Foot placement

Normal foot position is the perpendicular distance between the fibular head and floor where the participant is sitting on the chair with the knee in 90 flexion and ankle in neutral position. Anterior foot placement is defined as keeping any one of the legs 10 cm forward from the neutral position whereas the posterior foot placement is having the bilateral heels at 10 cm backward from the neutral position. Initial foot placement would affect the distance traveled by the body's center of gravity and leverage in raising from the seat.

During STS movement, COG (center of gravity) and POA (point of application) of ground reaction force plays an important role where the pathway of COG and POA changes in the anterior and posterior distance during the movement. Here, POA is defined as the point where a compound vector of ground reaction force acts whereas COG is the point at which the weight of the body or system. In anterior foot placement, forward displacement of COG occurs where anterior and posterior distance decreases but it takes longer time to lift off. In posterior foot placement, anterior and posterior distance decreases within a shorter period to lift off. Four initial foot positions to stand from the sitting positions are placement of foot in a neutral position where the bilateral foot is in 90-degree flexion, posterior foot placement where the bilateral foot is in 100-degree flexion, right staggered or left staggered where the asymmetrical knee is in 100-degree flexion [7].

Foot placement during STS movement, COG (center of gravity), and POA (Point of application) of ground reaction force play an important role. The pathway of COG and POA as well as changes in the anterior and posterior distances between COG and POA before and after doing the movement. Normal foot position is the perpendicular distance between fibular head and floor, where the subject is sat on a chair with knees in 90-degree ankles in a neutral position. The anterior foot is having one-foot 10cm forward from a neutral position. Posterior foot placement is defined as having both heels positioned 10cm backward from a neutral position.

Arm position
The segmental interaction between the upper limb, trunk, and lower limb in actions that involve transporting the total body over a fixed foot. so, the varying arm movement interlinked with the lower segment which helps to lift off. It shows a temporal linkage between the onsets of shoulder flexion and lower limb extension and the effect of the extent of arm movement on force production in the lower limb suggests that the arm plays a part in potentially the horizontal and vertical propulsion of the total body. Here, particularly augmented arm position might help to shift the COG forward which is associated with faster sit to stand time [8].

The Five times sit-to-stand test (FTSTS) measures lower limb muscle strength and may be useful in quantifying functional change of transitional movement. [9]. It was designed by Csuka and McCarty in 1985. It is used to assess functional lower extremity strength, transitional movement and balance [10]. Muscle strength is an important contributor to mobility performance. It is used to identify fall risk in older adults with dementia, stroke, vestibular and many neurological disorders [11] - [14]. The test is performed by standing up from sitting 5 times as quickly as possible without using the hands for support. The total duration is recorded in seconds. It is done on an unsupported chair with a seat height of 43cm high and 28cm depth. The test has been shown to have excellent interrater reliability and test-retest reliability on healthy subjects of different ages [15].

The normative values for the Five Times Sit-to-Stand Test (FTSTS) vary across different populations, particularly influenced by age and health status have been explored in various studies, providing a comprehensive understanding of performance benchmarks. The lower the time to complete the test the better the outcome of the test. The age matched norms score varies from 6.5 seconds ± 1.2 seconds for 14–19 years age groups to 11.4 seconds for 60-69 years age groups and 12.6 seconds for 70-79 of age group. The Minimal Detectable Change (MDC) time for the test is within 3.6 to 4.2 seconds and Minimal clinically important difference (MCID) is 2.3 seconds [16]- [17].

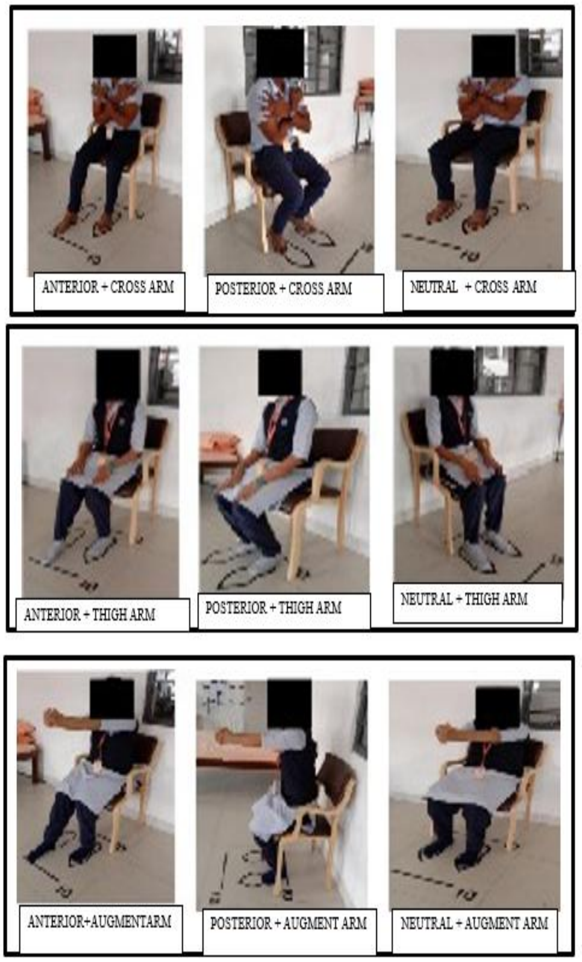
2. Research Methodology

The Ethics Committee of KMCH granted approval for the study protocol (EC/AP/1202/10/2024). This investigation involved a pretesting of the Five Times Sit to Stand Test (FTSTS), which serves as a pertinent outcome measure, as well as an exploration of the sit to stand exercise, which is prescribed as an integral component of rehabilitation programs for individuals who have experienced a stroke. The objectives and methodologies of the study were articulated with clarity to all participants, who subsequently provided their written informed consent.

Population and sample
The study encompassed a cohort of thirty young collegiate individuals who were selected utilizing a purposive sampling methodology. The participant group comprised both male (n=15) and female (n=15) individuals aged between 18 and 25 years, all of whom maintained healthy lifestyles; participants presenting with severe wheezing disorders, lower limb muscle spasms, recent fractures, disc-related complications, injuries to muscles and ligaments of the lower and upper limbs, as well as joint pain in the hip and knee regions were excluded from the study.

Procedure
Five times sit-to-stand test was used as a tool, and an armless height adjustable chair was used to ensure the participant's hip in 90-degree flexion on doing FTSTS and measured using a stopwatch. Participants were instructed to stand and sit five times as quickly as possible, on a count of 3, timing started when the participants back left the backrest and ended when the back touched the backrest after 5 times. Seat height was adjusted by calculating the lower leg length which is the perpendicular distance between the fibular head and floor when the participant is seated on a chair with 90-degree knee flexion. Two minutes of rest was provided between each trial to avoid muscle fatigue and the order of each placement was randomly allocated.

There were nine experimental test positions as depicted in **Picture 1**, wherein participants performed the Five Times Sit to Stand Test (FTSTS) with varied arm and foot placements. First the participants performed FTSTS with the foot posterior behind knee level with the arms on the thigh then performed second trial by crossing arms over the chest then the third trial by raising arms forward in augmented position. The FTSTS is executed a fourth time by positioning foot anterior to knee level and arms on the thigh, followed by a fifth execution with crossed arms and a sixth with arms raised forward in augmented position. For the seventh to ninth trial of the FTSTS, the foot is positioned neutrally while arms are placed in three different configurations.



Picture 1: Nine repeated Five times sit to stand test positions by varying foot and arm placement

3. Result

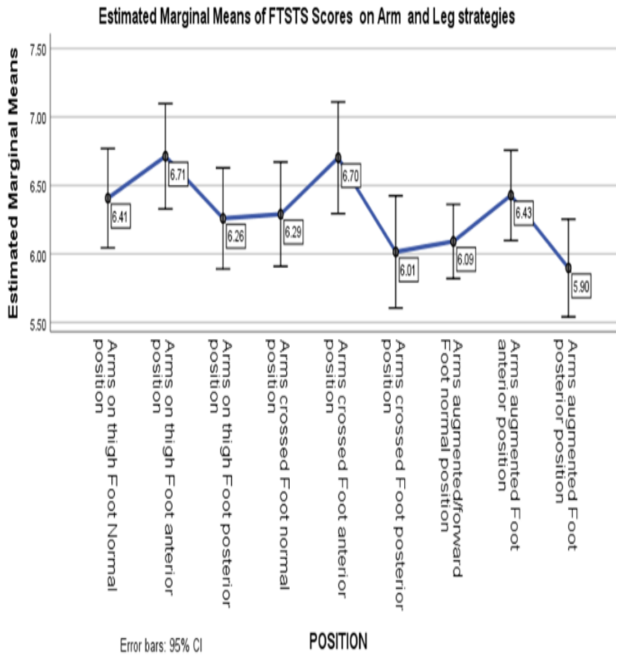
Descriptive statistics (mean and standard deviation) were calculated for timed scores of all test strategies. are presented in Table [2]. The normality assumption was verified using Shapiro-Wilk tests, which were not significant for any of the arm and foot position distribution scores. One-way repeated measure ANOVA was used to determine the statistical significance of differences between the test conditions. An alpha level of 0.05 was chosen for significance. All data were examined for violation of sphericity, determined by a significant value for Mauchly's test of sphericity. The Greenhouse-Geisser correction was used to determine significance when sphericity was violated. Post Hoc multiple comparison test with Bonferroni adjustment is used to evaluate the difference of completion times between nine strategies on the FTSTS test. All the analysis were made using Excel and IBM SPSS Statistics (version 26).

Table 1: General characteristics of the study participants (N=30)

Variables	Mean + SD
Age (years)	20 ± 1.52
Gender (male/female)	15/15
Height (cm)	163 ±11.52
Body weight (kg)	59 ±14.81
Body mass index (kg/m)	22 ±4.9

Abbreviation - SD: Standard Deviation

Among these various positions, posterior foot placement led to a significantly shorter time of 5.89 ± 0.95 seconds to complete five times sit to stand test in all three arm positions as shown in Graph 1. In addition, an augmented forward arm position leads to further shorter time than other arm positions. In addition, an augmented arm position leads to further shorter time than other arm positions, time was measured in seconds.



Graph 1: Error Bars for the nine test positions of FTSTS for the study participants

A repeated-measures ANOVA was performed to evaluate the effect of effect of various arm and foot positions or strategies on time taken to complete Five Times Sit to stand scores. Mauchly's test indicated that the assumption of sphericity had been violated, χ^2 ([35]) = [67.02], p = [.001], and therefore degrees of freedom were corrected using [Greenhouse-Geisser/Huynh-Feldt] estimates of sphericity (ε = [0.65]). There was significant main effect of various arm and foot strategies on time taken to complete Five Times Sit to stand scores, F (5.13, 148.83) = [12.08], [p = <*.001*], partial η^2 = [.29]. So, the null hypothesis that there is no significant difference between the test conditions will be rejected and concluded that the scores of nine test position means are not equal. There is a significant difference between different arm and leg positions.

Post-hoc pairwise comparisons with Bonferroni adjustment for multiple comparisons indicated that there was significant difference between the FTSTS score of selected positions as presented in Table [3]. The Arms augmented & Foot posteriorly placed led to significantly shorter FTSTS times than the augmented arm position.

Table 2: Time (in seconds) taken to complete the nine strategies on FTSTS

Various Arm and Foot FTSTS Strategies	Mean (SD) in seconds

1. Arms on Thigh & Foot normally placed	6.41±0.97
2. Arms on Thigh & Foot anteriorly placed	6.71± 0.03
3. Arms on Thigh &Foot posteriorly placed	6.26± 0.99
4. Arms Crossed & Foot normally placed	6.28 ± 1.02
5. Arms Crossed & Foot anteriorly placed	6.70 ± 1.09
6. Arms Crossed & Foot posteriorly placed	6.01 ± 1.09
7. Arms augmented & Foot normally placed	6.09 ± 0.72
8. Arms augmented & Foot anteriorly placed	6.42 ± 0.88
9. Arms augmented & Foot posteriorly placed	5.89± 0.95
Significant main effect of various foot and arm placements on FTSTS scores ($P < 0.001$).	

Abbreviation: - SD - Standard Deviation
FTSTS: Five Times Sit to Stand Test

Table 3: Significant Pair wise comparisons for test positions on FTSTS Time (in second)

Test position		Mean Difference	Std. Error	Sig.	95% CI	
1	9	.510*	.106	.001	.136	.883
2	3	.453*	.086	.000	.149	.757
	6	.698*	.103	.000	.333	1.063
	7	.622*	.115	.000	.214	1.030
	9	.816*	.108	.000	.435	1.196
5	6	.687*	.090	.000	.368	1.007
	7	.611*	.113	.000	.213	1.010
	9	.805*	.104	.000	.437	1.173
	7	.337*	.086	.019	.031	.642
	8	.530*	.093	.000	.200	.861

1-Arms on Thigh & Foot normally placed,**2**-Arms on Thigh & Foot anteriorly placed,**3**-Arms on Thigh &Foot posteriorly placed, **6**- Arms Crossed & Foot posteriorly placed,**7**- Arms augmented & Foot normally placed,**8**- Arms augmented & Foot anteriorly placed,**9**- Arms augmented & Foot posteriorly placed ** Indicates significance at P< 0.05*

4. Discussion

Sit to stand is a complex weight-bearing multiple-joint movement involved in various activities of daily living. It involves forceful muscle contractions of the ankle's plantar flexors, knee extensors, and hip extensors of which efforts are not evenly distributed with substantially higher knee extensor muscular effort needed.

The purpose of this investigation is to identify optimal positioning and effective strategies for transitioning from a seated to a standing position and vice versa, which can be assessed utilizing the Five Times Sit to Stand (FTSTS) test as a methodological instrument; furthermore, this study aims to establish the most straightforward and practical configurations for foot and arm positioning during sit-to-stand movements among young adult individuals. This research contributes to the comprehension of the kinematics associated with the execution of sit-to-stand movements, as well as elucidating the challenges that arise during sit-to-stand transfers due to improper positioning of the feet and arms, specifically within a cohort of healthy young adults.

Bryanton et al., stated the person who requires higher quadriceps effort had the shortest sit-to-stand task time. They concluded quadriceps effort requirement is the best indicator of one's standing capacity [18]. Glenn et.al stated that sit-to-stand depends on muscle power and velocity. The sit-to-stand velocity was also utilized as a functional independence measure. They found that the higher contraction velocity is a greater predictor of faster mobility compared to traditional measures [19]. A study by M.M. Khemlani et al. found posterior foot placement resulted in a smaller hip flexion angle in the before-extending phase of STS movement. The smaller hip flexion angle implies a shorter distance that the trunk and upper body segment are oriented to move forward to initiate the action of rising from the chair [20].

S. Kawagoe et al., concluded that reduced muscular effort required during rising from the seat when feet are placed posteriorly reduces tibialis anterior activation compared with normal position. This study shows that posterior foot placement could increase the speed of STS movement. Arm position is the body's segmental interaction between the varying arm movement is interlinked with the lower part of the body which helps to lift off [21]. Yoshioka et al, made a biomechanical analysis of the relation between movement time and joint moment development during a sit-to-stand task where they found during sit-to-stand fast and speed movements (less than 2.5 seconds), as the movement speed increased, the joint moments increased exponentially [22].

The current findings demonstrated markedly reduced FTSTS durations when the arm was positioned in an augmented (forward) manner compared to the conventional position of hands resting on the thighs. The diminished muscular exertion necessitated for rising from a seated position, when the feet are situated posteriorly, may elucidate the observed reduction in FTSTS durations associated with posterior foot placement. It has been established that there is a decrease in tibialis anterior muscle activation during the act of standing when posterior foot placement is contrasted with standard foot placement. Given that the activation of the tibialis anterior muscle facilitates an anterior rotational force of the shank about the ankle to advance the center of gravity forward Then, posterior foot placement in combination with the Crossed arm being the second fastest position to complete FTSTS. The average FTSTS times for the 9 conditions ranged from 5.90 to 6.71 seconds. Posterior foot placement shows a significant difference among all three-arm positions and the augmented position also shows a significant time difference in completing FTSTS as quickly as possible. The modification of arm and foot positioning that lessens the exertion required by individuals may enhance confidence in executing sit-to-stand movements and minimize fatigue, thereby promoting a more active lifestyle for persons with disabilities.

5. Conclusion

Posterior foot placement and augmented arm positioning during the five-times sit-to-stand test are executed in a more efficient time frame by healthy young adults aged 18 to 25 years. This investigation is not without its limitations. The demographic examined was confined to healthy young adults; consequently, the applicability of these findings to other age cohorts or populations remains questionable. Furthermore, the research solely focused on various configurations of foot placements and arm positions, neglecting the influence of chair design; thus, further biomechanical investigations are required. Additionally, the incorporation of video-based quantification could enhance the analysis, and considerations related to stroke patients could also be included.

Abbreviations:
FTSTS-Five times sit-to-stand tests, STS-Sit to stand, COG-Center of gravity, POA-Point of application,

Conflict of Interests:
The authors affirm the absence of any conflicts of interest related to this publication.

Acknowledgement:
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