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# Association between dynamic balance and ankle muscle characteristics

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# 동적 균형과 발목 근육 특성 사이의 관계

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Abstract The relationship between balance and ankle muscle characteristics (strength and flexibility) may be important to identify those at an increased risk of falling and to develop fall-prevention training programs. The association between ankle muscle characteristics (strength and flexibility) and balance has not previously been studied. The purpose of this study assessed the relationship between ankle muscle characteristics and balance. Sixteen healthy participants volunteered to participate in the study. Dynamic balance measured using Y-balance kit. Ankle muscle characteristics (strength and flexibility) measured using hand-held dynamometer and goniometry. The results indicated a positive correlation between ankle invertor muscle strength and Y-balance test performance. Clinicians should consider ankle muscle strength during therapeutic interventions to improve dynamic balance.

Key Words : Balance, Dynamic balance, Ankle muscle characteristics, Y-balance, Convergence

요 약 균형과 발목 근육 특성 (근력과 유연성) 사이의 관계는 낙상 위험의 증가에 대한 규명과 낙상방지 훈련프로그램을 발전시키기 위해서 중요할 것이다. 발목 근육 특성(근력과 유연성)과 균형사이의 관계는 이전에 연구되지 않았다. 이 연구의 목적은 발목근육특성과 균형사이의 관계를 평가하는 것이다. 16명의 건강한 참가자들이 본 연구에 자원하였다. 동적 균형은 와이-발란스 (Y-balance) 키트를 이용하여 측정하였다. 발목 근육 특성 (근력과 유연성)은 악력계와 고니어미터를 사용하여 측정하였다. 발목내번근력과 와이-발란스 (Y-balance) 측정 수행능력 사이에 양의 상관관계를 나타냈다. 임상가들은 동적균형의 발전을 위해서 치료적 중재를 하는 동안 발목 근력을 고려해야 한다.

주제어 : 균형, 동적균형, 발목 근육 특성, 와이-발란스, 융복합

## 1. Introduction

The ability to live as independently as possible is an important factor in life satisfaction for older people[1]. Two primary considerations in geriatric rehabilitation are the ability to maintain

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safe, functional balance when moving and to move independently[2]. Age-related musculoskeletal changes affect muscle strength and flexibility, resulting in impaired balance and gait[3,4]. These changes are closely related to the frequency of falls. In older people, falls can cause serious injuries such as hip (50%), arm (13%) fractures, and head injuries (10%) or even death[5,6].

Aging is associated with diminished muscle strength, changes in posture, and impaired balance[7-9]. The decrease in strength is likely due to reduced muscle mass, possibly related to decreased intensity of daily physical activity[10]. Additionally, a deficit in ankle range of motion (ROM) has been linked with decreased balance in older people[11]. The relationship between balance and lower-limb muscle characteristics (strength and flexibility) may be important to identify those at an increased risk of falling and to develop fall-prevention training programs[12,13].

Previous research has demonstrated the importance of assessing dynamic neuromuscular control for injury prevention using body relative movement testing[14]. Balance training devices have been developed to improve balance, such as those that induce physical challenges to balance by providing an unstable support surface. Examples include ankle discs, wobble boards, balance sandals, foam pads, tilting platforms and balance trampolines[15]. These devices do not quantitatively measure balance.

The Y balance test (YBT) is commonly used to measure lower extremity neuromuscular control during dynamic balance in clinic and sport field settings[16,17]. The YBT is a valid and reliable tool for quantitative balance assessment using body reactive movement testing[18]. The goal of the YBT is to maintain a single leg stance while reaching the contralateral leg as far as possible[19]. Previous studies using the YBT focused on hip and knee muscle strength and flexibility[20]. The coordination of ankle strength and flexibility affects the YBT[21]. To our knowledge, the association between ankle muscle characteristics (strength and flexibility) and balance has not previously been studied. This study assessed the relationship between ankle muscle characteristics and balance.

# 2. Method

## 2.1 Subjects

Sixteen healthy participants volunteered to participate in the study (12 male, 4 female; mean age: 23.2 ± 17 years, height: 173.1 ± 6.6 cm, weight: 70.4 ± 10.3 kg). Exclusion criteria included neurological disease and visual or vestibular impairment. An informed consent form was reviewed and signed by all participants prior to commencing the study.

## 2.2 Instrumentation

### 2.2.1 Y-balance test

The YBT Kit™ consists of a stance form to which three-pieces of PVC pipe are connected in the anterior, posterolateral, and posteromedial reach directions. Fig. 1 The posterior pipes are positioned 45° apart and 135° from the anterior pipe. Each pipe is marked in 5-mm unit for measurement. The participant pushes a target (reach unit) along the pipe, which normalizes the reach height (i.e., how far off the ground the reach foot is), and, to make the determination of reach distance more precise, the target measure the tape after the test.

Fig. 1. Y balance kit

### 2.2.2 Goniometry

A Baseline 360° plastic goniometer measured to the nearest degree for Maximal non-weight-bearing active ankle ROM. Subjects sit with the knee flexed and leg hanging off the end of a treatment table for both dorsiflexion and plantar flexion. The stationary arm of the goniometer was put along the midline of the fibula from lateral malleolus to the fibular head, with the movable arm along the midline of the fifth metatarsal. The axis of goniometer was placed about 1.5 cm inferior to the lateral malleolus[22-24]. The participant was asked to plantar flexion of the ankle as far as possible; and then the measurement was recorded, the subject activate dorsiflexion of the ankle as far as possible. To measure inversion and eversion, subjects were trained to invert and evert the calcaneus as far as possible. For both inversion and eversion, the goniometer was placed with the movable arm of the goniometer aligned with the midline of the calcaneus and the stationary arm of the goniometer in alignment with the midline of the leg[24]. The axis of the goniometer was put on the midpoint between the malleoli on the posterior side of the ankle. The average of three trials was used for all measurements. The measurements for goniometry is depicted in Fig 2.

### 2.2.3 Hand-held dynamometer

A digital handheld dynamometer (Isoforce GT-310, OG Ginken co. LTD, Japan) was used to measure each participant's maximum voluntary strength. The rater was a physical therapist with 5 years of experience in musculoskeletal health. The maximal isometric strength of the ankle dorsiflexors, plantar flexor, invertor, and evertor using the digital handheld dynamometer[25]. Participants were instructed to stop contracting the muscle when the tester finished counting to 5 seconds. The mean value of three peak measurements was used for data analysis. The measurements for hand-held dynamometer is depicted in Fig 3.

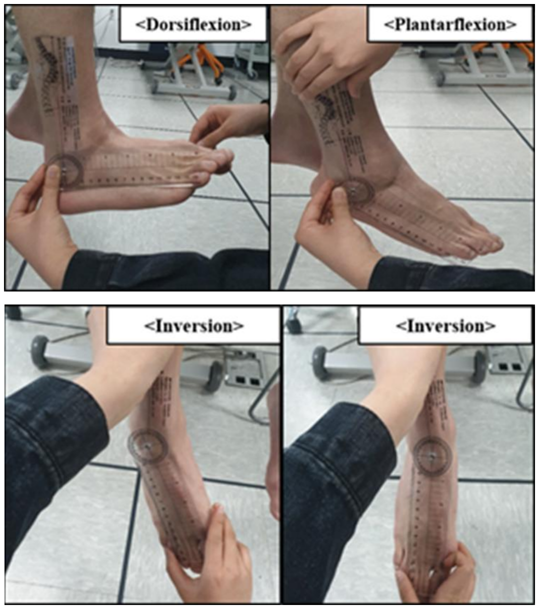


Fig. 2. Goniometry and ankle muscle flexibility measurements

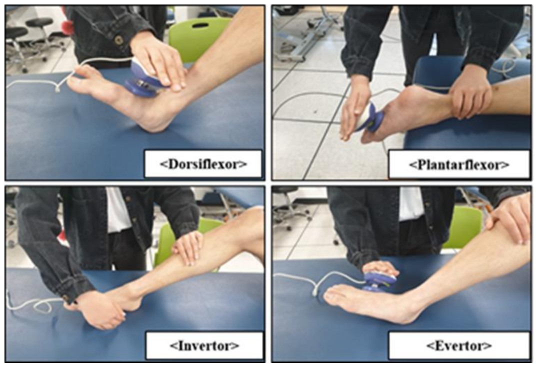


Fig. 3. Hand-held dynamometer and ankle muscle strength measurements

## 2.3 Procedure

Dynamic balance was evaluated using the YBT (Perform Better; Warwick, RI). With the left foot bare, participants stayed in balance on the center board of the YBT instrument. They were educated to keep their hands on their hips and reach as far as possible by pushing a board in the anterior, posteromedial, and posterolateral directions depicted in Fig. 4. Four trials in each direction were followed by three trials in each direction. YBT reach distance was normalized to leg length (%). Between-limb symmetry was analysed as the absolute difference between both limbs for each direction. The YBT was assessed as good intra-rater (ICC = 0.85-0.91) and inter-rater (ICC = 0.99-1) reliability[19]. Lower limb length (from anterosuperior iliac spine to the midpoint of the ipsilateral medial malleolus) was measured bilaterally with the subject lying in the supine position for normalization. Due to leg length differences between individuals, reach distance in three direction was normalized to the lower-limb length for data analysis by evaluating the maximized reach distance (%MAXD) using the formula (3×direction distance / lower-limb length×3)×100 = %MAXD[26]. The sum of 3 normalized reach distances (right and left in three directions each) was averaged to generate a composite distance. The investigation was conducted for two months.

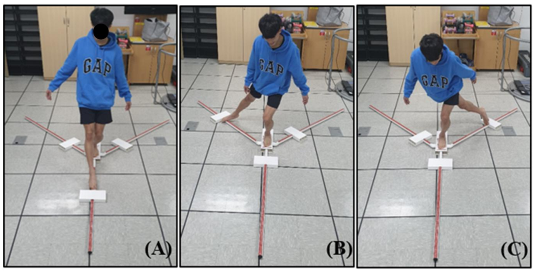


Fig. 4. Y balance test

## 2.4 Statistical analysis

Pearson's correlation coefficient was used to quantify the linear relationship between ankle muscle characteristics and balance (YBT distance and score). A p-value <0.05 was considered statistically significant. SPSS software for Windows (v. 23.0) was used to perform statistical analyses (SPSS, Inc., Chicago, IL, USA).

# 3. Results

The average value of the measured variables is as follows: MAXD: 0.99±0.12, strength of the ankle dorsiflexors: 13.53±5.15, plantar flexor: 15.71±4.41, invertor: 6.98±2.43, evertor: 6.63±2.39, ROM of dorsiflexion: 18.25±3.19, plantar flexion: 44.07±3.26, inversion: 22.59±5.23, eversion: 14.56±2.47. Muscle strength of the ankle invertor and plantar flexor was positively correlated with reach distance in all direction of the YBT ($p<0.05$). Table 1. Ankle plantar flexor muscle strength was positively correlated with performance in the anterior and posterior directions ($p<0.05$) Table 1. Ankle invertor muscle strength was positively correlated with performance in the posteromedial direction ($p<0.05$) Table 1. There was no correlation between YBT performance and ankle flexibility ($p<0.05$) Tables 2 and 3.

Table 1. Pearson correlation coefficient of Y balance test distance (3 directions) and ankle strength

| | | DF$^{e}$ | PF$^{f}$ | IV$^{g}$ | EV$^{h}$ |
|---|---|---|---|---|---|
| YBTD$^{a}$ | AT$^{b}$ | 0.33 | 0.50* | 0.50* | 0.30 |
| | PM$^{c}$ | 0.44* | 0.52* | 0.57* | 0.43* |
| | PL$^{d}$ | 0.29 | 0.31 | 0.41* | 0.20 |

YBTD$^{a}$:Ybalancetestdistance,AT$^{b}$:anterior,PM$^{c}$:Posteormedial,PL$^{d}$:posterolateral,DF$^{e}$:dorsiflexor,PF$^{f}$:plantarflexor,IV$^{g}$:invertor,EV$^{h}$:evertor

Table 2. Pearson correlation coefficient of Y balance test distance (3 directions) and ankle mobility

| | | Df$^{e}$ | Pf$^{f}$ | Iv$^{g}$ | Ev$^{h}$ |
|---|---|---|---|---|---|
| YBTD$^{a}$ | AT$^{b}$ | 0.12 | −0.08 | 0.24 | −0.05 |
| | PM$^{c}$ | −0.02 | −0.15 | 0.12 | −0.06 |
| | PL$^{d}$ | −0.02 | −0.22 | 0.14 | −0.03 |

YBTD$^{a}$:Ybalancetestdistance,AT$^{b}$:anterior,PM$^{c}$:Posteormedial,PL$^{d}$:posterolateral,Df$^{e}$:dorsiflexion,Pf$^{f}$:plantarflexion,Iv$^{g}$:inversion,Ev$^{h}$:eversion

Table 3. Pearson correlation coefficient of Y balance test score and ankle muscle characteristics

| | Ankle muscle strength | | | | Ankle mobility | | | |
|---|---|---|---|---|---|---|---|---|
| | DF$^{e}$ | PF$^{f}$ | IV$^{g}$ | EV$^{h}$ | Df$^{e}$ | Pf$^{f}$ | Iv$^{g}$ | Ev$^{h}$ |
| YBTS | 0.13 | 0.26 | 0.24 | 0.07 | −0.07 | −0.24 | 0.19 | −0.01 |

YBTS$^{a}$:Ybalancetestscore,DF$^{e}$:dorsiflexor,PF$^{f}$:plantarflexor,IV$^{g}$:invertor,EV$^{h}$:evertor,Df$^{e}$:dorsiflexion,Pf$^{f}$:plantarflexion,Iv$^{g}$:inversion,Ev$^{h}$:eversion

## 4. Discussion

Balance in humans involves integration and coordination of sensory, motor, and biomechanical activities to halt falls and enhance static and dynamic performance[27]. Failure of coordination in any of these activities may result in abnormal movement of the body, such as a sway, loss of balance, or a possible fall. In older people, balance impairment is one of the most frequently reported problems to clinicians; balance and gait disorders are the second leading causes of falls[28].

This study demonstrated a positive correlation between ankle invertor muscle strength and performance in the YBT. Plantar flexor and invertor muscle strength were positively correlated with performance in the anterior direction; invertor muscle strength was positively correlated with performance in the posterolateral direction. Ankle flexibility was not correlated with YBT performance. These results indicate that inverter muscle strength is important in controlling functional balance. Previous studies have reported that functional balance is positively correlated with muscle strength of the lower extremity[13]. Improving ankle strength is essential to improving dynamic functional balance.

Previous studies have reported correlations ranging from 0.29 to 0.63 between ankle ROM and balance scores[14]. Previous study Vandervoort et al. reported that decreased ankle ROM was a risk factor related to poorer performance in the TETRAX portable multiple system[26]. However, the results of this study did not demonstrate a correlation between ankle ROM and YBT performance. These indicated that knee and hip ROM is more important than ankle ROM in the YBT.

One limitation of this study is its generalizability, as only young healthy subjects were recruited as participants. Future studies should determine whether these findings can be generalized to subjects beyond this age range. Additionally, further research is required in subjects who have poor ankle muscle strength and flexibility.

## 5. Conclusion

This study investigated the correlation between dynamic balance and ankle strength and flexibility. The results indicated a positive correlation between ankle invertor muscle strength and YBT performance. Clinicians should consider ankle muscle strength during therapeutic interventions to improve dynamic balance.

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