J. Phys. Ther. Sci. 28: 2717–2721, 2016

The Journal of Physical Therapy Science

Original Article

Changes in movements of neck, trunk, and hip according to height and foot position during sit-to-stand

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Abstract. [Purpose] The purpose of this study is to analyze changes in movements of the neck, trunk and hip according to foot position while performing sit-to-stand (STS) exercises from a height-fixed chair. [Subjects and Methods] The study subjects consisted of 22 university students (12 males and 10 females). STS was conducted using a height-fixed chair at three positions: symmetric foot position, right foot position, and left foot position. Through three-dimensional motion analyzer, the movements of the neck, trunk, and hip were analyzed. [Results] While performing STS, the height was more influential on changed in angle of the neck, trunk, and hip. Moreover, when the height of the chair and the height of the subject were not matched correctly, more effective STS could be achieved when both of feet were laid symmetrically rather than at the other two positions. [Conclusion] It is necessary to employ an appropriate chair height that is matched with the height of the patients when therapy using STS is performed.

Key words: Foot position, Height, Sit-to-stand

(This article was submitted Apr. 6, 2016, and was accepted Jun. 9, 2016)

INTRODUCTION

Standing from a seated position is among the most commonly executed functional activities[1)]. In addition, the sit-to-stand (STS) movement has been widely used in physiotherapy practice for patients with strokes such as weight bearing on the affected leg, and dynamic balance. The STS movement is a motion that must be done to stand from a seated position, which requires capabilities of stably moving the center of gravity within the narrowing support plane as well as sufficient joint rotational force[2)]. The STS movement is defined as a movement from stable sitting posture to an unstably standing posture, in which coordination contractility between the lower extremity and the trunk is important[3)]. Here, the lower extremity pushes the body upward while maintaining front and rear stability of the knee and ankle joints, which moves the center of gravity forward and upward[4)]. During the STS movement, energy consumption or balance changes according to foot position at the initial posture or changes in posture[5)]. Most studies on STS, which have been employed not only in ordinary daily living but also physiotherapy practices, have been concentrated on joint torque and muscle activity according to chair height[6, 7)] or foot position[8)].

However, most chairs in public places such as concert halls, on buses, on trains, or at schools are height-fixed so there is little choice when it comes to adjusting the height of chairs during daily living. Thus, it is necessary to study a method of STS movement from height-fixed chairs for unspecified individuals. Accordingly, this study aims to analyze changes in the movements of the neck, trunk, and hip while performing STS on height-fixed chairs from symmetric and asymmetric foot

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Table 1. Changes in the angle of the neck according to foot position (unit: °)

		Symetric foot position[a]	Right foot position[b]	Left foot position[c]
Neck	Flexion-extension	36.50 ± 9.37	42.19 ± 8.12	44.31 ± 16.44
Neck	Lateral bending	6.77 ± 2.42	7.68 ± 2.08	7.36 ± 2.01
Neck	Rotation	6.77 ± 2.43	7.68 ± 2.08	7.36 ± 2.01

[a]SP, [b]RP, [c]LP

positions. Through the study result, we propose effective methods of STS for the elderly and patients with knee arthritis and who have suffered stroke and have difficulties in performing STS.

SUBJECTS AND METHODS

Study subjects used in this study were 22 university students (12 male and 10 female students) attending Kangwon National University in Kangwon-do, South Korea. This study was approved by the Kangwon National University Institutional Review Board (KWNUIRB-2015–06-003). The mean age and height of the subjects were 23.07 ± 1.64 years and 167.5 ± 6.54 cm. The mean weight and foot length of the subjects were 60.5 ± 8.62 kg and 250.35 ± 14.37 cm. All of the subjects were right-foot dominant. The identification of the dominant foot was first verified by the subjects' statements and then we had the subjects kick a football to identify which foot could kick the football farther to match the subjects' statements. The selection criteria required that the study subjects did not have a history of neuromuscular disease, musculoskeletal deformities, injuries in the lower extremity, or pathological symptoms in the hips or spine. This study was reviewed and approved by the Kangwon National University Institutional Review Board and all subjects signed an informed consent form.

For testing, the subjects were barefoot, dressed in shorts, and seated on a bench with their thighs unsupported. The height of the chair was set to 43.8 cm, which is the same as the height of seats in most subway in South Korea. The STS movement was repeated according to the subject's preferred speed[9)]. The experiment was conducted while the male subjects wore tight shorts and did not wear a top and the female subjects wore sport bras. The surface was even, and shoes and socks were taken off during the measurement. Prior to the experiment, the subjects practiced the STS movement five times to be familiar with the motion. The data were collected on an average value of STS movement five times. The subjects performed the STS five times for each of the three positions, totaling 15 times in all[10)].

Three foot positions were symmetrical foot positions (hereafter referred to as SP), right foot position (hereafter referred to as RP), and left foot position (hereafter referred to as LP). In SP, both of the feet were positioned 10 cm behind the knees; in RP, the right foot was positioned 5 cm ahead of the left foot; and in LP, the left foot was positioned 5 cm ahead of the right foot on the basis of the SP position. In order to prevent repeatability of the previous motion as well as fatigue, 30 min of rest was given in-between the experiments. A single researcher performed all the measurements to increase test-retest reliability and inter-rater reliability.

A motion analyzer (Motion analysis, Seoul, Korea) was used to analyze STS according to the foot positions. Two hawk cameras at a distance of 2.5 m and four hawk cameras at a distance of 3 m away from the subjects were fixed so that 13 markers attached to the subject were set within the cameras. The markers recognized by the camera were attached to locations three-dimensionally thereby measuring the angle of the neck, spine, and hip in the X, Y, and Z axes. In order to analyze the movements of the upper body according to the foot position, motions measured via the cameras were stored in Cortex, which is a software program in the motion analyzer. Each track stored was converted into a HTR file and measured via HTRanalysis2007 (Motion capture analysis Korea) software in terms of the X, Y, and Z axes. The X axis refers to a movement from the frontal axis to the sagittal plane (flexion-extension); the Y axis refers to a movement from the sagittal axis to the frontal plane (lateral bending); and the Z axis refers to a movement from the vertical axis to the horizontal plane (rotation). The data was an average value. It was analyzed by SPSS 20 version. Since changes in posture according to foot position and height had a correlation, which was analyzed using one-way ANOVA, the least significant difference (LSD) was used for post-hoc test. The statistical significance was set to $p<0.05$.

RESULTS

Changes in the angle of the neck during STS were analyzed. No statistical differences in flexion-extension, lateral bending, or rotation of the neck were found among the three groups ($p>0.05$). Therefore, angle changes according to the foot position were not found (Table 1).

Changes in the angle of the trunk during STS were analyzed. No statistical differences in flexion and extension of trunk were found ($p>0.05$). However, statistical differences in lateral bending ($p<0.01$) and rotation ($p<0.05$) were shown among the three groups. The least angle difference was found in SP, followed by RP and LP in an increasing order. Thus, the least change in the angle of trunk was found in SP whereas LP had the largest angle change of the trunk during STS movements (Table 2).

Table 2. Changes in the angle of the trunk and hip to foot position (unit: °)

		Symetric foot position[a]	Right foot position[b]	Left foot position[c]	LSD
Trunk	Flexion-extension	39.27 ± 10.86	42.50 ± 16.14	43.00 ± 18.49	-
	Lateral bending	6.68 ± 2.75	8.91 ± 3.64	11.73 ± 5.19	ab>bc***
	Rotation	9.09 ± 4.78	13.32 ± 8.79	15.00 ± 9.42	ab>bc*
Hip	Flexion-extension	38.41 ± 5.16	43.55 ± 8.40	42.46 ± 6.30	ac>bc
	Lateral bending	6.27 ± 2.05	12.27 ± 10.53	10.82 ± 10.72	-
	Rotation	6.32 ± 1.32	10.55 ± 5.23	9.81 ± 6.09	ac>bc

[a]SP, [b]RP, [c]LP, *p<0.05, **p<0.01, ***p<0.001

Table 3. Changes in the angle of the body according to height (unit: °)

Height (N) (cm)		Flexion extension	Lateral bending	Rotation
			Mean ± SD	
Neck***	158 (2)	35.00 ± 6.33	7.17 ± 1.94	7.17 ± 1.94
	160 (2)	55.33 ± 25.32	4.00 ± 0.89	4.00 ± 0.89
	162 (2)	48.17 ± 3.31	10.33 ± 2.58	10.33 ± 2.58
	164 (2)	41.50 ± 4.68	7.33 ± 1.86	7.33 ± 1.86
	166 (2)	46.67 ± 4.50	7.33 ± 1.86	7.33 ± 1.86
	170 (3)	31.56 ± 11.20	6.11 ± 1.62	6.11 ± 1.62
	173 (3)	35.00 ± 7.94	7.67 ± 1.80	7.67 ± 1.80
	175 (2)	45.67 ± 1.86	8.33 ± 1.37	8.33 ± 1.37
	178 (2)	45.83 ± 11.30	7.17 ± 0.75	7.17 ± 0.75
	181 (2)	33.00 ± 3.23	7.67 ± 1.86	7.67 ± 1.86
Trunk***	158 (2)	24.33 ± 1.21	6.17 ± 2.64	18.50 ± 6.16
	160 (2)	35.67 ± 3.14	8.00 ± 1.79	13.33 ± 1.03
	162 (2)	30.83 ± 2.23	6.17 ± 2.56	12.83 ± 7.23
	164 (2)	32.83 ± 1.72	9.50 ± 4.18	9.83 ± 4.96
	166 (2)	37.67 ± 4.93	11.33 ± 4.23	16.33 ± 10.44
	170 (3)	37.67 ± 10.70	7.89 ± 3.52	7.56 ± 1.88
	173 (3)	40.00 ± 0.87	8.67 ± 4.77	7.33 ± 1.32
	175 (2)	60.00 ± 3.10	6.67 ± 1.37	9.67 ± 2.73
	178 (2)	63.00 ± 29.99	12.50 ± 7.04	22.33 ± 17.50
	181 (2)	56.67 ± 3.72	15.00 ± 1.79	12.00 ± 6.26
Hip***	158 (2)	33.50 ± 6.63	6.33 ± 2.58	7.00 ± 2.61
	160 (2)	38.67 ± 2.88	6.67 ± 1.03	6.67 ± 2.73
	162 (2)	38.67 ± 5.72	6.00 ± 1.10	6.33 ± 2.42
	164 (2)	35.33 ± 5.28	9.50 ± 4.18	8.50 ± 1.64
	166 (2)	47.33 ± 10.17	16.33 ± 10.29	12.00 ± 4.10
	170 (3)	39.67 ± 3.81	7.44 ± 2.79	7.67 ± 2.06
	173 (3)	42.67 ± 5.00	9.00 ± 3.00	8.33 ± 1.80
	175 (2)	50.00 ± 0.89	8.00 ± 0.89	6.33 ± 0.52
	178 (2)	46.50 ± 6.83	23.50 ± 23.31	11.67 ± 8.55
	181 (2)	42.67 ± 1.86	6.67 ± 1.37	15.33 ± 9.89

***p<0.001

The difference in hip angle during STS was investigated (Table 2). Statistical differences in flexion-extension (p<0.05) and rotation (p<0.01) were found among the three groups. The least angle difference was found in SP and in RP, and the change in angle was similar to one another. No statistical differences in lateral bending were found (p>0.05).

Changes in the angle of the body according to the height of the subjects were studied. Statistically significant differences in flexion-extension, lateral bending, and rotation of the neck, trunk, and hip were found according to the subjects' height (Table 3). Thus, the results of this study indicate that the level of body movement varied according to height size during STD.

Table 4. Correlation of changes in body movements with height and foot position

	Neck			Trunk			Hip		
	Flexion-extension	Lateral bending	Rotation	Flexion-extension	Lateral bending	Rotation	Flexion-extension	Lateral bending	Rotation
Height	−0.192	0.099	0.099	0.695**	0.387**	−0.082	0.478**	0.179	0.333**
Foot position	0.264*	0.111	0.111	0.1	0.467**	0.296*	0.237	0.208	0.289*

*p<0.05, **p<0.01

Changes in flexion-extension, lateral bending, and rotation of the neck, trunk, and hip were examined according to height and foot position (Table 4). The height had a strong positive correlation with flexion-extension (r=0.695) and a correlation with lateral bending (r=0.387) of trunk. The height had a positive correlation with flexion-extension (r=0.478) and rotation (r=0.333) of hip.

The foot position had a weak positive correlation with the flexion-extension of the neck, while the foot position had a positive correlation (r=0.467) with lateral bending and a weak positive correlation (r=0.296) with the rotation of the trunk. The foot position had a weak positive correlation with the rotation (r=0.289).

Thus, the larger the height, the larger the range of flexion-extension and lateral bending of the trunk became as well as the range of flexion-extension and rotation of the hip. Furthermore, depending on changes in the foot position, the range of change in the flexion-extension of the neck, flexion-extension and rotation of the trunk, and rotation of the hip became larger.

DISCUSSION

The purpose of this study is to verify changes in the angle of the neck, trunk, and hip according to foot positions (SP, RP, and LP) during STS. In this study, no change in the neck angle due to foot position was found, whereas the most amount of change was identified in the trunk angle in SP followed by RP and LP. The least amount of change was seen in the hip angle in flexion-extension and rotation in SP. Thus, when both feet were symmetrical, the least amount of changes in the angle of the body were identified, which indicated that this is the most efficient posture. According to Blache et al.[8)], an asymmetric feet position lessens the load in lumbar spine and approximately 50% of the load in lumbar spine was increased while performing the STS movement from a low-height chair, which was inconsistent with some of our study results. This inconsistent result seemed to be due to a difference in the chair height. Blache et al.[8)] provide the height of the adjustable chair for the subject's height but in the present study, a fixed chair height was provided to measure changes in the body.

As the chair height was lower, the load was increased with the increased height of the subject at a fixed chair height while performing STS. The flexion of the trunk during STS became evident, which was a strategy to ensure more stability during STS, and the load in the lower extremity was increased accordingly. The study result was similar to the large change in the trunk movement in the present study. Although we did not measure the load in the lower extremity, the load in the lower extremity was supposed to increase in asymmetric foot position.

According to Schultz et al.[11)], a strategy was taken to ensure stability by forwarding the center of gravity as soon as the hip was off the chair in order to compensate the instability during STS, which was consistent with the large change in trunk movements in the results of the present study. Moreover, the results of the present study indicate that the level of movement of the body varied according to height size during STD. Thus, as the height became larger, the range of flexion-extension and lateral bending of the trunk became larger as well as the range of the flexion-extension and rotation of hip. Furthermore, depending on changes in the foot position, a range of change in the flexion-extension of the neck, flexion-extension and rotation of trunk, and rotation of the hip became larger.

In summary, while performing STS, the height was more influential on changes in the angle of the neck, trunk, and hip. Moreover, when the height of the chair and the height of the subject were not matched correctly, more effective STS could be achieved when both feet were laid symmetrically rather than in the other two positions. Thus, it is necessary to employ an appropriate chair height that is matched with the height of the subject during therapy using STS, especially for elderly persons or patients with stroke in physiotherapy practices.

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