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Validity of the lower extremity functional movement screen in patients with chronic ankle instability

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Abstract. [Purpose] The purpose of this study was to provide evidence of construct validity for the lower extremity functional movement screen (LE-FMS) based on hypothesis testing in patients with chronic ankle instability (CAI). [Subjects] The subjects were 20 healthy subjects and 20 patients with CAI who had a history of ankle sprain with pain for more than 1 day. [Methods] All participants were measured using the Foot and Ankle Disability Index (FADI) and evaluated with the LE-FMS. The screen included the deep squat, the hurdle step (HS) and the in-line lunge (ILL). The symmetry ratios (RS) were accurately measured during the deep squat trial. [Results] Between the two groups, there were significant differences in scores on the LE-FMS, HS, ILL, RS, FADI, and FADI-sport. The FADI was strongly correlated with both LE-FMS score (r=0.807) and ILL score (r=0.896). There was a strong relationship (r=0.818) between LE-FMS score and FADI-sport. [Conclusion] These results suggest that the LE-FMS may be used to detect deficits related to CAI. Additionally, this instrument is reliable in detecting functional limitations in patients with CAI.
Key words: Ankle, Chronic ankle instability, Functional movement screen

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INTRODUCTION

Lateral ankle sprains continue to be the most common injury sustained by physically active individuals[1)]. Although these injuries are often taken matter easy, up to 70% of individuals who sustain a single lateral ankle sprain experience lasting symptoms, recurring ankle sprains, and reduced functional capacity[2)]. repetitive frequency of ankle sprains and functional limitations have been described as chronic ankle instability (CAI)[3)].

The prevalence of CAI combined with the associated decreased quality of life has been evaluated[4)]. Subjective reports of function are classified as generic or specific measures, which include condition-specific, population-specific, and patient-specific instruments[5)]. Generic measures identify overall health and wellness and are designed to be clinically meaningful across various populations, body parts, and diseases. In contrast, specific measures are intended to quantify dysfunction related to specific conditions or body parts[6)].

Evaluation of CAI is performed using self-reported outcome instruments. The Ankle Instability Instrument[7)], Cumberland Ankle Instability Tool[8)], and Foot and Ankle Disability Index (FADI)[6)] are examples of discriminative instruments. FADI was reliable in detecting functional limitations assessed in patients with CAI. Also, it was sensitive to differences between healthy subjects and patients with CAI and was sensitive to improvements in function after rehabilitation in patients with CAI[6)]. The FADI-sport is designed to address this need by detecting deficits in higher-functioning subjects. However, CAI has been linked to several mechanical and functional limitations. Several mechanical impairments have been identified as contributing factors for CAI[9)]. Deficits in postural control and other functional impairments are thought to be the result of a loss in somatosensory information from damaged ligamentous mechanoreceptors[10)]; changes in sensory input may also be associated with damages in arthrokinematic function[11)]. Mechanical and functional ankle instability can contribute to CAI. Rehabilitation is more likely to address functional ankle instability rather than implies a comparison[12)]. Despite the frequency of ankle instability, no widely accepted outcomes tool is available to measure ankle function and stability[13)].

Functional performance tests require the integration of multiple body regions and systems to execute movement patterns, and therefore, may have an advantage over more traditional clinical measures[14)]. Components of range of motion, flexibility, muscular strength, endurance, coordination, balance, and motor control of multiple regions can be assessed simultaneously by observing the movement patterns in which the normal joint functions[15, 16)]. Functional

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performance tests have been commonly used to identify impairments related to ankle or knee injuries and to determine the readiness of an athlete to return to sports after injury[15]. The functional movement screen (FMS) is a relatively new measurement both for representing various movement factors and for forecasting the general risks regarding musculoskeletal injuries[17]. We concentrated on the three movements of the FMS most involved with the lower extremity (LE) for CAI[18].

Research is lacking on the LE-FMS and its ability to identify injuries of a specific joint. Instead, the focus of previous research has been on injury risk as a whole. The purpose of this research is to determine if the LE-FMS could be a valid tool for CAI, by exploring if a relationship exists between the LE-FMS and ankle stability.

SUBJECTS AND METHODS

The subjects were 20 patients with CAI and 20 healthy subjects who worked at a rehabilitation hospital in the Republic of Korea. The inclusion criteria being recruited were recruited within the workplace setting for participation. Subjects were classified as having CAI if they reported having the following: (1) instability that they attributed to the initial injury, (2) a history of ankle sprain with pain for more than 1 day, (3) the ankle giving way in the last 6 months, and (4) having one or more problems related to an item of the FADI. Exclusion criteria included subjects reporting any of the following: (1) history of ankle fracture, (2) bilateral ankle instability, (3) ankle injury within 3 months of participation, (4) history of anterior cruciate ligament injury, or (5) history of a balance disorder. Participation in the study was voluntary[19], and the subjects fully understood the content of the study. After providing an explanation of the study's purpose and the experimental method and processes, written informed consent was obtained from all subjects. The study was approved by the Daejeon University institutional review board. The subjects' characteristics are summarized in Table 1.

Table 1. General characteristics of subjects

	CAI group (n=20)	Healthy group (n=20)
Gender		
Male	9	8
Female	11	12
Age (years)	25.1±1.6[a]	27.4±3.1
Height (cm)	168.3±7.1	173.1±7.3
Weight (kg)	61.5±13.8	70.9±11.0

[a]Mean±SD
CAI: Chronic Ankle Instability

All subjects completed the FADI for self-reported measurement of function. Separate surveys were completed in order to reflect the function of the each ankle. The FADI has 26 items, and the FADI Sport has eight. Each item is scored from 0 (unable to do) to 4 (no difficulty at all). The four pain items of the FADI are scored 0 (none) to 4 (unbearable). The FADI has a total point value of 104 points, whereas the FADI Sport has a total point value of 32 points. The FADI and FADI Sport are scored separately as percentages, with 100% representing no dysfunction[6, 19].

The seven movement patterns of the FMS are the deep squat, in-line lunge, hurdle step, shoulder mobility, active straight leg raise, trunk stability push-up, and quadruped rotary stability. The LE movement and stability measurements were evaluated by the deep squat, in-line lunge, and hurdle step[18, 20].

Each movement of the FMS was scored on a scale of 0–3. A score of three indicated that the movement was performed correctly, a score of two indicated that the movement was done in an ineffective way, and a score of one indicated that the participant could not complete the movement. A score of zero was only given when the participant experienced pain throughout the movement. At the conclusion of the LE-FMS, the three movement scores were totaled to obtain the participant's FMS score. For the purpose of this study, the maximum score an individual could earn was 9[20, 21].

To perform the deep squat, participants began by standing with their feet shoulder-width apart. The subjects held a dowel across the top of their head with their elbows at a ninety-degree angle. Once prompted by the experimenter, the participants pressed the dowel up until their elbows were extended, squatted as deeply as possible, and then returned to the start position. If the participants performed the movement correctly except with their heels raised, then they were awarded a score of two. To accurately measure symmetry ratios (RS) during the deep squat trials, participants stood with their feet on a Wii balance board. Data were sampled at 100 Hz using the Balancia® program (Minto systems, Seoul, Republic of Korea). Assessing the force data for each individual load cell allowed for a center of pressure (COP) coordinate location to be determined for each sample[22]. The RS were calculated using the formula: $RS = A / NA$, in which RS is the dimensionless value of the symmetry ratios calculated by the division of the weight-bearing values of the affected side by the non-affected side. For the healthy group, the affected side is defined as the dominant lower extremity and non-affected is the non-dominant lower extremity. As such, the values of $RS = 1$ would represent complete weight-bearing symmetry in the orthostatic position. Values of RS >1 represented weight-bearing asymmetries towards the affected side, and values of RS <1, towards the non-affected side[23].

The hurdle step is the first of the bilateral movements. The experimenter first measured the height of the participant's tibial tuberosity from the ground using a ruler on the dowel. The dowel was then placed across the shoulders behind the neck, with the subjects lightly holding it in place. The participants then stepped over the hurdle, lightly tapped their heel on the ground in front, and then returned to the starting position. The participants performed the movement three times on each leg, and the experimenter scored the hurdle-stepping leg.

The in-line lunge began with the participant standing on the Wii balance board with one foot in front of the other. The front leg determined the side to be scored. The distance between the feet matched the height of the hurdle used in the

Table 2. Comparison of LE-FMS score, FADI, and FADI-sport between groups

Variables	CAI group (n=20)	Healthy group (n=20)	95% CI (lower to upper)
LE-FMS score	6.9±1.8[a]	8.2±1.8*	−2.212 to −0.388
FADI (%)	80.6±8.4	100.0±0.0*	−23.181 to −15.471
FADI-sport (%)	72.2±10.6	99.2±2.3*	−32.203 to −21.811

[a]Mean±SD, *p<0.05
CI: confidence interval of mean difference; CAI: chronic ankle instability; LE-FMS: Lower Extremity Functional Movement Screen; FADI: Foot and Ankle Disability Index

hurdle step movement. The dowel was set along the participant's spine, with one hand holding the dowel at the cervical spine, and the other holding at the lumbar spine. The arm at the cervical spine corresponded with the back leg.

The descriptive statistics of the means and standard deviations of all data measured in this study were produced using SPSS 18.0 (SPSS, Chicago, IL, USA). A Spearman's rank correlation coefficient measured the relationship between FMS scores and scores for both the FADI and FADI-sports. Intraclass correlation coefficients ≥0.80 reflected high reliability; 0.60–0.80, moderate reliability; and <0.60, poor reliability reliability[24]. Shapiro-Wilk tests of normality were used to determine if the dependent variables were normally distributed. Independent t-tests were used to compare differences between CAI and healthy group means in LE-FMS score, RS, FADI, and FADI-sport. χ^2 analyses for categorical variables were used to examine differences between group in deep squat, in-line lunge, and hurdle step. Statistical significance was set at p<0.05.

RESULTS

There were no significant differences in gender, age, weight, and height between the two groups (Table 1). Both groups showed significant differences in LE-FMS score, FADI, and FADI-sport (p<0.05) (Table 2). The differences in scores of the three movements on LE-FMS were compared between the CAI and healthy groups (Table 3). Between the two groups, there were significant differences in both in-line lunge (affected side and non-affected side) and hurdle step (affected side and non-affected side) (p<0.05). There were no significant differences between the two groups in the deep squat (p>0.05). However, there was a significant difference in the deep squat RS between the CAI and healthy groups (p<0.05).

To analyze concurrent validity of LE-FMS score, FADI, and FADI-sport, all patients with CAI (n=20) were included (Table 4). LE-FMS score was strongly correlated with FADI (r=0.807, p<0.01), and the in-line lunge of the LE-FMS was strongly correlated with FADI (r=0.896, p<0.01). There was a strong relationship between LE-FMS score and FADI-sport (r=0.818, p<0.01). The LE-FMS score correlated with all three movements (deep squat, r=0.717, p<0.01; hurdle step, r=0.682, p<0.05; in-line lunge, r=0.696, p<0.01).

Table 3. Comparison of scores on deep squat, HS, and ILL between groups

Variable	Score	CAI group (n)	Healthy group[a] (n)
Deep squat			
	0	0	0
	1	5	1
	2	6	9
	3	9	10
HS-A*			
	0	0	0
	1	3	0
	2	7	2
	3	10	18
HS-NA*			
	0	0	0
	1	2	0
	2	10	2
	3	8	18
ILL-A*			
	0	1	0
	1	3	0
	2	7	3
	3	9	17
ILL-NA*			
	0	0	0
	1	2	0
	2	9	2
	3	9	18

*p<0.05
[a]For the healthy group, affected is the dominant lower extremity and non-affected is the non-dominant lower extremity.
CAI: chronic ankle instability; HS: hurdle step; ILL: in line lunge; NA: non-affected limb stepping; A: affected limb stepping

DISCUSSION

Our main finding was that the LE-FMS may be used to detect functional deficits related to CAI. In addition, the hurdle step and in-line lunge movements were significantly different in patients with CAI than in healthy subjects. In this study, concurrent validity of the LE-FMS was determined using the FADI-sport and FADI as criterion standards.

We further investigated whether any of the individual FMS movements showed a relationship with ankle stability

Table 4. Correlation among LE-FMS score, FADI and FADI-sport for concurrent validity (n=20)

Variables	LE-FMS score	Deep squat	Hurdle step	In line lunge	FADI	FADI-sport
LE-FMS score	1.000[a]					
Deep squat	0.717**	1.000				
Hurdle step	0.682**	−0.076	1.000			
In line lunge	0.696**	0.599**	0.468*	1.000		
FADI	0.807**	0.555*	0.436	0.896**	1.000	
FADI-sport	0.818**	0.390	0.561*	0.875**	0.564*	1.000

[a]Spearman's rank correlation coefficient, *$p<0.05$ **$p<0.01$
LE-FMS: lower extremity functional movement screen; FADI: foot and ankle disability index

in any of the populations. In our results, a strong correlation was observed between patients with CAI and the in-line lunge movement. This suggests that the in-line lunge movement may be useful in identifying ankle instability symptoms in patients with CAI. For this reason, the in-line lunge measured many movement pattern deficiencies. It observed hip, knee, and ankle stability, as well as calf and quadriceps flexibility. The movement also required core stability[20]. However, the hurdle step observed single-leg stability, as well as stability in the knees and hips[10]. Dunyak[21] reported that the LE-FMS score had a low correlation with the Balance Error Scoring System (BESS) score, which is used as a gold standard for balance function in healthy adults. However, there was a high correlation with the in-line lunge with the BESS.

The scores of hurdle step and in-line lunge in the CAI group were lower than in the healthy group. Chronic unilateral ankle sprain leads to weaker hip abduction strength and less plantar flexion range of motion on the affected sides[25]. Weakness of the gluteus medius muscle may produce deviations in joint motion and subsequent loss of stability. Weaker hip abductors in the affected limb of patients with chronic ankle sprains support this view of a potential chronic loss of stability throughout the kinetic chain or compensations by the affected limb, thus contributing to repeat injury at the ankle[26].

The deep squat is used to assess bilateral, symmetrical, and functional mobility of the hips, knees, and ankles[27]. There was no significant difference in the deep squat between the CAI group and the healthy group, unlike the in-line lunge and hurdle step. However, the deep squat movement uses both legs in the closed-kinetic chain. Several subjects in the CAI group received only one score than the healthy group. Score of one signifies asymmetrical posture; the tibia and upper torso are not parallel, the femur is not below horizontal, and the knees are not aligned over the feet[20]. The RS result, which was measured during deep squat movement, shows asymmetrical weight bearing and COP distribution compared with the healthy group. The low score of the deep squat could be analyzed as the asymmetry of exercise performance and limited mobility[27]. However, it seems that the distinction between healthy people and patients with CAI was difficult to determine.

In this study, concurrent validity of the LE-FMS score showed positive strong correlations with FADI and FADI-sport. Therefore, this suggests that the LE-FMS score may be a valid method to determine a person's likelihood of CAI. Hurdle step and deep squat movements were not correlated with either FADI or FADI-sport. Therefore, these movements may not be able to identify CAI.

Although our study provides evidence of construct validity for use of the LE-FMS in patients with CAI, its scope was limited. More research needs to be conducted to evaluate the LE-FMS in various populations, including older subjects. We advocate the use of LE-FMS in young adults with CAI. As normative values are established through clinical practice and research, it will be important to assess the sensitivity and specificity of the LE-FMS in detecting pathologic conditions. Our results suggest that the in-line lunge of the LE-FMS was more suitable in detecting functional deficits for patients with CAI than was deep squat and hurdle lunge. Additionally, these instruments appear to be reliable in detecting functional limitations in patients with CAI.

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