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Original Article

Correlation of the Y-Balance Test with Lower-limb Strength of Adult Women

Dong-Kyu Lee, PT, MSc[1)], Gyoung-Mo Kim, PT, MSc[2)], Sung-Min Ha, PT, PhD[3)], Jae-Seop Oh, PT, PhD[4)*]

[1)] *Department of Rehabilitation Science, Graduate School, Inje University, Republic of Korea*
[2)] *Department of Physical Therapy, Baekseok University, Republic of Korea*
[3)] *Department of Physical Therapy, Sangji University, Republic of Korea*
[4)] *Department of Physical Therapy, College of Biomedical Science and Engineering, Inje University: 607 Obang-dong, Gimhae-si, Gyeongsangnam-do 621-749, Republic of Korea*

Abstract. [Purpose] The purpose of this study was to elucidate the relationship between Y-balance test (YBT) distance and the lower-limb strength of adult women. [Subjects] Forty women aged 45 to 80 years volunteered for this study. [Methods] The participants were tested for maximal muscle strength of the lower limbs (hip extensors, hip flexors, hip abductors, knee extensors, knee flexors, and ankle dorsiflexors) and YBT distances in the anterior, posteromedial, and posterolateral directions. Pearson's correlation coefficient was used to quantify the linear relationships between YBT distances and lower-limb strength. [Results] Hip extensor and knee flexor strength were positively correlated with YBT anterior distance. Hip extensor, hip abductor, and knee flexor strength were positively correlated with the YBT posteromedial distance. Hip extensor and knee flexor strength were positively correlated with YBT posterolateral distance. [Conclusion] There was a weak correlation between lower-limb strength (hip extensors, hip abductors, and knee flexors) and dynamic postural control as measured by the YBT.
Key words: Adult women, Lower-limb strength, Y-balance test

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INTRODUCTION

Falls are the major cause of fractures and head traumas in elderly individuals, especially women[1)]. Compared with men, women are more prone to falls and have a higher predisposition to fall-related injuries[2)]. Chen et al.[3)] reported that muscle mass and strength declines with advancing age in older adults, and that women have relatively lower muscle mass and strength than men. Lower-limb muscle weakness is a predictor of future falls[4)]. According to Frischknecht[5)], muscle strength decreases by up to 50% between 30 and 80 years of age, and the greatest losses occur in the lower limbs.

The relationship between balance and lower-limb muscle strength may be important for both the identification of persons with an increased risk of falling and the development of fall-prevention training programs[6)]. Aging is associated with diminished lower-extremity strength, although a decline in balance function has been reported in women from 40 years of age onward[7)]. However, to ensure the success of fall-prevention interventions, a training program should consider diverse approaches to improving dynamic postural control.

One testing device used to assess functional dynamic postural control is the Y-balance test (YBT) (Move2Perform, Evansville, IN, USA). The YBT involves reaching in three directions (anterior, A; posteromedial, PM; and posterolateral, PL) while standing on each foot. The advantages of the YBT are that it follows a standard protocol and has been shown to have high inter- (0.99–1.00) and intra-rater reliabilities (0.85–0.91)[8)]. Furthermore, YBT distances have been shown to be predictive of lower-extremity injury in basketball players[9)].

Despite evidence demonstrating the importance of preventing falls among women, the relationship between lower-limb strength and balance is not completely understood. No studies to date have examined the YBT using adult women. Therefore, the aim of this study was to elucidate the relationship between performance in the YBT and lower-limb strength of adult women.

SUBJECTS AND METHODS

Forty women aged 45 to 80 years volunteered for this study. The number of the participants in each age range was: 45–49, 4; 50–54, 6; 55–59, 9; 60–64, 1; 70–74, 4; 75–79, 10; and 80, 6. Their mean age was 65.73 ± 12.62 years, and their mean height and weight were 156.33 ± 5.77 cm and 53.85 ± 7.23 kg, respectively. All participants could walk by themselves without a cane or walker, had no history of

*Corresponding author. Jae-Seop Oh (E-mail: ysrehab@inje.ac.kr)

falls, and were healthy. No participants had a neurological disease, musculoskeletal problems, visual impairment, or vestibular disease, which might have affected performance in YBT tasks. All subjects read and signed an informed consent form approved by the Inje University Ethics Committee for Human Investigations prior to their participation.

A digital handheld dynamometer (PowerTrack II; JTech Medical, Salt Lake City, UT, USA) was used to measure the maximum voluntary strength of each participant. The maximal isometric strengths of the bilateral hip extensors, flexors, and abductors, knee flexors and extensors, and ankle dorsiflexors were assessed using the dynamometer. The testing positions described in the manual of this dynamometer were followed. The participants were instructed to avoid explosive contraction, and to gradually increase their effort to the maximum. They were told to stop contracting when the tester finished counting to 5 s[10]. Participants performed three trials for each muscle group, with a 30-s rest between trials. The mean peak value of six measurements of each side was used in the data analysis.

Quantitative balance was assessed during performance of the YBT, which was inspired by clinical applications of the star excursion balance test (SEBT). The participants pushed the reach-indicator block with one foot in the A, PM, and PL directions while standing on the other foot on a central footplate. All testing and practice were performed barefoot with the left and right limbs to eliminate balance and stability provided by shoes[11]. Each participant was allowed six practice trials in each direction and then performed three test trials in each direction. The subject maintained a single-leg stance with hands on the pelvis while pushing the reach indicator block with the contralateral leg as far as possible along the three directions. The reach distance was recorded in half centimeters as the point where the participant pushed the reach indicator block closest to the central footplate. To improve the reproducibility of the test, a consistent testing protocol was used.

A trial was classified as invalid if the participant did not return to the starting position, failed to maintain a unipodal stance on the platform, kicked the reach indicator block with the reaching foot to gain more distance, stepped on top of the reach indicator for support, or removed her hands from her hips. If an invalid trial occurred, the data were discarded, and the subject repeated the trial.

For normalization, the participants' lower-limb lengths in the supine position were bilaterally measured to the nearest half centimeter from the anterior superior iliac spine to the center of the ipsilateral medial malleolus. For data analysis, the reach distance in each direction was normalized to the limb length by calculating the maximum reach distance (%MAXD) using the following formula: (excursion distance / limb length) × 100 = %MAXD, because leg lengths differed among the individuals[12]. The mean distance in each direction on the right and left sides was used for the data analysis.

Pearson's correlation coefficients were calculated to quantify the linear relationship between the YBT distance and strength. Data were analyzed using SPSS software (ver. 18.0; Chicago, IL, USA), and results were considered significant at values of $p < 0.05$. Total variance is described by the coefficient of correlation (r) and the respective level of significance (p value). If a significant difference was found under all conditions, r was set at 0.7 because $r > 0.7$ represents a fair correlation[13].

Table 1. Pearson correlation coefficients of Y balance test distance and leg strength

	Anterior	Posteriomedial	Posteriolateral
	r	r	r
Hip flexor	0.523	0.675	0.641
Hip extensor	0.703*	0.720*	0.748*
Hip abductor	0.682	0.719*	0.653
Knee flexor	0.711*	0.814*	0.828*
Knee extensor	0.617	0.599	0.565
Ankle dorsiflexor	0.600	0.612	0.601

RESULTS

Lower-limb strength positively correlated with reach distance in all three directions of the YBT ($p < 0.05$) (Table 1). Hip extensor strength ($r = 0.703$, $p < 0.05$) and knee flexor strength ($r = 0.711$, $p < 0.05$) were positively correlated with performance in the A direction. Hip extensor ($r = 0.720$, $p < 0.05$), hip abductor ($r = 0.719$, $p < 0.05$), and knee flexor strength ($r = 0.814$, $p < 0.05$) were positively correlated with performance in the PM direction. Hip extensor ($r = 0.748$, $p < 0.05$) and knee flexor strength ($r = 0.828$, $p < 0.05$) were positively correlated with performance in the PL direction.

DISCUSSION

This study revealed a positive correlation between hip extensors and performance in all three directions of the YBT. Norris et al.[14] reported that the electromyographic activity of the gluteus maximus showed similar patterns of muscle recruitment during the SEBT in the A, medial, and PM directions. Hubbard et al.[15] reported that PM and PL excursions during the SEBT were correlated with hip extensor strength. The single-limb squat is unilateral weight-bearing exercise similar to the YBT. Both involve a mini-squat movement with contralateral reach by the lower extremity. Thus, we consider that an increased hip flexion range of motion is required for a greater reaching distance, which may have led to an increased demand on hip extensor strength to maintain postural control.

This study quantified the positive association between hip abductor strength and the PM reach distance. Hubbard et al.[15] also showed that the PM and PL reach distances on the SEBT were moderately correlated ($r = 0.49–0.51$) with hip abductor strength. Robinson et al.[16] indicated that greater hip range of motion is required for the posterior directions of the YBT. Therefore, hip abductor strength should be related to the PM distance, because the performance in the PM direction requires lateral stabilization of the pelvis. We suggest that the fair correlation between hip abductor

strength and PM performance implies that gluteal muscle strength partly accounts for the variance in YBT distances.

In our study, a significantly strong relationship was noted between knee flexor strength and performance in all three directions. Previous investigators[17] who evaluated the SEBT reported that the greatest amount of knee flexion range of motion occurred during performance of AM reach. Additionally, Ohkoshi et al.[18] reported increased hamstring activity as the trunk angle increased in the standing position. To perform the YBT, subjects lean forward and backward to maintain their balance, and the knee flexors must eccentrically contract to resist trunk movement. Consequently, the knee flexors may contribute to a greater YBT distance when body sway is converted from forward to backward motion.

This study had several limitations. We did not measure the range of motion of the lower extremities, and shorter YBT distances could have been the result of decreased range of motion of the lower extremity. It is difficult to predict falls and the effect of fall prevention interventions due to the lack of standardized methods of fall assessment using the YBT. Dynamic postural control during the YBT is reflected by the distance reached in each direction, with an increase in reach distance reflecting greater dynamic postural control. Additionally, it is difficult to apply the results of this study to subjects of a particular age group in a clinical setting. Further research is needed to explore the effects of rehabilitation programs using the YBT in preventing falls.

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