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Influence of the Relative Difference in Chair Seat Height according to Different Lower Thigh Length on Floor Reaction Force and Lower-limb Strength during Sit-to-Stand Movement

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Abstract Chair-seat height affects the burden on the lower-limbs during sit-to-stand (STS) movement. Previous studies used the same height chair, attaching importance to practicability, but the difference in each subject's lower thigh length may relate to the burden on the lower-limbs. This study aimed to examine the influence of different lower thigh lengths on floor reaction force and lower-limb strength during an STS movement. Thirty young-adult male subjects participated in this study (age: 22.7±2.6 yr, height: 172.8±4.8 cm, body-mass: 66.3±5.2 kg). The subjects were divided into three groups (G1>42 cm, 42 cm≧G2≧38 cm, 38 cm>G3) based on lower thigh length (G1: 44.1±2.5 cm, G2: 39.8±1.3 cm, G3: 34.3±2.1 cm). Namely, G1 was characterized by lower thigh length longer than 105% of 40 cm, G2 by 95–105% of lower thigh length and G3 by lower thigh length less than 95% of 40 cm, respectively. Subjects performed an STS movement twice from chairs at 40 cm-height and height adjusted by the lower thigh length of each subject. Vertical floor reaction force and electromyogram (EMG) on the rectus femoris and tibialis anterior muscles during an STS movement were measured to evaluate the force of knocking over and the burden on the lower-limbs. Fifteen parameters regarding floor reaction force (10) and EMG (5) were selected for analyses. Significant differences were found in floor reaction force at hip-syneresis (F1) and the impulse between hip-syneresis and appearance of the peak floor reaction force (F2). G1 was greater than G2 for the former, and G3 for the latter. Significant differences were found in active muscle mass of the tibialis anterior from the beginning of an STS movement to hip-syneresis (TE1) and peak active muscle level of the tibialis anterior (TE6). G1 was greater than G2 for the former, and G2 and G3 for the latter. It was suggested that when an STS movement is performed using a chair with the same height for each subject, the load imposed on the subject's leg at the time of an STS movement and the STS movement achievement strategy differed since chair seat height changes relatively by the difference in lower thigh length. Moreover, it is thought that the difference in these load conditions and movement strategies occurs when the chair seat height of a subject's lower thigh length is longer than 110%. When conducting the ability to achieve STS movement rating test, chair seat height considering each subject's lower thigh length may be needed. *J Physiol Anthropol Appl Human Sci 23(6): 197–203, 2004* http://www.jstage.jst.go.jp/browse/jpa

Keywords: sit to stand movement, floor reaction force, lower thigh length, strategy for achieving movement

Introduction

Sit-to-stand (STS) is one of the important activities of daily living (ADL) (Demura et al., 2003), and each of its parameters is used frequently (Riley et al., 1991). However, when becoming middle-aged to elderly, people have difficulty in accomplishing an STS movement with functional lowering of the leg muscles and balance function (Alexander et al., 1991). Moreover, the above-mentioned functional lowering also influences Quality of Life (QOL), which is accompanied by restrictions on their range of activities. Therefore, the ability to achieve STS movement is important in leading an independent everyday life.

Generally, the achievement ability of an STS movement is evaluated from repetition within a certain period (Jones et al., 1999; Nakatani et al., 2002) or the time for a certain number of repetitions (Netz and Argov, 1997). Lower-limb strength or muscle power required for an STS movement has been evaluated from floor reaction force at the time of knocking over an STS movement in recent years (Fleming et al., 1991; Lindemann et al., 2003; Nakatani et al., 2004). Since forcible knocking over is required when trying to stabilize quickly and achieve an STS movement, the superiority or inferiority of lower-limb strength or muscle power is reflected in a floor reaction force-time curve. Lindemann et al. (2003) reported that the exertion of muscle strength velocity from a hip-syneresis term (floor reaction force peak value) to a standing position term (weight) showed a high relationship with leg muscle power and isokinetic muscle performance of the knee joint (60 deg/s). However, they proposed parameters based on the point of inflection of a floor reaction force-time curve. Since an STS movement is classified into some movement phases (Schenkman et al., 1996a; Schenkman et al., 1996b) and the role of each phase over movement achievement also differs (Ebara et al., 2001), it may be necessary to choose parameters considering these factors. We classified an STS movement into some movement phases, referring to the reports of Schenkman et al. (1996a; 1996b) and Ebara, et al. (2001), and proposed parameters that reflect the rapidity or the forcibleness of movement (Yamada et al., 2002; Yamada et al., 2003; Yamada et al., 2004). Moreover, STS is one of shifting movements of the body's center of gravity from a sitting position to a standing position through many joints and many muscles. The degree of each joint and muscle involvement in an STS movement achievement changes with chair seat height (Vander Linden et al., 1994; Doorenbosch et al., 1994). That is, chair seat height is an important factor that specifies the achievement strategy of an STS movement and the burden on lower-limb muscles (Janssen et al., 2002). However, since a chair of the same height is generally used from a point of practicability in an STS test (Netz and Argov, 1997; Jones et al., 1999; Fleming et al., 1991; Lindemann et al., 2003), the burden on the lower legs will differ between people with long lower thigh length and short lower thigh length. It is necessary to show clearly and concretely how the difference in burden on the lower-limbs is influenced by lower thigh length.

This study aimed to examine the burden on the lower-limbs and the achievement strategy of movement when subjects who have different lower thigh length perform an STS operation from a chair of the same height.

Methods

Subjects

Thirty young-adult male subjects participated in this study (age: 22.7±2.6 yr, height: 172.8±4.8 cm, body-mass: 66.3±5.2 kg). All subjects were healthy and did not have lower-limb abnormalities. Written informed consent was obtained from all subjects after a full explanation of the experimental purpose and protocol. Subjects were divided into three groups (G1–G3) with different lower thigh length on the basis of chair-seat height (40 cm) used in a previous study (Nakatani et al., 2002) as follows: G1 (age: 20.4±1.6 yr, height: 179.1±7.2 cm, body-mass: 73.3±7.4 kg, lower thigh length; 44.1±2.5 cm): lower thigh length longer than 105% of 40 cm, G2 (age: 21.7±1.6 yr, height: 170.4±4.7 cm, body-mass: 70.2±15.0 kg, lower thigh length: 39.8±1.3 cm): 95%–105% of 40 cm, and G3 (age: 20.8±1.2 yr, height: 167.4±4.1 cm, body-mass: 64.6±8.9 kg, lower thigh length: 34.3±2.1 cm): lower thigh length shorter than 95% of 40 cm. Each group consisted of 10 subjects. The lower thigh length of the above 3 groups was confirmed to be significantly different.

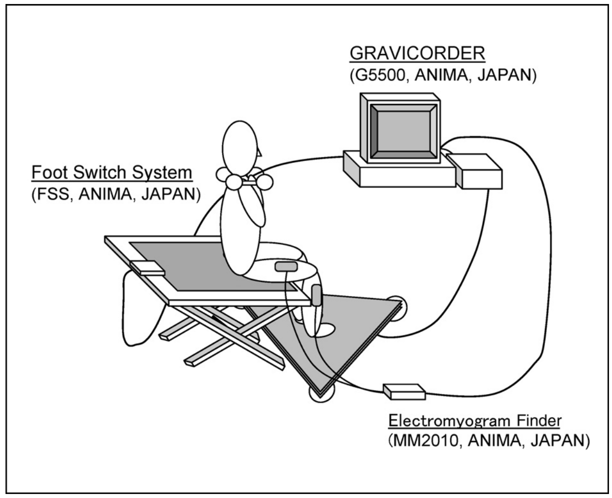

Fig. 1 Experimental design.

Materials

Figure 1 shows the experimental design in this study. Measurement of vertical floor reaction force and electromyogram (EMG) used a GRAVICORDER (G5500, ANIMA, Japan) and electromyogram finder (MM2010, ANIMA, Japan). Moreover, to accurately determine the time when the hips depart from the bearing surface of the chair, we developed a foot switch system (FSS, ANIMA, Japan) that can measure grounding/non-grounding on the bearing surface as an on/off signal. A GRAVICORDER simultaneously saved floor reaction force, EMG and foot switch system data every 1/500 s.

Experimental procedure

First, the lower thigh length of each subject was measured from the shank to the malleolus using a martin formula anthropometer (YAGAMI, Japan). Sitting posture and movement pattern during STS movement were explained to the subjects before measurement. In a sitting posture, the subject kept both legs with bare feet at shoulder width, stretched the trunk in a straight line, held a 90 degree ankle angle, and folded his arms. A subject stood up quickly from a sitting posture after a sign from the tester. Each subject conducted the above STS movement twice from a chair 40 cm high (Nakatani et al., 2002) and height adjusted by subject's lower thigh length and a 10 kg weight to impose strength supporting body weight. Considering the influence of fatigue, each subject took a minute rest between trials.

Parameters regarding floor reaction force and EMG

Figure 2 shows 10 floor reaction force parameters. As in the previous studies (Schenkman et al., 1996; Ebara et al., 2001), an STS movement was divided into four movement phases (initiation of an STS movement, hip-syneresis, extension of knee and trunk joints, end of an STS movement), and a

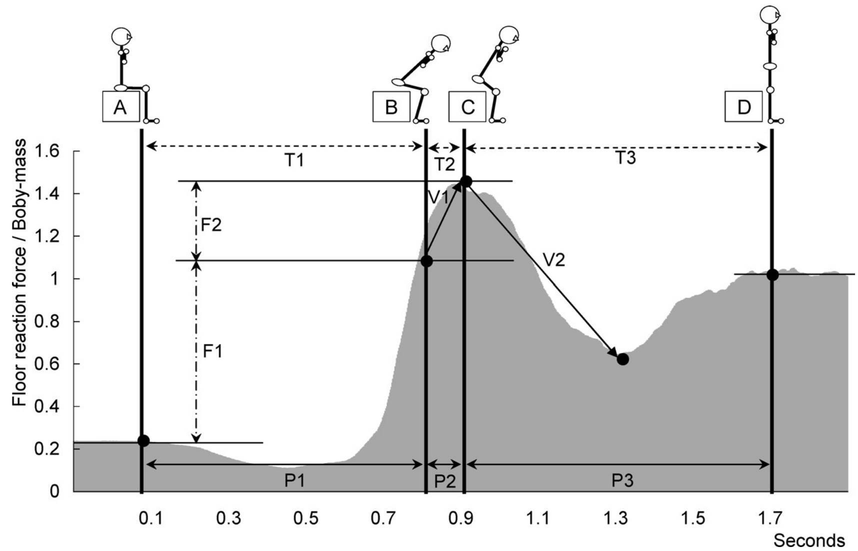

Fig. 2 Floor reaction force parameters.

Note) A: beginning of STS movement, B: hip-syneresis, C: peak value of floor reaction force, D: completion of STS movement, Values in figure are relative values.

<Force> F1: FRF at hip-syneresis, F2: FRF between hip-syneresis and peak value of FRF

<Time> T1: time from beginning of STS movement to hip-syneresis, T2: time from hip-syneresis to appearance of peak FRF, T3: time from appearance of peak FRF to completion of STS movement

<Impulse> P1: impulse between beginning of STS movement and hip-syneresis, P2: impulse between hip-syneresis and appearance of peak FRF, P3: impulse between appearance of peak FRF and completion of STS movement

<Velocity> V1: mean lifting velocity of FRF between hip-syneresis and peak FRF, V2: mean lifting velocity of FRF between peak FRF and minimum FRF after peak FRF appearance

selected force of knocking over from each movement phase. Reaching time, impulse rate per unit of time and lifting velocity of floor reaction force in each phase to evaluate quickness, work volume, and quickness of knocking over an STS movement were selected, respectively. In addition, the beginning and completion of an STS movement was defined as follows: the time point when floor reaction force in a sitting posture starts to decline, and the time point when floor reaction force starts to stabilize after reaching body-mass level. Floor reaction force used relative values divided by body-mass.

Figure 3 shows 5 EMG parameters. EMG of the rectus femoris and tibialis anterior muscles that highly contribute to achieving an STS movement (Shimada et al., 1999) was measured, and parameters based on each movement phase (initiation of an STS movement, hip-syneresis, extension of knee and trunk joints, end of an STS movement) were selected. Integration value, peak value, and reaching time to peak value in each phase to evaluate active muscle mass, peak level of muscle activity, and reaching time of peak level of muscle activity were selected. In addition, EMG data were converted to relative values based on peak EMG during an STS movement from the chair-seat height adjusted for lower thigh length after converting absolute values and moving average deviations.

It is considered that a difference in lower thigh length relates to the difference in muscle length and it affects the exertion of muscle strength. In addition, an STS movement has large individual differences in movement velocity and patterning. Therefore, each subject conducted an STS movement from a 40 cm high chair and height adjusted for the subject's lower thigh length in this study. We calculated relative values of parameters with a chair-seat height of 40 cm condition based on parameters on chair-seat height of the lower thigh length condition. Namely, the relative value was calculated by following formula.

[relative value=(measured value on 40 cm height condition) / (measured value on height of lower thigh length condition)]

Data analysis

To examine the influence of different lower thigh lengths on floor reaction force and lower-limb strength during an STS movement, analysis of variance (ANOVA) was used. When a significant difference was found, multiple comparisons were performed using Tukey's honestly significant difference (HSD) method (Demura, 2004; Demura, 2001; Mori and Yoshida, 1998). The probability level of 0.05 was considered as an indicative of statistical significance and the whole probability was adjusted according to Bonferroni's method.

Results

Significant differences were observed in mean lower thigh length among the three groups with different lower thigh length. The mean values of the differences were 4.3–5.5 cm

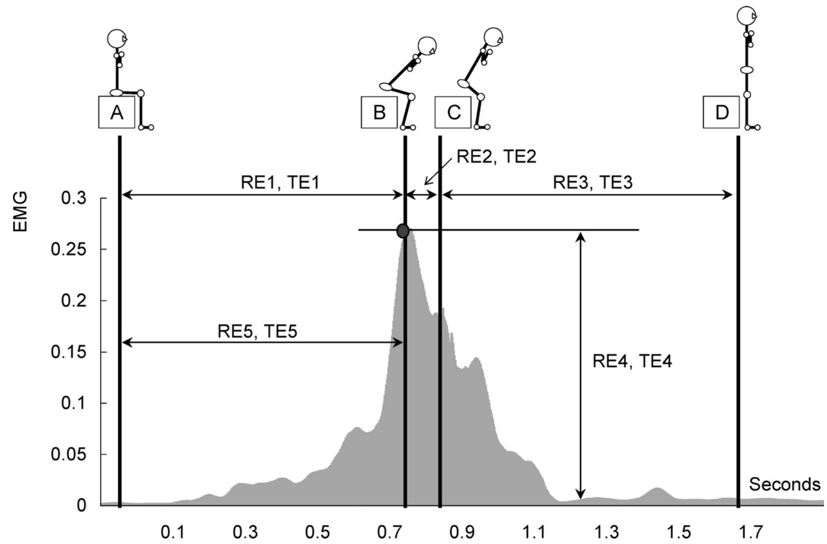

Fig. 3 Electromyogram parameters.

Note) A: beginning of STS movement, B: hip-syneresis, C: peak value of floor reaction force, D: completion of STS movement, RE: EMG of rectus femoris muscle, TE: EMG of tibialis anterior muscle, Values in figure are relative values.

<Active muscle mass>

RE1 and TE1: active muscle mass between beginning of STS movement and hip-syneresis, RE2 and TE2: active muscle mass between hip-syneresis and appearance of peak FRF, RE3 and TE3: active muscle mass between appearance of peak FRF and completion of STS movement

<Peak level of muscle activity>

RE4 and TE4: Peak level of muscle activity during STS movement

<Achievement time to peak level of muscle activity>

RE5 and TE5: Achievement time to peak level of muscle activity during STS movement

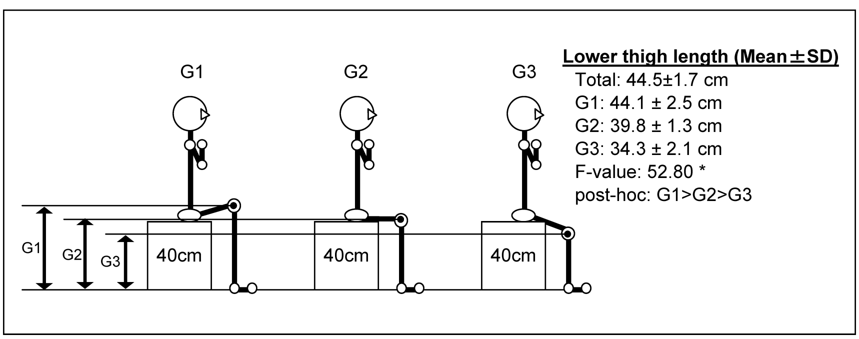

Fig. 4 Sitting posture of subjects in each group under 40 cm chair-seat height condition.

Note) G1: Subjects with longer lower-thigh-length than 105% of 40 cm, G2: Subjects with lower thigh length between 95 and 105% of 40 cm, G3: Subjects with shorter lower-thigh-length than 95% of 40 cm, *: $p<0.05$

(Fig. 4). Figure 5 shows the time course of mean floor reaction force on each group during an STS movement. Floor reaction force increased dramatically from initiation of an STS movement to hip-syneresis, and reached a peak value. Then, it decreased dramatically, and became steady at body-mass level by the time the STS movement was accomplished. Table 1 shows the results of analysis of variance (ANOVA) and multiple comparisons for each parameter. Significant differences were found in floor reaction force at hip-syneresis (F1) and impulse between hip-syneresis and the appearance of the peak floor reaction force value (F2). G1 was greater than G2 for the former, and G3 for the latter. However, significant differences were not found in any parameter regarding time and velocity. Significant differences were found in active muscle mass of the tibialis anterior from the beginning of an STS movement to hip-syneresis (TE1) and peak active muscle level of the tibialis anterior (TE6). G1 was greater than G2 for the former, and G2 and G3 for the latter. However, significant differences were not found in any EMG parameter regarding EMG of rectus femoris muscle.

Discussion

Three groups with different lower thigh lengths chosen in

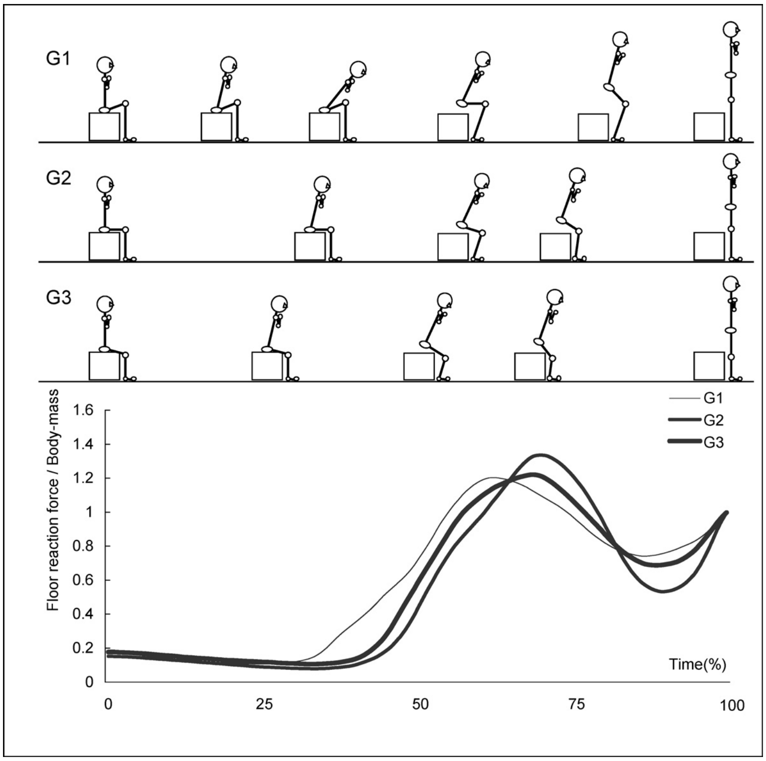

Fig. 5 Time course of mean floor reaction force on each group during STS movement.
Note) G1: Subjects with longer lower-thigh-length than 105% of 40 cm, G2: Subjects with lower thigh length between 95 and 105% of 40 cm, G3: Subjects with shorter lower-thigh-length than 95% of 40 cm, Values in figure are relative values.

this study showed a statistical difference. The respective length of the three groups differed about an average of 5 cm in length. When an STS movement is performed using a chair of the same height, as shown in Fig. 4, chair-seat height differs relatively according to each group because of the differences in lower thigh length in each group. Therefore, subjects with long lower thigh length have their body's center of gravity further below their knee joints than subjects with short lower thigh length at the time of an STS movement, and take a heavier burden on their lower-limbs. Since it is the upward shifting movement of body's center of gravity through multi-joint and multi-muscle groups, a movement achievement strategy may change with differences in knee joint angle and muscles employed.

From the results of analyzing floor reaction force and EMG parameters, G1 with lower thigh length longer than chair seat height had a floor reaction force (F1) and an active muscle mass of the tibialis anterior (TE1) from the start of an STS movement to hip-syneresis larger than G2 with lower thigh length at the same level equivalent to chair seat height. The impulse rate from hip-syneresis to the floor reaction force peak value (P2) was larger than G3 with lower thigh length shorter than chair seat height. Furthermore, the peak active muscle level (TE5) of the tibialis anterior muscle was larger than G2 and G3. The G1 subject group had a 4.1 cm higher knee joint position than the chair seat height (10% of chair seat height), and for G3 it was 5.7 cm lower (14.3% of chair seat height). Therefore, G1 forced a larger shifting of the body's center of gravity to the upper direction than the case of G2 at the time of hip-syneresis, and a strong knocking over force is needed. The phase of hip-syneresis to floor reaction force peak needs a stronger force than G3. Ellis et al. (1984) reported that when the chair seat height was low, knocking over force at the time of an STS movement is strong and a load imposed to the legs is large. Arborelius et al. (1992) compared the active mass of lower leg muscles with an STS movement under four chair seat height conditions, and reported that with a low chair, the active mass of the external vastus and rectus femoris muscles is larger than with a high chair, and achievement of STS movement is difficult. However, there was no significant difference in the floor reaction force and EMG parameters of G2 and G3, when lower thigh length is at the same level equivalent to chair seat height or shorter and there may be no difference in STS movement performance. That is, when lower thigh length is shorter compared with chair seat height (14.3% of chair seat height), it is not a significant problem, but when longer (10% of chair seat height), it may influence the burden on the lower legs. Consequently, the force of knocking over required for the STS movement achievement, i.e., the burden on the lower legs, changes with lower thigh length(s) when an STS movement is performed from a chair of the same height. Although subjects with lower thigh length of 110% or more of chair seat height have a larger burden, if the range of lower thigh length is +10 to −14% of chair seat height, it can be

Table 1 Results of analysis of variance and multiple comparison (Tukey's HSD)

			Variables	G1 (N=10)		G2 (N=10)		G3 (N=10)		F-value	Post-hoc
				Mean	SD	Mean	SD	Mean	SD		
Floor reaction force		Force	F1	1.06	0.10	0.88	0.13	0.92	0.13	5.45 *	G1>G2
			F2	1.20	0.35	1.89	0.80	1.56	0.81	2.28	
		Time	T1	0.94	0.16	0.94	0.21	0.99	0.15	0.26	
			T2	1.11	0.31	1.06	0.19	1.18	0.28	0.44	
			T3	1.10	0.20	0.92	0.16	0.95	0.16	2.70	
		Impulse	P1	0.95	0.16	0.85	0.16	0.94	0.24	0.78	
			P2	1.05	0.04	1.01	0.05	0.98	0.04	7.09 *	G1>G3
			P3	1.11	0.23	0.91	0.17	0.96	0.18	2.57	
		Velocity	V1	1.10	0.32	1.48	0.65	1.31	0.46	1.96	
			V2	1.09	0.17	1.24	0.39	1.08	0.16	0.96	
Electromyogram	Rectus femoris	Integration	RE1	0.82	0.33	1.33	0.85	1.04	0.31	1.96	
			RE2	1.10	0.55	1.52	0.76	1.61	0.94	1.17	
			RE3	1.05	0.52	0.83	0.55	1.17	0.49	1.00	
		Peak	RE4	1.03	0.59	0.78	0.37	1.15	0.36	1.57	
		Time	RE5	1.01	0.10	0.96	0.09	1.05	0.13	1.68	
	Tibiaris anterior	Integration	TE1	0.98	0.13	0.68	0.21	1.01	0.27	6.45 *	G1>G2
			TE2	1.57	0.67	2.16	1.13	1.48	0.87	1.50	
			TE3	1.38	0.43	1.30	0.63	0.96	0.40	1.83	
		Peak	TE4	1.14	0.30	1.09	0.39	1.04	0.30	0.20	
		Time	TE5	1.03	0.02	1.00	0.01	1.00	0.02	6.31 *	G1>G2,G3

Note) G1: Subjects with longer lower-thigh-length than 105% of 40 cm, G2: Subjects with lower-thigh-length between 95 and 105% of 40 cm, G3: Subjects with shorter lower-thigh-length than 95% of 40 cm, *: $p<\alpha'$, values are relative values (measured value on 40 cm height condition) / (measured value on height of lower thigh length condition).

judged that the difference in lower thigh length can be disregarded.

A significant difference could not be found among the 3 groups for parameters on force of knocking over including a floor reaction force peak value, and time and velocity parameters on quickness of movement. Downward exertion of muscle strength in a short time is required in order to perform quick movement, because an STS movement is an upward shifting movement of the body's center gravity (Vander Linden et al., 1994; Doorenbosch et al., 1994). Since, as shown in Fig. 5, G1 starts the movement with a knee joint angle of 90 degrees or less, the group has a more difficult posture for downward exertion of muscle strength compared with G2 and G3. Moreover, to achieve movement from a difficult posture, G1 must exert a force in a stage earlier than G2 and G3, greatly inclining the trunk forward with the start of an STS movement. In contrast, in G2 and G3, a large downward exertion of muscle strength is possible within a short time because the groups perform an STS movement from the state of a 90 degree or more knee joint angle in taking a sitting posture, From the above, it is inferred that there is not only a difference in the burden on the leg, but also there is a difference in the STS movement achievement strategy among G1, G2 and G3.

Arborelius et al. (1992) reported all EMG parameters of muscles indicated a significant difference between chair seat height conditions. In this study, a significant difference was found among 3 groups for the tibialis anterior muscle but not the rectus femoris muscle. The reason for this may be that the chair seat height in the study by Arborelius et al. (1992) was lower compared with this study. Since chair seat height specifies the load of an STS movement (Janssen et al., 2002) and thigh muscles largely contribute to the achievement of movement (Coriggan et al., 2001), the dependence on thigh muscles increases when the chair seat height is low. It is inferred that the difference of the degree of the burden on thigh muscles was also small, and there was no significant difference, because the relative differences among chair seat heights in each group in this study were smaller compared with the difference in their chair seat height conditions.

As a result, it is suggested that the load imposed on a subject's leg at the time of an STS movement and an STS movement achievement strategy vary since chair seat height changes relatively with differences in lower thigh length when an STS movement is performed using a chair of the same height with each subject. It is thought that the difference in these load conditions and movement strategies occurs when the chair seat height of a subject's lower thigh length is longer than 110%. When conducting the STS movement achievement ability rating test, chair seat height considering each subject's lower thigh length may be needed.

References

Alexander NB, Schultz AB, Warwick DN (1991) Rising from chair: effect of age and functional ability on performance biomechanics. J Gerontol A Biol Sci Med Sci 46: M91–M98

Arborelius UP, Wretenberg P, Lindberg F (1992) The effect of armrest and heights on lower-limb joint load and muscular activity during sitting and rising. Ergonomics 35: 1377–1391

Corrigan D, Bohannon RW (2001) Relationship between knee extension force and stand-up performance in community-dwelling elderly women. Arch Phys Med Rehabil 82: 1666–1672

Demura S, Sato S, Minami M, Kasuga K (2003) Gender and age differences in basic ADL ability on the elderly: comparison between the independent and the dependent elderly. J Physiol Anthropol Appl Human Sci 22: 19–27

Doorenbosch CA, Harlaar J, Roebroeck ME, Lankhorst GJ (1994) Two strategies of transferring from sit-to-stand: the activation of monoarticular and biarticular muscles. J Biomech 11: 1299–1307

Ellis MI, Seedhom BB, Wright V (1984) Forces in the knee joint whilst rising from a seated position. J. Biomed Eng 6: 113–120.

Ebara Y, Yamamoto S (2001) Text of body dynamics: Analysis of sit to stand movement. Ishiyaku Publishers, Tokyo, 1–4 [*In Japanese*]

Fleming B, Wilson D, Pendergast D (1991) A portable easily performed muscle power test and its association with falls by elderly persons. Arch Phys Med Rehabil 72: 886–889

Janssen WG, Bussmann HB, Stam HJ (2002) Determinants of the sit-to-stand movement: a review. Phys Ther 82: 866–879

Jones CJ, Rikli RE, and Beam WC (1999) A 30-s chair -stand test as a measure of lower body strength in community-residing older adults. Res Q 70: 113–119

Lindemann U, Claus H, Stuber M, Augat P, Muche R, Nikolaus T, Becker C (2003) Measuring power during the sit-to-stand transfer. Eur J Appl Physiol 89: 466–470

Netz Y, Argov E (1997) Assessment of functional fitness among independent older adults: Apreliminaly report. Percept Mot Skills 84: 1059–1074

Nakatani T, Ue H (2004) A new test for the evaluation of vertical force in sit-to-stand movement from a chair. Jpn J Phys Fitness Sports Med 53: 183–188 [*In Japanese*]

Nakatani T, Nadamoto M, Mimura K, Itoh M (2002) Validation of a 30-sec chair-stand test for evaluating lower extremity muscle strength in Japanese elderly adults. Japan J Phys Educ Hlth Sport Sci 47: 451–461

Riley PO, Schenkman ML, Mann RW (1991) Mechanics of a constrained chair-rise. J Biomech 24: 77–85

Schenkman M, Hughes MA, Samsa G, Studenski S (1996a) The relative importance of strength and balance in chair rise by functionally impaired older individuals. J Am Geriatr Soc 44: 1441–1446

Schenkman M, Riley P, Pieper C (1996b) Sit to stand from progressively lower seat heights: alterations in angular velocity. Clin Biomech 11: 153–158

Shimada Y, Kagaya S, Miyamoto S (1999) Analysis of sit to stand movement. Sogo Rihabiliteishon 27: 1023–1028 [*In Japanese*]

Vander Linden DW, Brunt D, McCulloch MU (1994) Variant invariant characteristics of the sit-to-stand task in healthy elderly adults. Arch Phys Med Rehabil 75: 653–660

Yamada T, Demura S, Yamaji S, Nakada M, Noguchi T (2002) Reliability of exertion patterns in vertical ground reaction force, electromyogram and stand parameters during a stand movement from the chair. Jpn J Test Evaluation Phys Educ Sports 2: 73–81 [*In Japanese*]

Yamada T, Demura S, Yamaji S, Kitabayashi T (2003) Reliability of the parameters regarding floor reaction force and EMG of lower body muscles, and the relationships among the parameters during a sitting to standing movement. J Educ Health Sci 48: 476–485 [*In Japanese*]

Yamada T, Demura S, Kitabayashi T (2004) Influence of seat height on floor reaction force and strength of lower-limbs during sit-to-stand movement. Jpn J Physiol Anthropol 9: 47–52 [*In Japanese*]

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