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기능적 족관절 불안정성을 평가할 수 있는 새로운 균형 평가법: 체질량 지수와 성별과의 연관성

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Novel Balance Tests for Assessing Functional Ankle Instability: Relationships with BMI and Gender

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=Abstract=

Purpose: To design novel balance tests to assess FAI and evaluate whether these tests are affected by BMI or gender, with the goal of developing reliable FAI assessment tests that are not influenced by these factors.

Materials and Methods: Participants included 20 young, healthy volunteers, 12 males and 8 females, with a mean age of 24±4 years and a mean BMI of 23±2.28. None of the subjects had known ankle instability. The following tests were assessed in each participant: single leg balance (SLB), percentage of leg press (PLP), single leg cycling (SLC), one leg squat (OLS), multiple direction reach-front/back/side (MDR-F/B/S), single leg hop (SLH), two leg jump (TLJ) and side step (SS). Data were analyzed using the SPSS 12.0 software program with ANOVA and *t*-test used.

Results: When grouped by BMI, we found that despite differences in BMI, the performances of all subjects were equivalent except for the one-leg-squat test, for which the mean ratios for underweight (1.69±0), normal weight (1.05±0.19), and overweight (0.93±0.30) individuals were significantly different ($p=0.02$); ratios for SLB ($p=0.273$), SLC ($p=0.903$), PLP ($p=0.664$), MDR-F/B/S ($p=0.498$, 0.908, and 0.503, respectively), SLH ($p=0.332$) were not significantly different. When calculated according to gender, we found that the OLS ($p=0.013$) and MDRS ($p=0.034$) were significantly different, while parameters for all the remaining tests were not affected.

Conclusion: We found that the SLB, PLP, SLC, MDR-F/B, and SLH ratios were unaffected by BMI or sex and, therefore, are reliable parameters for assessing ankle instability.

Key Words: Ankle, Balance, BMI, Gender, Instability, Parameters

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Introduction

Ankle sprains are common injuries, especially in sports that involve jumping and cutting movements.[1] Individuals with functional ankle instability are evaluated for postural stability using balance tests that indirectly provide feedback on the sensorimotor system.[2,3] Balance may be impaired by sensorimotor deficiencies associated with functional ankle instability. A reported 10-30% of individuals with sprained ankles go on to develop chronic ankle instability.[4,5] Recurrent ankle injury occurs in 70-80% of athletes who have experienced lateral ankle sprains,[6,7] while residual instability is seen in 20-40% of individuals after lateral ankle sprains.[8,9] Chronic ankle instability results from repeated anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL) injuries, and is associated with ligament laxity, muscle weakness, diminished proprioception, and/or postural control deficits.[10-12] Ankle instability can be mechanical or functional. Mechanical instability occurs when injury to a joint results in pathological laxity. Functional instability is associated with impairments in postural control, joint position sense, joint conduction velocity, and strength. Clinicians must be aware of which balance tests detect deficits that are associated with functional ankle instability.[13-18] Multiple tests have been designed to evaluate ankle balance to predict future ankle sprains.[19] Static and dynamic balance tests related to sensorimotor function have been advocated to evaluate functional instability. Stabilometers are used to evaluate dynamic balance but are more useful in the setting of acute, rather than chronic, ankle instability.[20] Recent research has been directed toward applying landing test protocols that assess time-to-stabilization and joint displacement resulting from jumping or stepping down to assess postural control.[21-25] It is critical to determine whether the results obtained truly reflect the prevailing instability or whether they are confounded by other factors. To our knowledge, there have been no studies assessing whether gender or BMI (Body Mass Index) has any effect on functional ankle stability, which, in turn, could affect the results of balance tests. In the current study, we determined whether balance deficits were present in a sample of healthy individuals using static and dynamic balance tests designed to assess if BMI or gender had any effects on these parameters.

Materials and Methods

1. Subjects

The participants were 20 young, healthy volunteers, 12 males and 8 females, with a mean age of 24 years (range, 21-28 years) and a mean BMI of 23±2.28 (14 normal weight, 5 overweight, and 1 underweight). All were essentially right-handed and footed. We explained the study to all participants and got the informed consent from them, and got permission from KUGH IRB (Korea University Guro Hospital Institutional Review Board).

2. Test procedures

Functional ankle stability was studied using static and dynamic balance tests designed by our center. In the static balancing category, participants had to carry out 5 types of exercises as follows. *Single leg balance (SLB):* Each participant had to balance on one leg with hands on hips and eyes

Figure 1. Participant performing the Single Leg Balance test with his left leg.

Figure 2. Participant performing the Percentage of Leg Press test with his right leg on the leg press machine.

open with the unsupported leg bent to 90 degrees at the knee and the foot held behind. The time until they lost balance and touched the unsupported foot to the ground was recorded in seconds (Fig. 1); *Percentage of leg press (PLP):* Each participant was asked to do a one-leg-press until full knee extension using either leg on a leg press machine and the percentage in 1 repetition maximum (RM) was calculated (Fig. 2); *Single leg cycling (SLC):* Participants were asked to cycle

Figure 3. Participant performing the Single Leg Cycling test using his right leg on the cycling machine.

Figure 4. Participant performing the One Leg Squat test with his left leg bent to 70 degrees at the knee and the unsupported right leg held in near full extension.

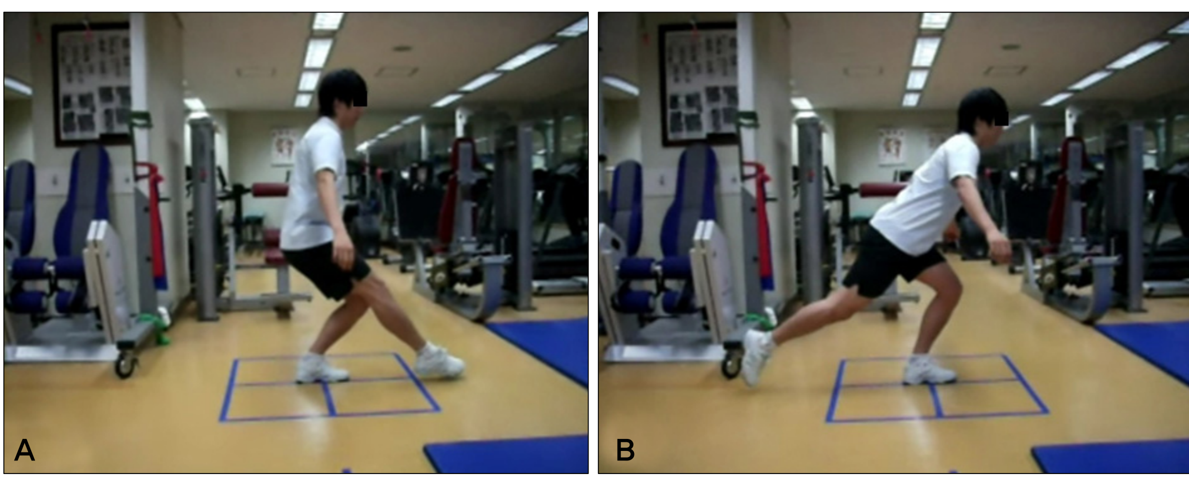

Figure 5. Participant performing the Multiple Direction Reach test to the front, back, and side, his left leg anchored to baseline and reaching out with his right leg. (A) Multiple Direction Reach test to the front. (B) Multiple Direction Reach test to the back. (C) Multiple Direction Reach test to the side.

with one leg at a time and the time until stopping from exhaustion was recorded in seconds (Fig. 3); *One leg squat (OLS):* Participants were asked to squat on one leg, bending the knee to 70 degrees while keeping the unsupported leg in front in almost full extension at the knee and to hold the position as long as possible without losing balance (test terminated when the unsupported foot touched the ground) and the time was noted in seconds (Fig. 4); *Multiple direction reach test-front/back/side (MDR-F/B/S):* Participants were asked to reach out with one foot, keeping the other foot anchored to the baseline, and the distance reached by that foot from the baseline where the toe touched the ground without lifting the anchored leg at baseline was noted in different directions, to the front, in meters, then to the back; and lastly to the side, of the baseline (Fig. 5). In the dynamic balancing category, each participant was asked to carry out 3 types of exercises: *Single leg hop (SLH):* Each participant was asked to do a single hop from the baseline, on one leg, using a full swing of both upper arms, keeping the unsupported leg knee bent at 90 degrees and the foot behind, the distance covered from the baseline, in meters, was recorded (Fig. 6); *Two leg jump (TLJ):* Each participant was asked to jump, starting with both feet on the ground at the baseline, both knees bent to 90 degrees, carrying out the jump using a full swing of both upper arms, and landing again on both feet, the distance covered from baseline, in meters, was recorded (Fig. 7); *Side step (SS):* Each participant first stood at a central anteroposteriorly marked baseline with feet placed equally on either side, then stepped the left foot sideways, touching a line marked to the left side 2 feet away from the central baseline, then brought the foot back to the neutral position, this was then repeated on the contralateral side, alternating for 30 seconds, with the number of repetitions recorded (Fig. 8). All participants carried out each test using the left leg first and then using the right leg, except for the TLJ and SS for which the test had to be carried out using both legs simultaneously.

Figure 6. Participant performing the Single Leg Hop test with his right leg.

Figure 7. Participant performing the Two Leg Jump test.

3. Statistical analysis

We grouped participants by gender for initial performance evaluation. Values were recorded independently for each leg, and the ratios of right to left sides were calculated. Since all participants were right side dominant, we considered the right-left ratios to be equally distributed. We used SPSS

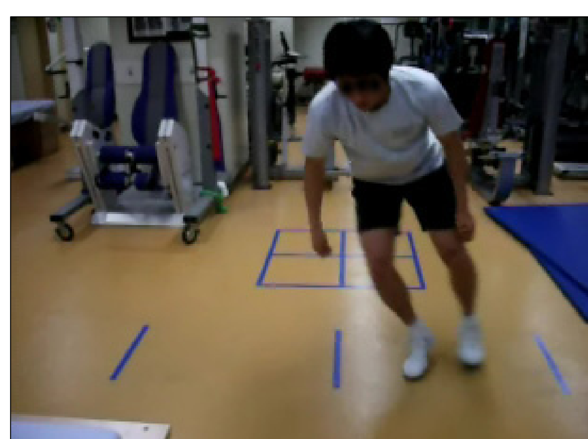

Figure 8. Participant performing the Side Step test, the centre line is the baseline, the lines to the right and left of the baseline are those to be touched while side stepping.

12.0.1 (for windows, IBM Corp. New York, NY) for statistical analysis. Assuming equal variances, 2-tailed independent samples *t*-test results were obtained for each leg independently and for the ratios. The 2-tailed tests were used for ratios for final interpretation. Next, we analyzed the results according to BMI. We divided participants into 3 groups: overweight (5 participants, BMI>25), normal weight (14 participants, 23<BMI<25), and underweight (1 participant, BMI<18.5). Similar analyses were carried out again using these categories (Table 2). Ratios were calculated between and within groups, but only ratios between groups were considered for final interpretation. We applied the one-way ANOVA test for the final analysis.

Table 1. The Table Shows Results for All the Tests According to BMI of Individuals

		Mean	*p*-value
SLB ratio	Underweight	1.43±0	
	Normal	0.92±0.39	
	Overweight	1.10±0.49	0.398
PLP ratio	Underweight	0.80±0	
	Normal	1.00±0.23	
	Overweight	1.01±0.03	0.614
SLC ratio	Underweight	1.25±0	
	Normal	1.00±0.17	
	Overweight	1.31±0.71	0.284
OLS ratio	Underweight	1.69±0	
	Normal	1.05±0.19	
	Overweight	0.93±0.30	0.020
MDRF ratio	Underweight	1.06±0	
	Normal	0.98±0.07	
	Overweight	0.99±0.10	0.573
MDRS ratio	Underweight	0.93±0	
	Normal	1.04±0.08	
	Overweight	1.02±0.07	0.428
MDRB ratio	Underweight	1.00±0	
	Normal	1.03±0.12	
	Overweight	1.03±0.13	0.974
SLH ratio	Underweight	0.96±0	
	Normal	1.04±0.11	
	Overweight	0.98±0.05	0.432
TLJ(m)	Underweight	1.22±0	
	Normal	1.96±0.42	
	Overweight	1.96±0.49	0.285
SS(Rep)	Underweight	18.00±0	
	Normal	28.79±5.96	
	Overweight	30.40±6.66	0.210

SLB, single leg balance; PLP, percentage of leg press; SLC, single leg cycling; OLS, one leg squat; MDRF, multiple direction reach front; MDRS, multiple direction reach side; MDRB, multiple direction reach back; SLH, single leg hop; TLJ, two leg jump; SS, side step; m, meters; Rep, repeats.

Results

The total number of the patients in our study of which 12 were males and 8 were females. A mean age of 24±4 years and a mean BMI of 23±2.28 (14 normal weight, 5 overweight, and 1 underweight). The mean SLB and PLP ratio of underweight, normal, overweight were 1.43, 0.92±0.39, 1.1±0.49 and 0.8, 1.0±0.23, 1.01±0.03 respectively. The mean SLC and OLS ratio of each groups were 1.25, 1.00±0.17, 1.31±0.71 and 1.69, 1.05±0.19, 0.93±0.30 respectively. The mean MDR-F/B/S ratio of each groups 1.06, 0.98±0.07, 0.99±0.1/1.0, 1.03±0.12, 1.03±0.13/0.93, 1.04±0.08, 1.02±0.07 respectively. The mean SLH, TLJ and SS of each groups were 0.96, 1.04±0.11, 0.98±0.05, 1.22, 1.96±0.42, 1.96±0.49 and 18, 28.79±5.96, 30.4±6.66 respectively (Table 1).

Table 2. The Table Shows Results for All the Tests According to Sex of Individuals

	Sex	Mean	*p*-value
SLB ratio	M	0.90±0.38	
	F	1.12±0.45	0.359
PLP ratio	M	1.07±0.18	
	F	0.87±0.15	0.830
SLC ratio	M	1.10±0.48	
	F	1.08±0.17	0.404
OLS ratio	M	1.03±0.15	
	F	1.09±0.38	0.013
MDRF ratio	M	1.00±0.08	
	F	0.97±0.07	0.535
MDRS ratio	M	1.02±0.05	
	F	1.04±0.11	0.034
MDRB artio	M	1.02±0.13	
	F	1.03±0.09	0.492
SLH ratio	M	1.04±0.05	
	F	1.00±0.15	0.069
TLJ(m)	M	2.22±0.25	
	F	1.47±0.22	0.841
SS(Rep)	M	32.08±5.12	
	F	23.50±4.24	0.516

SLB, single leg balance; PLP, percentage of leg press; SLC, single leg cycling; OLS, one leg squat; MDRF, multiple direction reach front; MDRS, multiple direction reach side; MDRB, multiple direction reach back; SLH, single leg hop; TLJ, two leg jump; SS, side step; m, meters; Rep, repeats.

The mean SLB and PLP ratio of male, female were 0.90±0.38, 1.12±0.45 and 1.07±0.18, 0.87±0.15 respectively. The mean SLC and OLS ratio of each groups were 1.1±0.48, 1.08±0.17 and 1.03±0.15, 1.09±0.38 respectively. The mean MDR-F/B/S ratio of each groups were 1.00±0.07, 0.97±0.07/ 1.02±0.13, 1.03±0.09/1.02±0.05, 1.04±0.11 respectively. The mean SLH, TLJ and SS ratio of each groups were 1.04±0.05, 1.00±0.15, 2.22±0.25, 1.47±0.22 and 32.08±5.12, 23.5±4.24 respectively (Table 2).

There were no significant differences in the ratios of SLB ratio (p=0.359), SLC ratio (p=0.404), SLC ratio (p=0.404), MDR-F/B ratio (p=0.535 and 0.492), SLH ratio (p=0.069), TLJ (p=0.841) and SS (p=0.516) according to gender, while the results for OLS ratio, MDRS ratio were found to be significantly different (for all, p<0.05, Table 2). When analyzed by BMI only the OLS ratio was significantly different (p=0.020); all other ratios were not significantly different (for all, p>0.05, Table 1).

Discussion

Although some previous studies indicated that balance deficits may not always be associated with functional ankle instability,[17,26] a recent meta-analysis found that balance deficits usually coexist with functional ankle instability.[27] Various static balance tests have been designed to assess functional ankle instability. These include the foot lift test (FLT), the time-in-balance test (TBT), and the balance error scoring system (BESS).[1,15] Such tests are suggested to be accurate and valid for assessing balance deficits associated with functional ankle instability.[1,15,27] Some researchers have argued that dynamic tests provide superior assessments of lower extremity function. The star excursion balance tests (SEBTs) were designed to address this concern and are basically multidirectional reach tests.[28,29] Despite studies indicating the clinical importance of postural control, most recent research is conducted in laboratory settings, and therefore requires sophisticated instruments. There have been studies performed using simple, inexpensive equipment,[30] but they lack validation of reliability. All of these tests assess balance deficits associated with functional ankle instability, but little thought has been given to common factors that could affect the outcomes of these tests, such as gender or BMI. We believe these concerns require serious consideration; as such factors are likely to affect performance during balance tests. Therefore, we designed balance tests that combine static and dynamic balancing to assess the sensorimotor function of the ankle. The purpose of these tests was to assess the effects of the same stresses on the ankles of the participants who were healthy and without any ankle instability. Any significant differences in outcomes according to BMI or gender could indicate that a particular test is not appropriate for assessing balance deficits. Tests that do not demonstrate statistically significant differences according to gender or BMI may be more dependable tests for assessing balance deficits.

Conclusion

The single leg balance ratios, percentage of leg press single leg cycling ratios, multiple direction reach–front/back ratios and single leg hop ratios, tow leg jump and side step test were unaffected by BMI or sex, and appear to be reliable for assessing ankle instability. These tests may prove to be cost effective tools for assessing lower extremity functional deficits given their simple nature and lack of required expensive equipment. Limitations of the current study include the small sample size and the fact that only young participants were included. Future research should examine the validity of these tests in individuals with functional ankle instability.

Conflicts of Interest

All the authors emphatically state there is not conflict of interest between the authors and no fund or grants were received for the work.

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