原 著 論 文

Reliability of center of gravity transfer velocity during the sit-to-stand movement and its relationship with leg muscle strength

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Abstract

The velocity of center of gravity transfer during the sit-to-stand (STS) movement has been measured by three dimensional motion analysis. This analysis is useful for the evaluation of leg muscle function but is not practical. This study aimed to propose an alternative measurement method which can conveniently measure center of gravity transfer velocity. In addition, the study aimed to examine this method's applicability to the elderly by clarifying the reliability of evaluation parameters and their relationship with maximal isometric leg extension strength in young adults. Maximal isometric leg extension strength and center of gravity transfer velocity during a STS movement from a chair height set at the knee joint were measured twice in 30 young male adults (age: 20.3 +/- 5.2 yr). Peak and mean values of center of gravity transfer velocity were selected as evaluation parameters, as their reliabilities were very high (ICC = 0.92 and 0.85). Neither parameter showed a difference between the mean values of the two trials. Limits of agreements were -31.8 and 32.6 cm/s for peak velocity and -22.8 and 25.0 cm/s for mean velocity, and 95% confidence intervals were -5.7 to 6.5 cm/s and -3.4 to 5.6 cm/s, respectively. Maximal isometric leg extension strength showed a weak relationship with peak velocity (r = 0.07), but a significant and moderate one with mean velocity (r = 0.46). In conclusion, mean transfer velocity of center of gravity during the STS movement has a high reliability and a significant relationship with leg extension strength. The present measurement of center of gravity transfer velocity is useful for the evaluation of the elderly's leg muscle function because of its lower physical burden and utility of a less expensive device as compared with previous methods.

Key words : sit-to-stand, center of gravity, leg muscle function

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1. Introduction

During a sit-to-stand (STS) movement, center of gravity changes largely from a lower support base to a higher position (Doorenbosch et al., 1994; Vander Linden., 1994). This center of gravity transfer becomes unstable and decreases as leg muscle function decreases with age (Hughes et al., 1994). Hence, many elderly people fall during the STS movement (Mano, 2003). Because a STS movement precedes ambulation and other basic daily living activities (Riley et al., 1991), the ability to perform this movement stably and smoothly is indispensable for maintenance of an independent life (Alexander et al., 1991).

Schot et al. (2003) conducted fitness conditioning based on a general strength training design for the elderly and reported that peak forward, upward and downward transfer velocities of center of gravity and completion time improved significantly (increased 16, 59 and 26% and decreased 27%, respectively). They also found that the stability of the STS movement increased. Namely, the completion time and the stability of the STS movement are judged to be improved by adequate leg muscle function training. From the above, center of gravity transfer velocity during the STS movement is inferred to be a useful index for evaluating leg muscle function decline with age or improvement with training.

However, clinically evaluating the elderly's leg muscle function by center of gravity transfer velocity during the STS movement has not been examined in detail. Although the parameter selected by Schot et al. (2003) has been generally measured by three dimensional motion analysis (Yokoi et al., 1986; Pai & Rogers, 1990; Okada & Ae, 1996; Gross et al., 1998; Mourey et al., 1998; Hirschfeld

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et al., 1999; Moxley Scarborough et al., 1999; Schot et al., 2003; Mitui & Zushi, 2006), the determination of center of gravity position by the above method is too difficult to apply clinically. The development of an alternative measurement method which can simply and properly measure center of gravity transfer velocity will be required. However, when establishing a new measurement method, it is important to determine the safety and physical burden of the measurement method and the reliability of measured values in the elderly. Fundamental research will be necessary to examine these in advance in young adults before examining by using the elderly.

This study aimed to propose an alternative method to simply measure center of gravity transfer velocity and to examine its applicability to the elderly by clarifying the reliability of evaluation parameters and their relationship with maximal isometric leg extension strength in young adults.

2. Methods

2.1. Subjects

Thirty young male adults without leg disorders (age: 20.3 +/- 5.2 yr; height: 173.0 +/- 5.5 cm, body-mass: 64.6 +/- 6.8 kg) participated in this study. 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 Comittee".

2.2. Materials

Figure 1 shows the experimental schema in this study. Center of gravity transfer velocity during the STS movement was measured by FITRO Dyne Premium (Fitronic s.r.o., Slovakia). This device can measure the length of a pulled or returned cord from the bobbin, which works with a built-in rotary encoder. As shown in Figure 1, subjects wore a belt at the crista iliaca height. Moreover, the cord was fixed at the left crista iliaca position on the belt, and the length of the pulled or returned cord was measured with time when each subject performed the STS movement. The center of gravity is located in the abdomen during a sitting posture and transfers from the abdomen to the lumbar spine during movement, and stabilizes at lumber spine (Ebara & Yamamoto, 2001). Crista iliaca transfer velocity measured by change of the pulled or returned cord length with time is assumed to reflect center of gravity transfer velocity during the STS movement. Data was recorded with a personal computer every 1/100 second. Isometric leg muscle strength was measured using the Leg press platform (d-5595, Danno, Japan). Subjects were instructed to perform a maximal exertion from a position with the knee and hip joints fixed at 90 degrees.

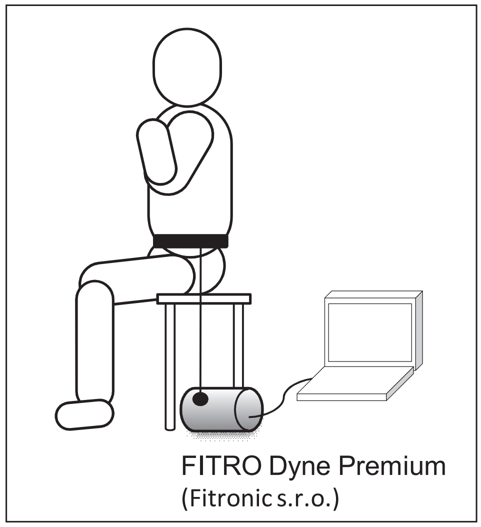

Figure 1. Experimental schema

2.3. Procedure

Prior to measurement of center of gravity transfer velocity, isometric leg muscle strength was measured using a leg press platform. After taking a seated position with a 90 degree knee and hip joint angle with the arms crossed, subjects were told to extend their knee and hip joints with maximal effort to measure leg muscle strength. When measuring center of gravity transfer velocity, the subjects sat on a chair adjusted to their knee height with the following posture: maintain both legs shoulder width apart with bare feet, stretch the trunk in a straight line, hold a 90 degree ankle angle, and fold their arms crossed in front of the chest. Then, they were instructed to stand up as fast as possible from a sitting posture after the tester's signal. After thorough explanation and one practice trial, each test was performed. Isometric leg muscle strength and center of gravity transfer velocity were measured twice with sufficient rest between both trials.

2.4. Parameters

Figure 2 shows a typical example of the center of gravity transfer velocity change with time during STS movement and two parameters selected in this study. In reference to a previous study (Schot et al., 2003), we selected the peak velocity of the center of gravity transfer and the mean velocity from the beginning to the completion of the movement as evaluation parameters. Isometric leg extension strength was used a value divided by body-mass. The mean value of two trials was used for analysis.

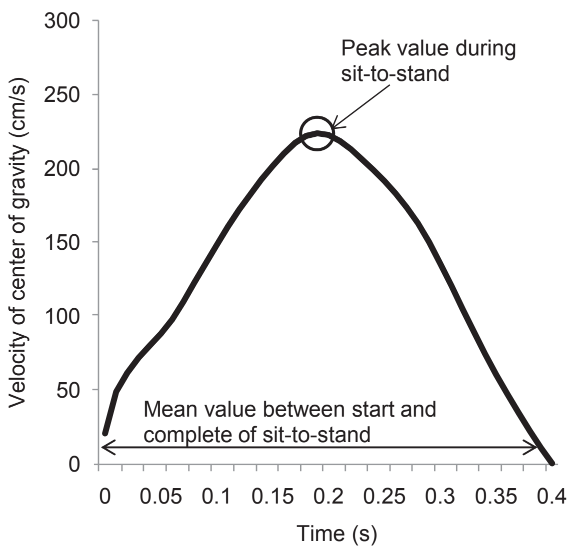

Figure 2. Parameters selected in this study

2.5. Statistical analysis

The cross-correlation was calculated to examine the reproducibility of center of gravity transfer velocity change with time. The intra-class correlation coefficient (ICC) was calculated to examine the reliability of selected parameters. A Bland-Altman plot was used to ascertain a trend between the difference and the mean of both trials for each parameter. Moreover, limits of agreement were calculated to ascertain the amount of error. Pearson's correlation was used to examine the relationships between peak and mean velocities of center of gravity transfer and isometric leg extension strength. A p value less than 0.05 was indicative of statistical significance.

3. Results

Figure 3 shows a typical example of center of gravity transfer velocity change with time during the STS movement of both trials. Center of gravity transfer velocity increased from the beginning of the movement and decreased linearly after reaching a peak value. Moreover, similar changes were found in both trials, and cross-correlations between time course data of center of gravity transfer velocity of both trials were over 0.9 (Range of lag: +/-0.08s). Table 1 shows the means, standard deviations and ICCs of peak and mean velocities of center of gravity transfer. The reliabilities of both parameters were very high (ICC > 0.8). Moreover, there was no trend between the difference and the means of both trials in either parameter; limits of agreement were -31.8 and 32.6 cm/s for peak velocity and -22.8 and 25.0 cm/s for mean velocity, and their 95% confidence interval was -5.7 to 6.5 cm/s and -3.4 to 5.6 cm/s, respectively (Figure4). Figure 5 shows the relationships between peak and mean velocities of center of gravity transfer and isometric leg extension strength. Isometric leg extension strength had a very low relationship with peak velocity (r = 0.07) but a significant and moderate relationship with mean velocity (r = 0.46).

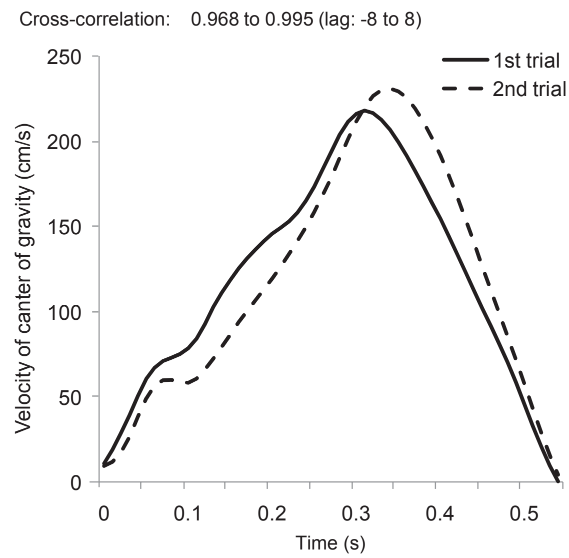

Figure 3. Typical example of center of gravity transfer velocity during STS movement (22yr, Male)

4. Discussion

Center of gravity transfer velocity during a STS movement increased from the beginning of the movement and decreased linearly after reaching a peak value (Figure2). This transfer velocity consists of forward and upward directions (Hirschfeld et al., 1999; Ebara & Yamamoto, 2001). We assumed that the crista iliaca transfer velocity from a sitting to an upright posture directly reflects center of gravity transfer velocity. Center of gravity transfer velocity during the STS movement measured by the present method indicated similar patterns to forward and upward velocities of center of gravity transfer obtained by three dimensional motion analysis reported by Hirschfeld et al. (1999). Moreover, cross-correlations of each subject between time course data of center of gravity transfer velocity in both trials were over 0.9 (Range of lag: +/- 0.08s). The STS movement accompanies a rapid upward transfer of the center of gravity from the sitting to standing positions and involves multiple joints and muscle groups

Table 1. Intraclass correlation coefficients of both parameters

	1st trial		2nd trial		ICC
	Mean	SD	Mean	SD	
Peak velocity	175.0	29.3	174.6	29.0	0.92
Mean velocity	86.3	16.9	85.2	15.3	0.85

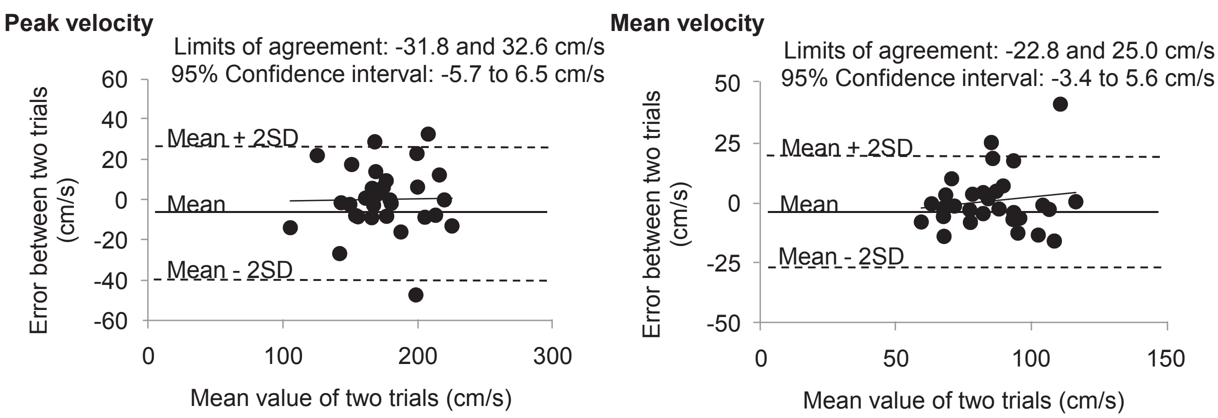

Figure 4. Bland-Altman plot and limits of agreement of both parameters

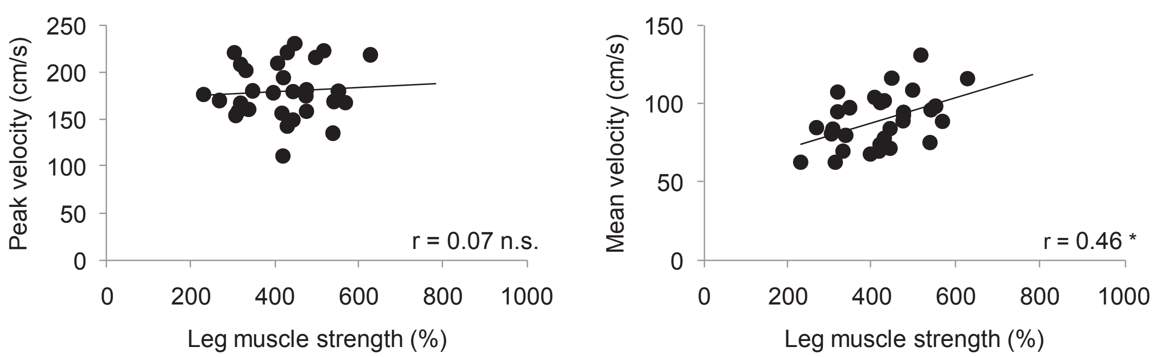

Figure 5. Correlations between leg muscle strength and both parameters. *: $p < 0.05$, Leg muscle strength was indicated by % of body mass

(Doorenbosch et al., 1994; Vander Linden et al., 1994), and several strategies are used to achieve the movement (Hughes et al., 1994). Hence, it was assumed that the STS movement largely differs between trials or among subjects. However, the present results showed similar changes in center of gravity transfer velocity between trials. Hence, the reproducibility of center of gravity transfer velocity pattern during the STS movement is very high.

The reliability coefficients of peak and mean velocities of center of gravity transfer were very high (ICC = 0.92 and 0.85, respectively). Moreover, Bland-Altman plot of both parameters did not show special trends. Namely, relationships between errors with trials and measured values were not found. Hanke et al. (1995) conducted three dimensional motion analysis of STS movement with fast, normal and slow speed using young adults and examined the reliability of peak value and the time to reach the peak value of a center of gravity moment. They reported that although the reliability coefficient of time to reach the peak value of each movement was low to moderate, the peak value itself was very high (over 0.81) and this parameter is useful for clinical evaluation of physical function. This study measured center of gravity transfer velocity by a simpler method than three dimensional motion analysis. Therefore, although peak and mean velocities of center of gravity transfer differ from evaluation parameters based on moment (kg • cm/s), both parameters are closely related to velocity and are also similar to parameters selected by Hanke et al. In addition, both parameters selected in this study have higher reliability than the parameters of Hanke et al. calculated by three dimensional motion analysis. Moreover, various constraints such as posting markers and maintaining a specific posture for calibration are also imposed on subjects during the three dimensional motion analysis. Upon consideration of the above, the measurement method proposed in this study is judged to be very practical because of its decreased physical burden on the elderly.

Meanwhile, isometric leg extension strength showed a low relationship with peak velocity ($r = 0.07$) but a moderate one with mean velocity ($r = 0.46$). Moxley Scarborough et al. (1999) examined the relationships between maximal quadriceps muscle strength and peak forward and upward moments during the STS movement and the completion time of the STS movement. They reported that because maximal quadriceps muscle strength is moderately related to each parameter ($|r| = 0.39$-0.53), improvement of leg muscle function, including the femoral muscle, is useful for the achievement of the STS movement in the elderly.

Moreover, Schot et al. (2003) conducted 8 week (60-90 min/day, three times per week) fitness conditioning based on a general strength training design for the elderly and reported that peak forward, upward and downward center of gravity transfer velocities and completion time improved significantly (increased 16, 59 and 26% and decreased 27%, respectively) as did stability of movement. All parameters were related to center of gravity transfer velocity during the STS movement. Therefore, a significant relationship was assumed to be found between peak velocity of center of gravity transfer and leg muscle function in this study as well as in the above studies. However, no significant relationship was found. This may be the result of using young healthy male adults in this study, as opposed to a different subject population included in previous studies. The STS movement is easier for the young adults to perform because it requires submaximal exertion of strength and there are no large individual differences in the measured values. However, because the elderly have larger individual differences in leg muscle function (Alexander et al., 1991), a measured value is inferred to show this difference even in the exertion of a submaximal STS movement. Moreover, the present method can measure STS movement easily without a large physical burden and can provide feedback for daily life. Further studies will be required to examine the relationships between both parameters and leg muscle function in the elderly and subjects with functional disability.

5. Conclusion

The mean value of the center of gravity transfer velocity during the STS movement has high reliability and a significant relationship with leg extension strength and is judged to be a useful parameter to evaluate leg muscle function. Measurement of center of gravity transfer velocity during the STS movement using the present device is practical and useful for the evaluation of the elderly’s leg muscle function because of decreased physical burden and cost.

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