

Effects of balance evaluation comparison of dynamic balance and Y balance

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This study measured balance ability using both an existing clinical test tool, the Y-balance test (YBT), and an automated version of the YBT named the dynamic balance test (DBT) developed in this study. Correlations between the two methods were examined to determine whether the DBT can be used as an objective tool for balance ability evaluation. The subjects included in the study were 32 healthy male adults in their 20s, who were randomized into two groups, YBT and DBT, to compare the balance ability between the two groups. The maximum stretching distances of both legs in the anterior (AT), posteromedial (PM), and posterolateral (PL) directions were measured. Furthermore, to compensate for the difference in length between left and right legs, the mean and standard deviations were determined using the standardization formula,


and the standardized values were represented as percentages. For the statistical analysis of the data, an independent *t*-test was performed using SPSS ver. 18.0. The test results showed no significant differences between the two groups in both left and right legs in the AT, PM, and PL directions ($P > 0.05$). Therefore, measuring balance ability with the DBT, which uses digital sensor measurement technology (an automated data recording, wireless data transmission, storage, and management system; measurement is possible even by one subject of balance ability test), was found to be advantageous in respect to the YBT in terms of time, efficiency, and convenience.

Keywords: Balance, Dynamic balance test, Y-balance test, Leg length

INTRODUCTION

Balance is an ability to maintain a posture through the interactions between the musculoskeletal system and the nervous system and to maintain a state of equilibrium while keeping the center of gravity within the base of support (Nichols, 1996). Balance is accomplished through the complex process of identifying the movements of the body through the sensory organs, inputting them into the central nervous system, sending them out to the musculoskeletal system after sensory integration, and then performing the reaction. Balance is an indispensable element in all functional activities of daily life, including standing up, sitting, and walking (Yavuzer et al., 2006). It is a high level integration process that includes adaptive and predictive mechanisms as well as an information integration process that includes musculoskeletal elements—such as muscular strength, the flexibility

of the spine, and joint movement range—and the proprioceptive sense, the vestibular organ, and the visual organ. Hence, the ability to maintain balance is the most basic and indispensable element of daily life and purposeful human activity (Cohen et al., 1993) and is integral to the many tasks that require the adjustment of body posture and balance with regard to space. The adoption of correct or stable posture through balance is significant because it supports and protects the body from injury or progressive disability and helps individuals to maintain the health, structure, and function of the body (Eng and Chu, 2002). Balance can be considered to be either static or dynamic. Static balance is a state wherein the body can stand upright on a steady support surface, whereas the body is moving during dynamic balance. Movements in an unstable environment can promote dynamic balance and posture control more than movements in a stable environment because they can potentially change the order

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Received: October 6, 2018 / Accepted: October 30, 2018

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of the nerve root mobilization pattern (Franklin et al., 2003; Gribble et al., 2004).

Dynamic balance is an ability to maintain a desired posture by putting the center of gravity within the base of support while the body is moving (Wade and Jones, 1997). Evaluation tools for dynamic balance include the Berg balance scale, the star excursion balance test (SEBT), and the Y-balance test (YBT) (Berg et al., 1992; Duncan et al., 1990). The Berg balance scale evaluates static and dynamic balance abilities through 14 items related to three categories: sitting, standing, and posture change. However, the discrimination of the measurement tool can be decreased because it has a high risk of a ceiling effect (de Oliveira et al., 2008; Hatch et al., 2003; Mao et al., 2002; Salbach et al., 2001). The SEBT is a dynamic balance measurement tool that evaluates muscular strength, flexibility, and the proprioceptive sense of the legs. In this test, eight lines are drawn at 45° intervals; the leg to be tested is placed at the center, and the other leg is stretched as far as possible, and the reach is measured (Coughlan et al., 2012; Plisky et al., 2009). In contrast, the YBT only measures three directions— anterior (AT), posterolateral (PL), and posteromedial (PM)—thus increasing repeatability and reducing the evaluation time; moreover, the YBT has high intrarater reliability (intraclass correlation coefficient = 0.88–0.99) (Coughlan et al., 2012; Plisky et al., 2009; Shaffer et al., 2013). The YBT is more reliable than the SEBT because it uses a standardized kit, thus reducing the scope of errors, whereas the SEBT uses various measurement methods (measurement of the position of the foot that touches the floor, measurement with the leg stretched on the floor or held in the air, etc.) (Plisky et al., 2009).

However, YBT can only be undertaken when the rater, inspector, and recorder are present. The rater directly checks the measured values after the test, records them on the test sheet, and indicates the balance ability level. The rater must also visually check errors regarding the subject's performance and return the box-shaped bars that were moved during the balance measurement to their original position. To address these problems, this study developed the dynamic balance test (DBT) using digital sensor system measurement technology (an automated data recording, wireless data transmission, storage, and management system; measurement is possible only by one subject of balance ability management). Its correlation with YBT is examined to determine the usability of the DBT as an objective tool for balance evaluation.

MATERIALS AND METHODS

Participants

The subjects of this study were 32 healthy adult males who were studying at Dong-eui University in Busan. Only those who expressed an intention to participate in this experiment after listening to the content and purpose of this study were selected as subjects. They had not had any musculoskeletal diseases in last three months, walk normally, and had no ankle pain. Before starting the experiment, they were given a sufficient explanation of its purpose and method, voluntarily participated in the experiment, submitted written consent, and participated in the experiment in a random sequence. This study was approved by the research ethics committee (DIRB-201803-HR-E-15).

Measurement tool

Y-balance test

In this study, the balance ability of the subjects was measured using the YBT, which measures muscular strength, flexibility, and the proprioceptive sense of the lower limbs in three directions—AT, PM, and PL—with one leg supporting the body and the other leg stretched (Plisky et al., 2009). For both legs, the distance from the center footrest to the tip of the stretched leg was measured in centimeter units. To minimize the learning effect, participants practiced the position six times (Hertel, 2000), and the maximum value of the three measurements was used. An attempt was regarded as a failure and the subject measured again if the supporting foot was removed from the ground, if the body was supported with the stretched foot in order to keep balance, or if the subject did not return to the starting position (Plisky et al., 2009). Furthermore, the lengths of the left and right legs were measured to compensate for differences in leg lengths. To measure the leg length, the length from the anterior superior iliac spine (ASIS) to the medial malleolus was measured. The mean and standard deviations were determined using the standardization formula, and the standardized values were represented as percentages. The standardization formula was: $\text{measured value}/\text{leg length} \times 100$ (Plisky et al., 2006).

Dynamic balance test

In this study, the balance ability of the subjects was measured using the DBT, which uses the same platform, measurement method, and evaluation criteria as those of the YBT. This is an automated system that uses digital sensor system measurement technology (an automated data recording, wireless data transmis-

sion, storage, and management system; measurement is possible only by one subject of balance ability management). The stretched point during the balance measurement was measured to two decimal places in centimeter units. Furthermore, the subjects practiced six times before measurement to minimize the learning effect (Hertel, 2000), and the maximum value of three measurements was used. The attempt was regarded as a failure, and the subject was measured again, if the body was supported with the stretched foot in order to keep balance, or if the subject did not return to the starting position (Plisky et al., 2009). Furthermore, the lengths of the left and right legs were measured to compensate for differences in leg length. To measure the leg length, the length from the ASIS to the medial malleolus was measured. The mean and standard deviations were determined using the standardization formula, and the standardized values were represented as percentages. The standardization formula was: measured value/leg length \times 100 (Plisky et al., 2006).

Measurement method

The subjects were randomized into two groups: YBT group ($n = 16$) and DBT group ($n = 16$). After listening to the explanation about the experiment, the lengths of both legs were measured with a tape measure. Before performing the task, participants practiced 6 times to minimize the learning effect. For both groups, the maximum distance that they can stretch their foot through box-shaped bars in the AT, PM, and PL directions before returning were measured. To prevent a compensation effect, participants took a rest for 30 sec after each measurement. This test was performed three times for each foot, and the maximum value of the three measurements was used as the result.

Data analysis

The data collected from this study were analyzed with IBM SPSS ver. 18.0 (IBM Co., Armonk, NY, USA). The mean and standard deviations of each measured item were calculated. The significance level of the balance ability between the two groups was determined using the independent t -test. The significance

Table 1. Characteristics of study participants ($n = 32$)

Characteristic	Value
Gender, male:female	32:0
Age (yr)	22.57 \pm 2.02
Height (cm)	175.57 \pm 9.77
Weight (kg)	73.57 \pm 13.26

Values are presented as number or mean \pm standard deviation.

level of statistical processing was set at 0.05.

RESULTS

General characteristics of the research subjects

The subjects were 32 males; their age was 22.57 \pm 2.02 years, their height was 175.57 \pm 9.77 cm, and their weight was 73.57 \pm 13.26 kg. The general characteristics of the subjects are listed in Table 1.

Comparison of balance ability between two groups

Comparison of right leg balance ability between two groups

The measured distances of the Right leg in the AT, PM, and PL directions showed no significant difference between the YBT and DBT groups ($P > 0.05$) (Table 2).

Comparison of left leg balance ability between two groups

The measured distances of the left leg in the AT, PM, and PL directions showed no significant difference between the YBT and DBT groups ($P > 0.05$) (Table 3).

DISCUSSION

Balance is classified as static or dynamic. Static balance is an ability to maintain a desired posture while keeping the center of gravity within the base of support without shaking the body. Dynamic balance is an ability to maintain a posture while keeping

Table 2. Comparison of right leg maximum stretching distances of Y-balance and dynamic balance

Direction	Y Balance ($n = 16$)	D Balance ($n = 16$)	t	P -value
Right AT (cm)	70.32 \pm 7.92	68.34 \pm 7.04	0.753	0.468
Right PM (cm)	112.22 \pm 7.97	114.33 \pm 6.86	-0.814	0.439
Right PL (cm)	114.48 \pm 7.12	111.49 \pm 6.06	1.288	0.215

Values are presented as mean \pm standard deviation.

Y Balance, Y-balance; D Balance, dynamic balance; AT, anterior; PM, posterior medial; PL, posterior lateral.

Table 3. Comparison of left leg maximum stretching distances of Y-balance and dynamic balance

Direction	Y Balance ($n = 16$)	D Balance ($n = 16$)	t	P -value
Left AT (cm)	71.17 \pm 7.49	69.01 \pm 5.71	0.92	0.37
Left PM (cm)	114.45 \pm 6.50	116.02 \pm 8.66	-0.58	0.57
Left PL (cm)	114.07 \pm 7.94	112.81 \pm 6.82	0.48	0.63

Values are presented as mean \pm standard deviation.

Y Balance, Y-balance; D Balance, dynamic balance; AT, anterior; PM, posterior medial; PL, posterior lateral.

the center of gravity within the base of support while one's body is moving and there is an external stimulus or one wants to maintain a desired posture (Berger et al., 2008). The representative test for measuring dynamic balance is the YBT, which was developed from the modified SEBT. The YBT tests balance in three directions (AT, PM, and PL) using the lower limbs. It is a simple and reliable test for dynamic balance (Lai et al., 2017; Plisky et al., 2009; Shaffer et al., 2013; Wilson et al., 2018). In this study, balance ability was measured using YBT and DBT, which is an automated version of YBT, in order to find whether the DBT can be used as an objective tool for balance evaluation by examining the correlation between YBT, which is an existing clinical evaluation tool, and DBT. The test results showed no statistically significant differences in the AT, PM, and PL directions both for left and for right legs.

The YBT uses a platform for measuring the distance of three box-shaped bars in the AT, PM, and PL directions. The posterior bars are located at 135 degrees from the AT bar, and the angle between the two posterior bars is 90 degrees (Plisky et al., 2009). This method was developed to solve the limitation of the traditional SEBT test method. The YBT can make a better evaluation of the movements of subjects because it can check the stretched distance, determine success or failure by checking whether the foot used for balancing is removed from the ground, and whether the stretched foot touches the ground, and it also improves the reproducibility of the measurement (Plisky et al., 2009). However, remeasurement using the YBT is time consuming as the equipment needs resetting each time. Measurement can also only be performed when the rater, inspector, and recorder are present, and the YBT has a measurement accuracy problem due to the visual error of the inspector. Thus, the rater must pay more attention to errors that may occur during the measurement of dynamic movements, such as the removal of the foot from the footrest, and it is difficult to mark the distance reached while paying attention to the movement of the subject. Furthermore, it is cumbersome for inspectors or recorders to check the measurements and record them on the test sheet, and it is probable that the inspection results may be inaccurate due to the psychological pressure that the subject experiences because both the inspector and recorder are watching.

After measurement, the box-shaped bars are returned to their original position by the rater. Each platform indicates the measurements in five millimeter units (Plisky et al., 2009), and the test results may vary according to the cognitive ability and mobility of the subjects because errors must be checked with the naked

eye by the rater (Lark et al., 2009). Therefore, inaccurate measurements may be introduced by visual error, and the precision of the measured distance may be low. Conversely, the DBT is an automated system using digital sensor system measurement technology (an automated data recording, wireless data transmission, storage, and management system; measurement is possible only by one subject of balance ability management) using the same platform, measurement method, and evaluation criteria as those of the YBT. Because it is motor driven, during the measurement of balance ability, when the box-shaped bars are pushed by the subject, they are returned automatically to their original positions and the distances are measured simultaneously, and the precision level is high because the data are recorded up to two decimal points. The system is convenient and efficient, as it can measure the subject's balance ability without the presence of an inspector or recorder. Even for repeated measurements, the same results can be obtained with no visual error by the inspector.

Furthermore, the DBT results with adults in their 20s showed no significant difference to those of the YBT. Thus, the DBT appears to have better precision and accuracy as test equipment for dynamic balance ability, while the measurement method is the same as that of the YBT. The DBT can measure distances more accurately than the YBT, and the data can be sent from the measuring instruments via Bluetooth and recorded in real time by the storage system thus enabling big data analysis. Therefore, the DBT showed advantages over the YBT regarding time, accuracy, and convenience, although the results did not show significant differences between the two methods in terms of balance ability measurement.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGMENTS

This paper was supported by R&BD program for regional outstanding researchers, startups and innovative firms (BISTEP).

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