Paper

Proposal of a Screening Parameter for Preventive Nursing Care by Comparing Center-of-gravity Transfer Velocity during Sit-to-stand Movement between Healthy and Pre-frail Elderly

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This study aimed to examine the difference in center-of-gravity (CG) transfer velocity during sit-to-stand (STS) movements between healthy elderly (HE) and pre-frail elderly (PfE) females. Subjects were 24 HE females (age, 79.5 ± 4.9 years) and 24 PfE females (age, 79.5 ± 4.9 years) who were able to independently stand up from being seated in a chair. Peak and mean velocities (PV, MV, respectively) of CG transfer during STS movements were used as evaluation parameters. HE subjects were significantly faster for both parameters (PV: PfE, 60.8 ± 18.8 cm/s; HE: 99.0 ± 14.3 cm/s; MV: PfE, 29.6 ± 10.7 cm/s; HE, 52.3 ± 10.3 cm/s) and the differences were large (Cohen's d = 2.29 and 2.17). Cutoff values between HE and PfE were 84.8 cm/s (sensitivity, 87.5%; specificity, 95.8%) for PV and 40.1 cm/s (sensitivity, 87.5%; specificity, 79.1%) for MV, and the area under the receiver operating characteristic curves was significantly large (0.953 and 0.927, respectively, for PV and MV). In conclusion, our results showed that CG transfer velocity during STS movements can be used for accurate evaluation of the physical function level of the elderly.

Key words : sit-to-stand movement, pre-frail elderly, screening, cut-off point

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1. Introduction

The sit-to-stand (STS) movement is defined as an upward movement transferring the center of gravity (CG; vander Linden et al., 1994; Doorenbosch et al., 1994), and it is divided into the following two phases: (a) trunk flexion and (b) trunk and knee extension. The former is the phase between trunk flexion with forward (horizontal) transfer of CG from the initiation of movement to lifting of the hips off the chair, whereas the latter is the phase between hip lift-off and standing posture with hips and knees extended. It is important for the elderly to have a minimum level of lower limb strength and balancing ability to achieve rapid, smooth, and stable STS movements. Independence of the elderly is strongly affected by the function level of STS movements (Alexander et al., 1991). Significant relationships between the characteristics of the trunk and knee extension phase of STS movement and muscle strength, activities of daily living score, and fall risk score have been reported in previous studies (Yamada and Demura, 2009a; Yamada and Demura, 2009b; Yamada and Demura, 2010). Thus, measurement and evaluation of CG transfer characteristics during this movement phase is considered important in physical support aimed at maintaining independence of the elderly and the provision of adequate preventive nursing care.

CG position is generally determined by three-dimensional (3D) motion analysis (Hirschfeld et al., 1999; Pai and Rogers 1990; Schot et al., 2003; Moxley Scarborough et al., 1999; Gross et al., 1998; Mourey et al., 1998). However, because the determination of CG position by the above method is problematic in the clinical setting, it is necessary to develop an alternative measurement method capable of easy and accurate measurement of CG transfer velocity. Yamada and Demura (2009a) proposed a method of measuring transfer velocity of the iliac crest which yields a similar displacement to CG during STS movements, and they examined the reliability of measured values and the relationship with lower limb strength in young adult males. Consequently, the above method was reported to be capable of easy and accurate measurement and evaluation of CG transfer velocity during STS movements, and with very good reliability intraclass correlation coefficient (ICC) = 0.85 and moderate relationship with lower limb strength (r = 0.46). However, an adequate screening parameter aimed at preventive nursing care has not been proposed to date.

When assistance or nursing care is required, a great deal of work and time input is required to improve the level of physical function so that individuals can regain their independence. This is the focus of preventive nursing care. Community support projects have recently been developed in Japan for the elderly who need assistance or nursing care, the so-called pre-frail elderly (PfE). This group is defined as elderly subjects >65 years of age with marked decrease in vital functions, such as motor and oral functions, and who are likely to need nursing care in the near future. According to the Ministry of Health, Labour and Welfare (2011), this group totaled 943,344 (3.2% of the elderly population of 29,066,130) in March 2011. Although an increase in the numbers falling into this group in future as well as that of the elderly needing assistance or nursing care is of concern, the focus of many projects related to assistance or nursing care status of the PfE is aimed at preventing their condition from deteriorating. Therefore, it is desirable to create a screening parameter for the PfE with a certain level of physical function and who can participate in a physical improvement program. Such a parameter would be calculated on the basis of a marked decrease in vital functions as its baseline.

Therefore, this study aimed to clarify whether a simple and easy method of evaluating physical function using CG transfer velocity could discriminate between physical function in the PfE and healthy elderly (HE), and to calculate the cutoff value of the above transfer velocity during STS movements with regard to preventive nursing care.

2. Methods

2.1. Subjects

Study participants were 24 HE females (age, 79.5 ± 4.9 years; height, 145.1 ± 4.8 cm; body mass, 46.3 ± 7.3 kg) and 24 PfE females (age, 79.5 ± 4.9 years; height, 143.3 ± 5.9 cm; body mass, 47.9 ± 7.9 kg) with no lower limb disorders, who were capable of standing up independently from a chair. PfE were defined as elderly subjects (>65 years) with a high likelihood of needing nursing care in the near future and judged by the answer for basic check list used in grasping target for second prevention operations by the Ministry of Health, Labour and Welfare. From the results of this basic check list, the elderly who were judged to target for second prevention were indicated as requiring preventive nursing by the Community General Support Centers of individual local governments and guided to participate in the operations of second prevention by day care or visiting. The present subjects were judged to target for second prevention by the basic check list, and to participate in a program aimed at improving locomotor and oral cavity function, nutrition, gonalgia, lumbago and prevention/supporting staying indoors, cognitive function, and depression by day care. No significant intergroup differences were found in regard to age and physical characteristics (Table 1). All

Table 1. Age and physique characteristics of the healthy and pre-frail elderly

	Pre-frail elderly		Healthy elderly				
	n = 24		n = 24		t-value	*p*	d
	Mean	SD	Mean	SD			
Age, years	79.5	4.9	79.5	4.9	0.03	*0.977*	0.01
Height, cm	143.3	5.9	145.1	4.8	1.12	*0.268*	0.33
Body-mass, kg	47.9	7.9	46.3	7.3	0.70	*0.490*	0.21

d Cohen's d

subjects underwent a physical examination and were judged capable of participating in the present study. Written informed consent was obtained from all subjects after they had been given a full explanation of the study purpose and protocol. The study protocol was approved by the Ethics Committee on Human Experimentation of Faculty of Education, Kanazawa University (authorization number: 19-18).

2.2. Experimental equipment

Figure 1 shows the experimental schema of the study. CG transfer velocity during STS movements was measured by FITRO Dyne Premium (Fitronic s.r.o., Slovakia). This device measures the length of a cord pulled or returned from the bobbin, and incorporates a built-in rotary encoder. As shown in Figure 1, subjects wore a belt at the level of the iliac crest. The cord was fixed at this position on the belt, and the length that the cord moved was measured against time with each STS movement. CG is located abdominally during the sitting posture but transfers to and stabilizes at the lumbar spine during movement (Ebara and Yamamoto 2001). Iliac crest transfer velocity measured from the distance traveled by the cord length against time is assumed to reflect CG transfer velocity during STS movements. Data were uploaded to a personal computer every 0.001 s.

2.3. Experimental procedure

Prior to measurement of CG transfer velocity during STS movements, subjects were instructed to adopt the appropriate sitting posture and movement during measurement. Subjects maintained both lower limbs (with bare feet) one shoulder width apart, held the trunk vertical, ankles at a 90º, and crossed their arms over their chest. STS movements were carried out as quickly as possible from a sitting posture after the tester gave the signal. CG transfer velocity during movements was measured twice, with sufficient rest allowed between trials to prevent fatigue. Chair height was adjusted to the height of individuals' knees.

2.4. Parameters

Figure 2 shows a typical example of changes in CG transfer velocity over time during STS movements for the two parameters selected in this study, which were selected in reference to a study by Schot et al. (2003): maximum and mean velocity of CG transfer from start to finish of the movement. The mean value of two trials was used for analysis.

2.5. Statistical analysis

Intertrial reliability of peak velocity and mean velocity (PV and MV, respectively) of CG transfer during STS movements in both groups was examined by intraclass correlation coefficient (ICC). An independent t-test was used to examine intergroup difference between PV and MV of CG transfer during STS movements, and mean difference was calculated by Cohen's d (Cohen, 1988). Moreover, an adequate cutoff value for PV and MV of CG transfer during STS movement for both groups

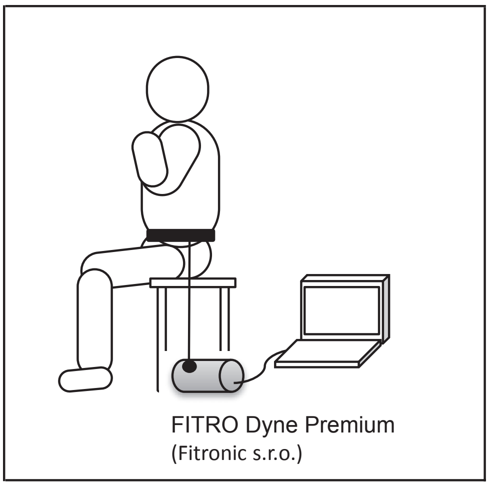

Figure 1. Experimental schema

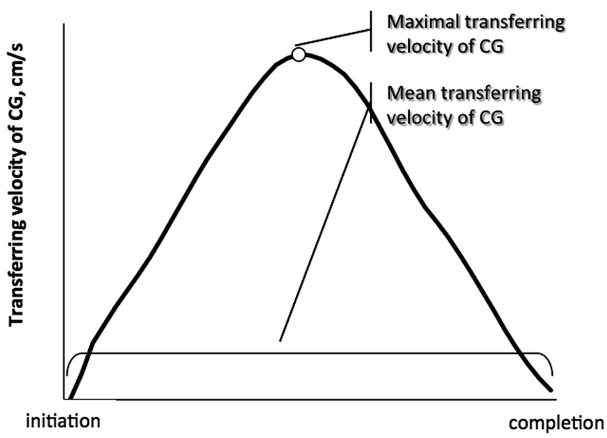

Figure 2. Parameters selected in this study CG center of gravity

was calculated by the area under the receiver operating characteristic (ROC) curve (AUC) and 95% confidence intervals (CI), sensitivity, and specificity by ROC analysis. The cutoff value was determined by both of the following indices: minimum = $(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2$ (Perkins and Schisterman 2006; Akobeng 2007); and maximum = sensitivity + specificity – 1 (Fluss et al., 2005; Akobeng 2007). p-values of <0.05 indicated statistical significance.

3. Results

Table 2 shows the intertrial reliability coefficients of PV and MV for CG transfer velocity during STS movements for both groups. No significant difference was observed in both parameters in both groups, and coefficients were significantly high (ICC = 0.77–0.94). Figure 3 shows typical examples of changes in CG transfer velocity during STS movements in both groups. In both groups, transfer velocity increased at the start of STS movement and decreased after reaching a peak value. Peak transfer velocity in HE was higher and was attained sooner than that in PfE. Figure 4 shows mean intergroup differences in CG transfer velocity. Both parameters were significantly higher in HE females than in the PfE females (d = 2.29 and 2.17, respectively). Figure 5 shows ROC curves, AUC, sensitivity, specificity, and cutoff values for PV and MV of CG transfer during STS movements. AUC (0.953 and 0.927, respectively), sensitivity (87.5% for both parameters), and specificity (95.8% and 79.1%, respectively) for both parameters were favorable, with cutoff values of 84.8 and 40.1 cm/s for PV and MV, respectively.

4. Discussion

Intertrial reliability coefficients of PV and MV of CG transfer during STS movement were high (ICC = 0.77–0.94; Table 2) in both groups. Hanke et al. (1995) performed a 3D motion analysis on fast, normal, and slow STS movements in young adults, and examined the intertrial reliability of the peak values of CG momentum and time taken to attain these. Consequently, although intertrial reliability coefficients of time to attain peak

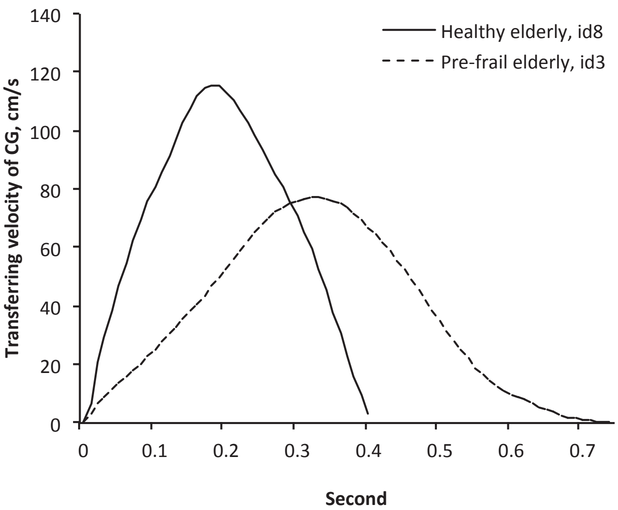

Figure 3. Typical example of the change in center of gravity transferring velocity during STS movement in the healthy and pre-frail elderly
CG center of gravity

Table 2. Trial-to-trial reliability of the peak and mean velocity of CG transfer during STS movement in the healthy and pre-frail elderly

			1st trial		2nd trial					
		n	Mean	SD	Mean	SD	F-value	*p*	ICC	*p* <
Maximal velocity of CG, cm/s	Healthy elderly	24	97.7	13.9	100.3	17.5	3.67	*0.068*	0.90	*0.001*
	Pre-frail elderly	24	58.5	20.2	63.0	18.9	0.84	*0.369*	0.77	*0.001*
Mean velocity of CG, cm/s	Healthy elderly	24	51.9	10.9	52.8	11.7	1.35	*0.258*	0.94	*0.001*
	Pre-frail elderly	24	28.9	10.7	30.2	11.4	0.21	*0.650*	0.80	*0.001*

CG: center of gravity

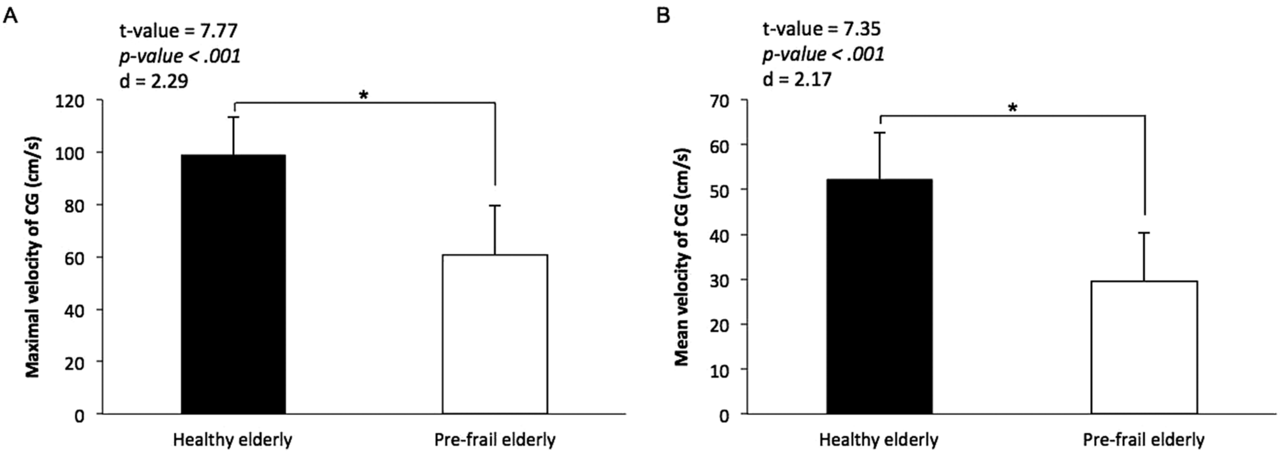

Figure 4. The difference of the peak (A) and mean (B) velocity of center of gravity transferring during STS movement between healthy and pre-frail elderly

CG center of gravity, d Cohen'sd, * p < .05

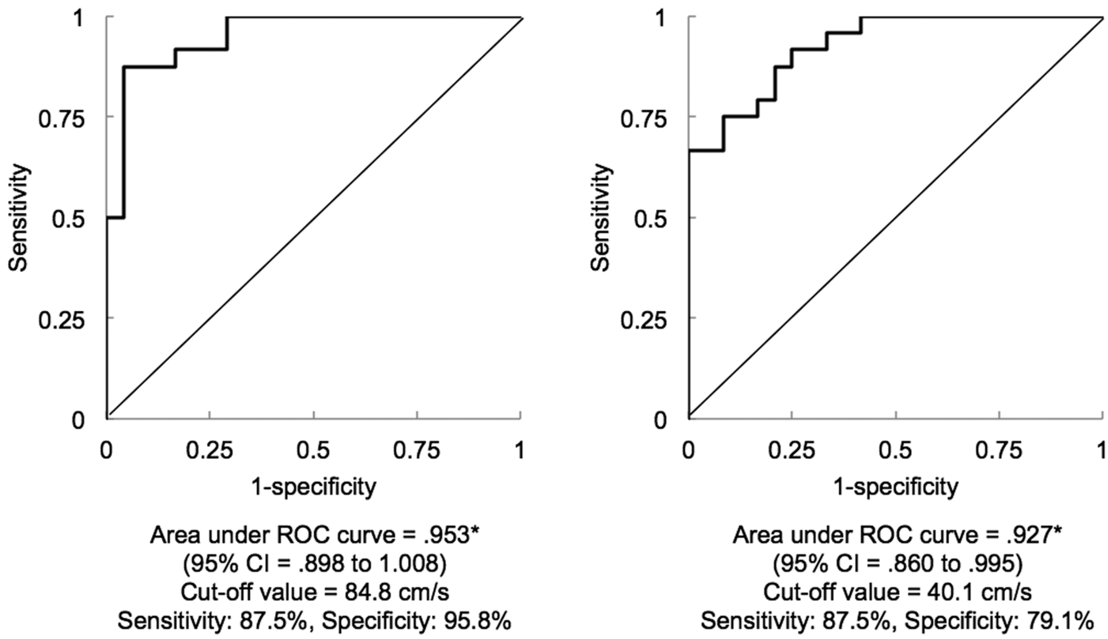

Figure 5. ROC curve, AUC and cut-off value of the peak and mean velocity of center of gravity transferring during STS movement

* *p* < .05, CI Confidence interval

value at all speeds were moderate or low, the peak value was very high (>0.81), and these authors reported their findings as being useful in the clinical evaluation of physical function. The reliability coefficient of both parameters selected in the present study was equal to or greater than that of the parameters selected for 3D motion in the report by Hanke et al. Although the parameters in the present study were not evaluated by 3D motion analysis, the ease of measurement of these parameters may be more applicable to the clinical evaluation of physical function. In short, investigation using 3D motion analysis is difficult because of the necessity of placing markers and it requires complicated data processing. Moreover, when subjects are selected from the PfE as in the present study, it is desirable that they fully understand the test conditions and a large burden is not placed upon them. In particular, the PfE have decreased cognitive and vital functions in addition to a marked decrease in physical function, and it is highly likely that they will require assistance or nursing care in future. Thus, because the intertrial reliability of the values measured in this study was found to be high, with a marked decrease in both physical and cognitive functions in both groups, the test method described here is considered applicable for such individuals.

The time to attain peak value and resolution of CG transfer velocity in HE were very similar to those observed in young adults in a study by Yamada and Demura (2009a). That study examined the relationship between CG transfer velocity during STS movements and isometric knee extension strength in young adults using a similar method to that of the present study. However, peak values differed twofold (HE in the present study, approximately 120 cm/s; young adults reported in Yamada and Demura, approximately 210 cm/s). Moreover, the magnitude of, and time to attain peak value were markedly lower and slower, respectively, in PfE than in HE and young adults (Figure 3). The findings of the study by Yamada and Demura in regard to time course of CG transfer velocity during STS movements are similar to those for PV and MV noted in the present study. Yamada and Demura (2009a) reported significant and moderate relationships between the same parameters used in the present study and isometric knee extension strength recorded in young adults. Moreover, Schot et al. (2003) examined changes in CG transfer velocity during STS movements with strength training, and reported that movement speed and stability of STS movements was enhanced following training. From the foregoing, it can be inferred that the ability to carry out STS movements is dependent on muscle strength and power, and that decreased velocity of CG transfer during STS movements in both groups in our study as compared with young adults may be attributed to compromised physical functions such as muscle strength and power. Moreover, such restriction on movement may be more marked in PfE than in HE, and the parameters investigated in our study are deemed to be useful in discriminating between the two groups with regard to their future requirements for assistance and nursing care.

The cutoff values for PV and MV during STS movements, which discriminate between HE and PfE, were 84.8 cm/s (sensitivity, 87.5%; specificity, 95.8%) and 40.1 cm/s (sensitivity, 87.5%; specificity, 79.1%), respectively. Moreover, AUC for both parameters (>0.9) was high (PV: AUC = 0.953, 95% CI = 0.898–1.008; MV: AUC = 0.927, 95% CI = 0.860–0.995). Akobeng (2007) classified the discriminant ability of this test on the basis of AUC as either high (>0.9), moderate (0.7–0.9), or low (0.5–0.7), and reported that values >0.9 were desirable in screening tests. Because PV and MV of CG during STS movements in this study fulfilled Akobeng's criteria, they are judged as useful screening parameters capable of discriminating between HE and PfE. Moreover, sensitivity and specificity of both cutoff values were high for both parameters. Hebert et al. (1996) altered the sensitivity and specificity of cutoff values that had discriminated against the risk of lowered physical function in the community-dwelling elderly in previous studies, and reported values of 79%–97% and 50%–82%, respectively. Seino et al. (2009) constructed a test battery for PfE and examined the cutoff value that discriminated between HE and PfE, reporting sensitivity and specificity as 82.2% and 81.9%, respectively. In the present study, the sensitivity and specificity for PV and MV of CG transfer during STS movements were equal to and greater than those of the abovementioned studies. However, those studies screened physical functions in the elderly using numerous (4–11) items, and it is considered desirable in such studies to use fewer screening items over a shorter time span with regard to the physical demands of such tests. Although CG transfer velocity during STS movements in this study was evaluated by only one test, this was judged to be very useful because this test can accurately screen PfE with minimum inconvenience. Meanwhile, Seino et al. (2009) examined the cross-validity of their cutoff value and reported that this was capable of screening with high precision among subjects. Because cross-validity was not examined in the present study, we cannot comment on whether similar results could be obtained using other subjects. However, similar results may be obtained because our method showed greater precision than that of Seino et al. (2009). Further research is required to compare results from different studies.

5. Conclusion

CG transfer velocity during STS movements is a useful parameter with which to evaluate physical function status and screen the PfE.

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