The Change of Low Limb Angle during Balance Training

Dong-Yeop Lee, Jeong-Woo, Jeon, Sung-kil Kim, Ji-Heoan Hong, Jae-ho Yu, Jin-Seob Kim, Won-Jun Lee
Dept. of Physical Therapy, SunMoon University
e-mail:leedy@sunmoon.ac.kr

균형 훈련 시 다리 각도 변화

이동엽, 전정우, 김성길, 홍지헌, 유재호, 김진섭, 이원준
선문대학교 물리치료학과

Abstract

This study measures the angle of lower joints to look into the effect of movement speed on joint dynamics of the lower extremities. This study was conducted with a sample group of 13 subjects who did not have any injury or past medical history of their lower extremities and agreed to participate in the study. We attached 17 markers to the subjects' bodies for 3D motion analysis and controlled the speed of movement by a metronome. All measurement data were analyzed using the Repeated Measure ANOVA($p < .05$).

A significant difference was found in the angle of the knee joint when performing the motion in the anterior direction($p < .05$). In conclusion, when performing YBT, the speed affects joint kinetics of the lower extremities.

1. Introduction

This includes the ones such as jumping to a new position, attempting to remain as stationary as possible immediately after the jump, or attempting a purposeful segment movement (to reach) without compromising an established BOS. This dynamic balance evaluation of postural stability does not take an accurate measurement of participation in exercise, but its measurement of physical activity evaluation is more accurate rather than of static balance one [1, 2]. Among the tests for evaluating dynamic balance, SEBT (Star Excursion Balance Test) is a widely used method for evaluating dynamic postural stability and YBT (Y Balance Test) is a highly reliable evaluation method as the one for evaluating dynamic balance by a balance measurement device using in 3 directions of anterior, posteromedial, and posterolateral out of 8 directions of SEBT.

2. Methods

2.1 participants

3D Motion Analyzer, Y-balance Kit, and Metronome were used for the experiment. These devices were used to measure the angle of the joints when performing the dynamic balance ability of the subjects' lower extremities. Subjects move the COM by performing Y-balance training in three directions of anterior (Ant), posteromedial (PM), and posterolateral (PL) using the Y-Balance Kit [Figure 3]. Using the Y-Balance Kit, the reaching distance of one leg when performing dynamic balance operation (the moving radius of COM) was recorded by each direction. The speed of the Metronome was set to 60BPM and it counted how many times the Metronome sounded while one leg returned after reaching its highest point. Based on this result, the speed of the Metronome was set to 80%, 100%, 120%, 140% [3] (48BPM, 60BPM, 72BPM, 84BPM) of it and the subjects received the instruction to reach the same height and return within the time when it sounded by the same number.

2.2. Measuring distance of dynamic balance L/E (Y-balance Kit)

This study measured the angles of the lower joints (hip joint, knee joint, and ankle joint) when performing Y-balance training in four environments with different speeds for comparative analysis. The subjects performed YBT at the speed that the

individual felt most comfortable with and recorded the point they reached. Those four speeds were 80%, 100%, 120%, and 140%, respectively, based on the speed of YBT that the subjects felt most comfortable with. Before the measurement, the researcher explained the purpose and method of the experiment to the subjects. To provide all the participants with the same environment, the participants wore the same pants and the markers were attached by the same researcher to reduce any error of intervention. The subjects stood on one foot in the middle using the Y-balance Kit and pushed the block in the anterior, posterolateral, and posteromedial directions with the other leg to measure the point they reached in each direction [Figure 1].

[Fig. 1] 3D motion analyzer

2.3. Experiment procedures

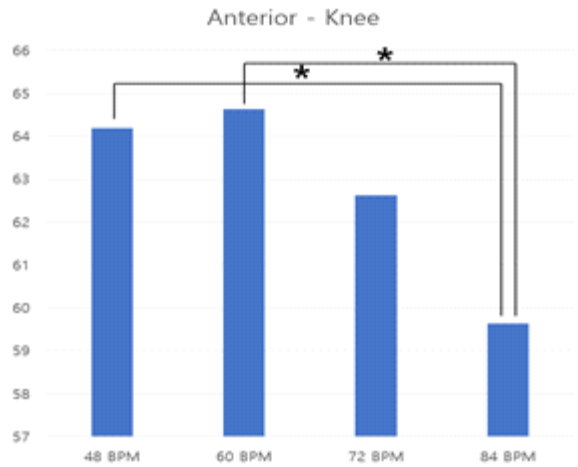
The height and weight of all participants were measured before the experiment. According to [Figure 4], the subjects recorded the time taken for their YBT and the point they reached. After that, the motion was performed according to a randomly selected speed in each direction. To minimize the effect of the participants' fatigue under measurement on the result and to prevent side effects such as muscle convulsions, they took a one-minute rest after the measurement in one direction was completed, and a sufficient break time was given between measurements.

2.4. Data analysis

Descriptive statistics were used to analyze the mean and standard deviation (SD) of each variable. For all statistical analysis, it used SPSS/PC Ver.28.0.0 for Windows program (SPSS Inc., Chicaco, IL). It used Repeated Measure ANOVA to analyze the difference in angles of lower joints by the speed of movement. The statistical significance level was set to $\alpha = .05$.

3. Results

This study measured and compared the joint angle of the stance leg when performing YBT at four different speeds. The joint angle by each direction is as shown in [Table 2]. As a result of the normality test, it was found that all variables followed a normal distribution. ($p > .05$) Repeated Measure ANOVA (RM ANOVA) was performed to compare the average joint angle by each speed. In some variables (PL-knee, PL-ankle), the analysis was made by applying Greenhouse-Geisser ε as it violated Mauchly's test of sphericity. As a result of the univariate test, there was a significant difference in the knee joint in the anterior direction. As a comparison result by the response of the corresponding variables, significant differences were found between 48BPM and 84BPM, and between 60BPM and 84BPM, respectively [Table 2]. ($p<.05$) There was no significant difference in other variables[Fig 2].



[Fig. 2] 3D Comparson knee angle in ante. direction of speed

4. Discussion and Conclusion

The Y-Balance Test is a measurement tool of body balance derived from SEBT and it consists of anterior, posterolateral, and posteromedial. It is more time-efficient than SEBT and as an index to measure dynamic balance and predict injuries, it is widely used and its reliability has been recognized [4, 6, 7]. According to Nelson et al. (2021), who studied the kinematic predictors of YBT, the maximum factor of YBT for reaching the anterior direction is flexion of the knee joint and the opposite rotation of the trunk works in addition [8]. Robinson and Gribble also reported that flexion of the hip joint was significantly correlated with the distance reached in all three directions, while flexion of the knee joint was significantly correlated with the distance reached in ANT direction [9]. Also in a study by Kang et al., the extension of the trunk played a major role in the movement of anterior direction [10]. The balance compensation strategy of the trunk and the hip joint is used to maintain the COM above the BOS and not lose the balance while the leg reaches [4]. As the speed of movement of COM increases, it

becomes difficult to maintain posture control and the risk of falls increases. [5]. Although no significant difference was found in the study, the angle of the hip joint and ankle joint also decreases as the speed increases in the movement in the anterior direction. A wider range movement of the trunk or ankle of reaching leg may have been used instead of minimizing the movement of the stance leg joint to achieve the same distance reached while moving the COM rapidly. For movement in the PM and PL directions, abduction of the hip joint and transverse plane rotation of the trunk are mainly used [8]. Hip abductor and extensor strength should be related to the posterior distance, because the performance in the PM and PL direction requires lateral stabilization of the pelvis [11 12]. Anterior reaching involves movement in the sagittal plane, whereas PM and PL reaching involve the frontal plane because the foot stretches medial and lateral. However, in this study, only the movement of the sagittal plane was considered, while the movement of the frontal plane or the transverse plane was excluded. Also, because only the movement of the lower joints was observed, the movement data of the trunk was not collected.

There was no significant difference when movements were performed in the posterolateral and posteromedial directions. This result suggests that changes in the speed when performing YBT affect the kinematics. This study supports the studies showing that the angle of the joints changes when controlling the speed of dynamic movement, and based on this, it is expected to be able to evaluate such defects in the control ability of nerve roots through dynamic movements performed at various speeds.

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