原 著 論 文 <第8回大会優秀発表>

The influence of various upper limb supports on the output of leg muscle strength and the rating of perceived exertion during sit-to-stand movements

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Abstract

Many of the elderly cannot stand up from a chair without using their upper limbs. This study aimed to examine the influence of various upper limb supports on output of leg muscle strength and the rating of perceived exertion during sit-to-stand (STS) movements. Ten healthy young males without lower limb disorders (age: 25.6 +/- 3.9 yr) stood up from the chair and adjusted each subjects' knee joint height as fast as possible. The following was selected as upper limb support conditions: folding their arms crossed in front of the chest (CON), putting their hands on their knees (HK), grabbing the arm rests (AR), and grabbing the hand rails (HR). Rate of force development (RFD) and rating of perceived exertion (RPE) measured by visual analogue scale during STS movement were measured in each condition. RFD in the AR condition was significantly lower than that in the other conditions (65.2-77.2%). RPE in AR and HR conditions was significantly lower than that in CON and HK conditions (35.6-51.9%). In conclusion, the burden on lower limbs during STS movement was judged to be smallest when using the arm rest.

Key words : Sit-to-stand, burden on lower limb, rating of perceived exertion

[Received November 8, 2009 ; Accepted February 8, 2010]

1. Introduction

STS movement precedes ambulation and other basic daily living activities (Riley et al., 1991). Therefore, the level of leg muscle function to achieve this movement is indispensable for the independent life of the elderly (Alexander et al., 1991). However, many of the elderly need care or use of upper limbs when achieving STS movement. Such elderly people frequently use supporting devices in daily life such as arm rests and hand rails during an STS movement.

Until now, some researchers have examined the influence of the use of supporting devices such as arm rests and hand rails on STS movements. Arborelius et al. (1992) compared the ankle, knee and trunk joints moments during STS movements with and without using arm rests to examine the influence of arm rests on the burden on lower limb joints and the characteristics of muscle activities during STS movements in the healthy subjects. They reported that maximal trunk joint moment during STS movements when using arm rests was about 50% compared to not using them. Moreover, Bahrami et al. (2000) examined the above by the same methods for the healthy young adults and reported that maximal knee and trunk moment during STS movement using hand rails was about 50% compared to not using them. In addition, Sanford et al. (1995) examined the effect of the use of hand rails on the amount of independent achievement and safety of STS movements for healthy elderly and the elderly with gait disorders, and reported that output of leg muscle strength and instability during STS movements were reduced by using hand rails.

From the above, the physical burden imposed during STS movements may be reduced by the use of supporting devices such as hand rails and arm rests in any young adult, elderly, or physically handicapped person. Above all, because the elderly and physically handicapped persons with a marked decreased physical function can achieve STS movements by using the above supporting devices as well as young adults (Doorenbosch et al., 1994), it will contribute to facilitate independent living. Moreover, using supporting devices as one form of

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※ 本論文は，日本体育測定評価学会第8回大会における「優秀発表」が審査を経て論文化されたものである。

training for functional recovery may be useful for the elderly who find it difficult to achieve STS movements independently. However, previous studies (Arborelius et al., 1992; Bahrami et al., 2000; Sanford et al., 1995) have not examined whether arm rests or hand rails are useful for reducing the burden on lower limbs during STS movements. In addition, it may be necessary to identify which supporting device to use relative to the difficulty level of achieving STS movements for the purposes of training, though this has not yet been examined. It will be helpful for the elderly and physically handicapped persons to identify the supporting device which results in the smallest burden to the lower limbs and to further identify the difference among supporting devices on physical burden.

This study aimed to examine the influence of various upper limb supports on the output of leg muscle strength and rating of perceived exertion during STS movements.

2. Methods

2.1. Subjects

Ten young male adults without leg disorders (age: 25.6 +/- 3.9 yr; height: 173.0 +/- 5.2 cm, body-mass: 71.0 +/- 3.6 kg) participated in this study. For purposes of the present study, it is desirable that the elderly and physically handicapped persons find it difficult to achieve STS movements without supporting devices or upper limb support are selected as subjects. However, it is difficult for them to participate in all experimental conditions in addition to the above conditions with supporting devices. Therefore, this study selected young adults as subjects. Written informed consent was obtained from all subjects after a full explanation of the experimental purpose and protocol. The experimental protocol in this study was approved by an inquiry committee of studies intended for humans, the "Kanazawa University Health & Sports Science Ethics Committee".

2.2. Experimental condition and procedure

Prior to the measurement of vertical ground reaction force, subjects were instructed on the proper sitting posture and STS movement. They stood up from a sitting posture on a chair adjusted to their knee height with the following posture after the tester's signal: maintain both legs shoulder width apart with bare feet, stretch the trunk in a straight line, and hold a 90 degree ankle angle. The use conditions of the upper limbs were as follows: arms crossed in front of their chest (Control: CON), hands on their knees (Hands on knees: HK), using arm rests (Arm rest: AR) and hand rails (Hand rail: HR) (Figure 1). The whole body load during the STS movement is supported by legs in the CON condition. The STS movement in the HK condition is achieved by pushing on the subject's knees with his hands without a supporting device. The movements in HR and AR conditions are achieved by using supporting devices (hand rails and arm rests) as follows: grabbing and pulling the hand rails (HR condition) and pushing the arm rests (AR condition). In addition, the hand rails were set at the extension position

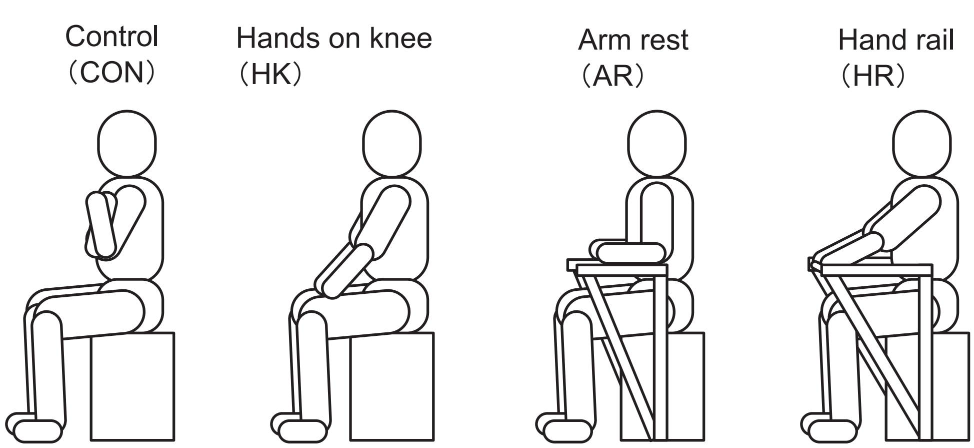

Figure 1. Upper limb support conditions

of both arms on the cubital joint height in the sitting posture of each subject (Sanford et al., 1995; Bahrami et al., 2000). The arm rests were set at cubital joint height in a sitting posture for each subject (Arborelius et al., 1992). They were instructed to stand up as fast as possible in all conditions. STS movement in each condition was conducted twice in a random order. Moreover, a sufficient rest between trials was set to eliminate fatigue effect.

2.3. Materials and measures

Vertical ground reaction force during STS movements in each condition was measured by Gravicorder G5500 (Anima, Japan). A Gravicorder simultaneously saved data on ground reaction force every 1/200 second. Moreover, visual analogue scale was used for evaluating the rating of perceived exertion (RPE) on the lower limbs during STS movements in each condition. Subjects were plotted at the closest point, which perceived the degree of physical burden after the STS movement in each condition on the scale stated on paper (0: absolutely, 100: burdensome).

2.4. Variables

The time course of ground reaction force data was differentiated and its maximal value (rate of force development: RFD) was selected in reference to previous studies (Fleming et al., 1991; Lindemann et al., 2003; Nakatani and Ue, 2004). It was reported that RFD significantly relates to leg muscle strength and power (Lindemann et al., 2003; Nakatani and Ue, 2004). When muscle strength output during STS movement is small, it is assumed that the burden to lower limbs is also small. Also, the distance between 0 and the plotted point on the VAS, which was plotted for each subject, was calculated as RPE on lower limbs. In addition, in both variables, a mean value of 2 trials was used for analysis.

2.5. Statistical analysis

The intra-class correlation coefficient (ICC) was calculated across trials to examine the reliability of RFD in each condition. The difference of RFD and RPE among mean values in each condition was examined by one-way analysis of variance (ANOVA) with repeated measures. Tukey's HSD method was used for multiple comparisons. A probability level less than .05 was indicative of statistical significance.

3. Results

Table 1 shows ICC of RFD for each condition. The ICC of RFD in the HK condition was moderate, but it was high in the other conditions. Table 2 shows the results of one-way analysis of variance and multiple comparisons for RFD and RPE in each condition. RFD during STS movements in the AR condition was significantly lower than that of the other conditions, corresponding to 65% of the CON condition. The RPE in the AR and HR conditions on the VAS was significantly lower than that in the CON and HK conditions, corresponding to 40% and 36% of the CON condition.

Table 1. Intra-class correlation coefficient of RFD in each condition

		RFD		
		1st trial	2nd trial	ICC
CON	Mean	17.94	17.39	0.83
	SD	3.23	2.77	
HK	Mean	15.05	16.81	0.60
	SD	3.72	3.98	
AR	Mean	12.14	10.91	0.86
	SD	3.57	2.97	
HR	Mean	14.38	15.47	0.79
	SD	3.75	4.20	

Table 2. Results of one-way analysis of variance and multiple comparison for RFD and RPE in each condition

		CON	HK	AR	HR	F-value	*p*	post-hoc
RFD	Mean	17.67	15.93	11.52	14.93	11.50	*0.000*	CON,HK,HR>AR
	SD	2.78	3.29	3.11	3.63			
RPE	Mean	27.15	20.94	10.86	9.67	11.21	*0.000*	CON,HK>AR,HR
	SD	16.00	13.70	9.33	8.53			

4. Discussion

The reliability of RFD during STS movements without upper limb support (CON condition), using armrests (AR condition) and hand rails (HR condition) was high (ICC > .79). Yamada and Demura (2005) examined the reliability of ground reaction force during STS movements using young adults, and reported that many variables were good. Moreover, Currier (1990) insisted that a value over .70 was good in behaviometrics. Although the reliability of RFD in the CON, AR and HR conditions were somewhat lower than that reported by Yamada and Demura (2005), they are judged to have a high reliability. Meanwhile, reliability of RFD during STS movements with hands on both knees (HK condition) was lower (ICC = .60). Bahrami et al. (2000) reported that stability during STS movements was increased by using a supporting device such as an arm rest. Namely, the supporting base is enlarged by using the upper limbs during an STS movement (Pai and Rogers., 1990; Carr., 1992; Vansant., 1992; Vander Linden et al., 1994). Therefore, trial-to-trial reliability was inferred to be high in all conditions by using the upper limbs, but the present results do not suggest this. Yamada and Demura (2005) reported that most variables with lower reliability evaluated the movement phase with large individual differences on movement strategies such as the trunk flexion phase. Because an STS movement is achieved on contact with multiple joints and muscle groups (Doorenbosch et al., 1994; Vander Linden., 1994), movement characteristics and muscle activity are inferred to be different between trials. In addition, because muscle strength output of upper limbs affects the measured values in the present HK condition, trial-to-trial reliability might be lower.

RFD during STS movements in the AR condition was significantly lower than that in the other conditions. Arborelius et al. (1992) examined the influence of arm rests on the burden imposed on lower limbs during an STS movement and reported that maximal trunk moment when using arm rests corresponded to about 50% without them. Moreover, Bahrami et al. (2000) reported that maximal knee and trunk moments during STS movements with hand rails corresponded to about 50% of that without them based on the same method. Subjects can transfer the center of gravity upward or forward by using arm rests or hand rails during STS movements, respectively. Therefore, the burden on the lower limbs may be reduced by muscle strength output from the upper limbs. Meanwhile, RFDs during STS movements in the present AR and HR conditions were 65.2% and 84.5% of that in CON condition, and 90.2% of that in HK condition. Alexander et al. (1991) reported that STS movements with upper limb support differed in movement strategy as compared with the movement without any support, and the strategy depended on upper limb support. Although the reduction rate in the burden to lower limbs during STS movement was greater than that of previous studies (Arborelius et al., 1992; Bahrami et al., 2000), the present result supported that of Alexander et al. Although variables selected in previous studies focused on each joint moment, the present variables focus on the sum of muscle strength output via each joint. This may be related to the difference in rate of reduction among these standing points. Further studies will be required to examine the influence of supporting devices and upper limb support on each leg joint moment and a relationship between each leg joint moment and leg strength. Meanwhile, it was suggested that STS movements using arm rests are achieved by using lower muscle strength output as compared with the movement using the other upper limb supports. Namely, when the elderly with marked decreased physical function and physically handicapped persons with locomotory disorders find it difficult to or are unable to achieve STS movements, using arm rests may help in the achievement of their STS because it poses the smallest burden.

RPE on lower limbs during STS movements was greater in CON and HK conditions than in the other conditions. This difference may be related to using or not using upper limb supports. Whole body load during STS movements are supported only by the legs in the CON condition. Meanwhile, STS movements in the HK condition are achieved by pushing knee joints with the subjects' hands without supporting devices. Therefore, the burden on the lower limbs may be almost the same as that of CON condition. Alternatively, RPE on lower limbs in HR and AR conditions may be reduced because the center of gravity is lifted by muscle strength output of the upper limbs. From the above, the STS movement performed from a chair with arm rest or hand rail is judged to be useful to reduce RPE on lower limbs. However, also in results of RFD, it was suggested that burden to lower limbs is little reduced even if pushing the subject's knees with his hands during the STS movement.

However, RPE on lower limbs during STS movement did not differ between AR and HR conditions, but RFD differed between the above both conditions. Namely, the psychological effect of using supporting devices may not always correspond with the actual burden imposed on the lower limbs. Forward and upward transferring of center of gravity occurs during the STS movement (Doorenbosch et al., 1994; Vander Linden., 1994). Therefore, using supporting devices which the elderly can exert strength to raise upper body upward by arms may be useful to reduce burden imposed on lower limbs. A chair with an armrest is very suitable for the above purpose. Meanwhile, a hand rail is placed at position which subjects extend both arms forward. Hence, during an STS movement performed from a chair with a hand rail, after shifting the upper body near a hand rail, the STS movement can be supported by pushing the hand rail with arms. It is inferred that the difference in use of these supporting devices affected output of leg muscle strength. However, psychological burden is considered to have reduced largely by using both supporting devices.

5. Conclusion

RFD during STS movements using arm rests was the smallest. The subjective burden on the lower limbs during STS movements with arm rests and hand rails was lower than that during the movement without upper limb support. From the above, the STS movements using arm rests were judged to impose the smallest burden on the lower limbs.

Appending

This study was presented as a poster in the 8th conference of the Japanese Society of Test and Measurement in Health and Physical Activity held at the Musashino Cooking College on March 8th 2009. This paper has been written based on the content of that poster.

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