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A Study of the Reliability of a New Dynamic Trunk Balance Measuring Device

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Abstract

Objective: A new method of evaluating sitting balance that improved on a previous device was developed. However, the reliability of body trunk balance measured by this device is unknown. The purpose of this study was to verify its reliability within and between examiners.

Methods: This was a cross-sectional study involving healthy adult males (age 20 to 45 years) who were able to walk. The seating surface could be vibrated at a constant cycle (0.2 Hz, 0.4 Hz, 0.6 Hz), the pressure of the seating surface under vibration was detected by three small force sensors installed under the seating surface, and the center of pressure (COP) could be calculated. Measurements were performed by two examiners, and each participant was measured three times in a sitting position. The platform was tilted to the left and right at a front face inclination angle ± 7°, with two cycles in 10 s (0.2 Hz), while the participant's gaze was fixed to a mark 2 m in front of the participant at eye height, and the participant was asked to maintain the position of the head constant. Measurement was then performed for 30 s. The fluctuation of the center of gravity on the seat surface over time was measured, and the total trajectory length of the COP was used as the evaluation item. To examine the reliability of the measuring instrument, ICC (1.3) was obtained as the intra-class correlation coefficient for intra-examiner reliability, and ICC (2.1) was obtained for inter-examiner reliability.

Results: The ICC for intra-examiner reliability was 0.815, and that for inter-examiner reliability was 0.789. No adverse events occurred during balance evaluation.

Conclusion: This device could be used to evaluate dynamic trunk balance with relatively high reliability. Thus, the present device appears to be useful for quantitatively evaluating dynamic trunk balance conveniently and safely.

Keywords: Trunk balance; Trunk stability; Sitting balance; Dynamic balance

Introduction

The percent of people over the age of 65 years in Japan was 23.1% in 2010, and it is expected to reach 33.4% in 2035 [1]. It is thought that the aging of society will advance with remarkable speed in the future. The most common causes of people being bedridden in Japan are cerebrovascular disease, dementia, and senescence. Fractures due to falls are also serious problems that cause disability and interfere with independent living [2]. Therefore, prevention of falls and fractures is very important to maintain the healthy life span of elderly persons. Balance impairment has been cited as a risk factor for falling [3], and it is important to evaluate it properly. Measurement of balance capability involves static assessments, such as a standing center-of-gravity examination [4], a one-leg standing test, and dynamic assessments, such as the timed up and go test [5] and the functional reach test [6], but in both cases, there is a risk of falling during the assessment itself. There have also been reports that the trunk muscle strength of the elderly is important for fall prevention and balance ability [7].

We tried trunk balance evaluation with the patient in the sitting position in order to safely and easily evaluate the balance ability of elderly persons with a risk of falling. However, in order to evaluate the trunk balance ability of patients in a sitting position, which can provide greater stability than the standing position [8], some external action force (disturbance) is necessary. Therefore, we have developed a sitting balance measurement device capable of measuring trunk balance ability by adding a constant disturbance that periodically tilts the seating surface in the frontal plane, and we have reported its usefulness [9,10]. In this study, a new method of evaluating sitting balance that improved on the previous platform was created. The improvement with this device is that the seat surface can be inclined up to ± 7° more than the previous platform in the frontal plane, and the inclination is variable. For elderly people with a high risk of falling, body trunk balance measurement can be handled, even for athlete-level subjects, with less danger. However, the reliability of body trunk balance measured by this device is unknown.

The purpose of this study was to verify reliability within and between examiners based on the hypothesis that the new sitting balance gauge has high reliability.

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Materials and Methods

This was a cross-sectional study to confirm the reliability of this new method of assessing balance ability in healthy participants. The participants were healthy adult men ranging in age from 20 to 45 years who were able to walk. Exclusion criteria were those who had a disease making them prone to falls, those who had previously undergone spinal surgery, those who were on pharmacological therapy for some disease, those with communication disabilities, and those who were judged unsuitable as participants.

The new type of dynamic locus balance evaluator used in this study is shown in Figure 1. The seating surface can be vibrated at a constant cycle (0.2 Hz, 0.4 Hz, 0.6 Hz), the pressure of the seating surface under vibration is detected by three small force sensors installed under the seating surface, and the center of pressure (COP) can be calculated.

Figure 1: The new type of dynamic locus balance evaluator.

The measurement was performed by two examiners, and each participant was measured three times after 2 practice attempts. The participants adopted a sitting position with the lower limbs completely separated from the floor surface on the measuring device, and the arms were crossed at the front of the chest so as to eliminate the influence of the upper limbs. In this state, the platform was tilted to the left and right at a front face inclination angle ± 7°, with two cycles in 10 s (0.2 Hz). While the seating surface was swaying, the participant's gaze was fixed to a mark about 1 cm in diameter set at a position 2 m in front of the participant at eye height, and the participant was asked to maintain the position of the head constant. Measurement was then performed for 30 s. The fluctuation of the center of gravity on the seat surface over time was measured, and the total trajectory length of the COP was used as the evaluation item.

The purpose, method, privacy protection, etc. of this research were explained to each potential participant, and written, informed consent was obtained from each one.

In the statistical analysis, to examine the reliability of the measuring instrument, ICC (1.3) was obtained as the intra-class correlation coefficient for intra-examiner reliability, and ICC (2.1) was obtained for inter-examiner reliability. For the analysis, SPSS version 19.0 for Windows (SPSS, Chicago, IL, USA) was used, and the significance level was set to 5%.

Results

Table 1 shows the outline of the participants. There were no adverse events during measurement.

Characteristic	**Mean ± SD**
Age (y)	36 ± 8
Height (cm)	171.0 ± 9.6
Weight (kg)	65.0 ± 5.0
BMI (kg/m^2)	22.2 ± 1.6

Table 1: General characteristics of participants (SD: Standard Deviation; BMI: Body Mass Index).

The results for the total COP trajectory length measured with the new sitting balance gauge are shown in Table 2. The intra-examiner reliability was 0.815, and the inter-examiner reliability was 0.871.

Trial				**ICC1**.3
	Subject 1	Subject 2	Subject 3	
COP LNG (mm), mean ± SD	1151 ± 116	1053 ± 37	1102 ± 145	0.815

Table 2: Intra-examiner reliability of measurement (COP LNG: trajectory length of center of pressure; ICC: Intraclass Correlation Coefficient; SD: Standard Deviation).

Trial			**ICC2.1**
	Examiner A	Examiner B	
COP LNG (mm), mean ± SD	1125 ± 88	1078 ± 88.8	0.871

Table 3: Inter-examiner reliability of measurement (COP LNG: trajectory length of center of pressure; ICC: Intraclass Correlation Coefficient; SD: Standard Deviation).

Discussion

In this study, the reliability of trunk balance ability measured with a new sitting balance measurement device was verified using intra-class correlation coefficients. According to the ICC criteria by Fleiss et al., ICC>0.75 is classified as excellent reliability, with fair to good reliability with the ICC=0.40-0.75, and poor reliability with the ICC<0.40 [11]. From the results of this study, the new sitting balance gauge was seen to be very reliable both within and between examiners.

Maaswinkel et al. reviewed methods for assessment of trunk stabilization and distinguished four main categories of perturbation methods: trunk loading, trunk unloading, moving platform; and upper limb (un) loading [12]. They reported that applying the perturbation by a moving/tilting platform is only suitable if the pelvis of the subject is restrained in either a seated or a standing position. Our device is distinguished by a moving platform, and the seated position is suitable for evaluation of trunk balance.

As a quantitative evaluation of trunk balance in the sitting position, Cholewicki et al. reported a method for quantifying postural control of the lumbar spine during unstable sitting with a hemispherical unstable chair with a force plate directly underneath, and they evaluated the locus of COP [13]. Then, van Dieen et al. measured trunk stability with a similar device. They repeated every test 4 times and reported that the within-examiner reliability of the locus of COP was ICC=0.63 [14]. In a report using an unstable chair with a spring, with 5 measurements after 11 practice exercises, the within-examiner reliability of the locus of COP was ICC=0.76-0.87, and the between-examiner reliability was ICC=0.26-0.43 [15]. In a report using a device called a physical human-robot interaction, trunk stability was evaluated by the data obtained from the encoder of 3 measurements after 4 practice exercises, with within-examiner reliability of ICC ≥ 0.84. They reported higher reliability than the previous report [16].

Quantitative evaluation of trunk stability using an unstable chair was found to provide good reliability if a sufficient number of measurements were performed. However, the trunk balance evaluating apparatuses using unstable chairs that have been reported so far were all equipped with a plate for assisting the lower limbs, and the influence of the lower limb under measurement could not be excluded.

Our new sitting balance device was able to safely and precisely measure dynamic trunk balance without any influence of the lower extremities, because there was no plate assisting the lower limbs. In addition, both within-examiner and between-examiner reliabilities were excellent with 3 measurements after 2 practice exercises in this study.

As a limitation of this study, there were few participants, only healthy adult males were evaluated, the evaluations were done only on the same day, and the results were not compared with those of other clinical laboratory methods.

Conclusion

This device could be used to evaluate dynamic trunk balance with relatively high reliability. The present device appears to be useful for quantitatively evaluating dynamic trunk balance conveniently and safely.

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