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Original Article

Postural control systems in two different functional movements: a comparison of subjects with and without chronic ankle instability

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Abstract. [Purpose] The aim of this study was to evaluate postural control during two different movements of the Functional Movement Screen in patients with chronic ankle instability compared with healthy subjects. [Subjects] This study was a cross-sectional survey of 50 participants comprised of 25 chronic ankle instability patients and 25 healthy subjects. [Methods] All subjects were subjected to measurement of the Foot and Ankle Disability Index and center of pressure and Functional Movement Screen testing. The deep squat and hurdle step were performed for the lower extremities in Functional Movement Screen testing. Then, the center of pressure was measured with balance assessment software using a Nintendo Wii Balance Board. The center of pressure path length, velocity, and area of the 95% confidence ellipse and Functional Movement Screen scores were evaluated for all subjects. [Results] The results showed significant differences in center of pressure path length, velocity, and area of the 95% confidence ellipse between the groups for the hurdle step with the non-affected limb. However, there were no significant differences between groups for the deep squat and hurdle step with the affected limb. [Conclusion] The results of this study showed that there was a difference in the hurdle step with the non-affected limb in chronic ankle instability patients compared with normal subjects.
Key words: Chronic ankle instability, Center of pressure excursion, Functional movement screen

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INTRODUCTION

Functional movements and balance are elements that decrease the risk of injuries[1)]. Functional movement is defined as the ability to produce and maintain a balance between mobility and stability through the kinetic chain while performing fundamental patterns with accuracy and efficiency[2)]. Functional movement can be effected by a lack of proprioception and postural control[3)]. The Functional Movement Screen (FMS) is a valid and reliable method of assessing symmetry of motion and risk of injury[4)]. Three of the seven kinds of movement of the FMS are correlated with the function of the lower extremity. There movements are the deep squat, hurdle step, and in-line lunge.

Chronic ankle instability (CAI) has been linked to several mechanical and functional insufficiencies, and several mechanical impairments have been identified as contributing factors for CAI[5)]. Deficits in postural control and other functional impairments are thought to be the result of a loss of somatosensory information due to damaged ligament mechanoreceptors[6)]. Postural stability can be defined as postural balance or postural steadiness while postural balance is defined as the ability to stay upright or to recover equilibrium after external dynamic perturbations; under altered somatosensory conditions, postural steadiness, sometimes refers to standing as still as possible on a force platform[7)].

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Table 1. Characteristics of subjects

	Patients with CAI (n=25)	Control[b] (n=25)
Gender (person)		
Male (n)	10	11
Female (n)	15	14
Age (yrs)	24.8±1.5[a]	27.4±3.1
Height (cm)	165.3±6.9	168.5±7.5
Weight (kg)	59.9±12.4	65.3±11.1
BMI (kg/m^2)	21.5±4.0	23.1±2.6
ROM-NA (deg)	34.6±6.7	38.2±7.1
ROM-A (deg)	28.2±7.4	39.5±4.2
FADI (%)	77.2±7.3	100.0±0.0

[a]Means±SD
[b]For the control group, affected is the dominant lower extremity and non-affected is the non-dominant lower extremity
BMI: body mass index; ROM: range of motion; NA: non affected; A: affected; CAI: chronic ankle instability; FADI: the foot and ankle disability index

Postural control is facilitated by postural movements that control body sway such that the center of mass remains above the area of support[8)]. Direct measures of the postural control movements quantified the sway angle of the center of mass or the kinematics of specific joints[9)]. Indirect methods include, for example, the quantification of the center of pressure (COP) movement or the measurement of activation of muscles involved in postural control[10)]. These represent outcomes of the inertial forces of the body and restoration of equilibrium forces of the postural control system[11, 12)]. Recently, the Wii, designed and marketed by Nintendo, has attracted considerable attention as a new generation device. As an accessory of the Wii, the Wii Balance Board (WBB) is designed to test balance[13)].

Thus, CAI patients should realize that assessment of functional movements and balance as a possible means of injury prevention is as important as evaluating and treating injuries. The purpose of this study was to compare the COP displacement during two kinds of movement of the FMS measurable on a WBB in patients with CAI and healthy subjects.

SUBJECTS AND METHODS

We recruited CAI patients (n=25) and healthy subjects (n=25) who worked at a rehabilitation center in the Republic of Korea. The subjects were recruited from the workplace setting to participate in this study. Subjects were classified as having CAI if they reported having the following: (1) instability that they attributed to an initial injury, (2) giving way in the last 6 months, and (3) one or more problems according to the items of the Foot and Ankle Disability Index (FADI). Subjects were excluded if they reported any of the following: (1) bilateral ankle instability, (2) history of ankle fracture, (3) ankle injury within 3 months of participation, and (4) history of balance disorder. Participation in the study was voluntary, 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 the subjects. The study was approved by the Daejeon University institutional review board. All subjects completed the FADI for self-reported measurement of function. The FADI has 22 items. Each item is scored from 0 (unable to do) to 4 (no difficulty at all). The $ICC_{2,1}$ for the FADI was 0.89[14)]. The subjects' characteristics are summarized in Table 1.

All participants performed COP measures and FMS testing. The FMS was developed as an evaluation tool for functional movement[15)]. We evaluated COP excursion related to the deep squat and hurdle step. Balance was assessed on a WBB with the feet apart during the deep squat and hurdle step. Each position was measured three times. For the current study, sampling for data collection was performed at 50 Hz and 10 Hz (using a low-pass filter). Measurements were taken for 15 and 30 seconds with a 60-second rest between each task. The reliability had an ICC ranging from 0.66–0.94, and the pressure points on the center of pressure validity had an ICC ranging from 0.77–0.89[16)]. Parameters calculated from the COP data included the standard deviation of the path length, velocity, and area of the 95% confidence ellipse (area 95)[17)].

For the deep squat, the subject assumed the starting position by placing the feet shoulder width apart on the WBB. The subject then raised a dowel overhead to fully extend the elbows. The subject then rested the dowel on top of the head and adjusted the hand position so that the elbows were at 90°. The subject then slowly performed the deepest squat possible, keeping the heels on the floor, head and chest facing forward, and the dowel raised as high as possible overhead. The subject was instructed to keep the knees aligned over the feet, with no valgus collapse. If these conditions were met, the subject received a score of 3. If the subject could not meet the conditions for a score of 3 in the deep squat, then the movement was

Table 2. Center of pressure outcome measures

Task		Patients with CAI	Control[b]	95% Confidence Interval	
				lower	upper
Deep squat					
	Path length (cm)	55.58±12.62[a]	51.62±7.39	−2.89	10.83
	Velocity (cm/s)	6.47±1.17	6.13±1.40	−0.51	1.20
	Area95 (cm^2)	22.54±8.89	21.44±9.53	−4.97	7.16
HS-NA					
	Path length (cm)	75.58±18.37*	65.28±11.88	0.06	20.54
	Velocity (cm/s)	8.72±1.51*	7.46±1.49	0.27	2.25
	Area95 (cm^2)	64.46±27.28*	49.22±15.27	0.56	29.93
HS-A					
	Path length (cm)	70.07±14.53	69.01±10.45	−7.31	9.41
	Velocity (cm/s)	8.17±1.32	7.94±1.67	−0.76	1.22
	Area95 (cm^2)	70.32±26.78	69.78±32.40	−22.04	17.12

[a]Means±SD *$p<0.05$
[b]For the control group, affected is the dominant lower extremity and non-affected is the non-dominant lower extremity
CAI: chronic ankle instability; NA: non affected limb stepping; A: affected limb stepping; HS: hurdle step

performed again with an FMS kit board placed under the heels for evaluation of a score of 2. If requirements listed for a score of 2 were not achieved, then the subject received a score of 1. If the subject experienced pain during the movement, a final score of zero was given for the deep squat test.

For the hurdle step, the height of the tibia was measured from the floor using the tibial tuberosity as a reliable landmark and a dowel as the measuring device. The hurdle's marking cord was adjusted to the tibial tuberosity. The dowel was positioned across the shoulders behind the neck, and the subject stood on a WBB. The subject stepped over the hurdle with one leg, touched his/her heel to the floor while maintaining the stance leg in an extended position, and then returned the moved leg to the starting position. The same procedure was repeated with the other, and leg scored the hurdle-stepping leg. A score of 3 was given for the hurdle step if the subject's hips, knees, and ankles remained aligned in the sagittal plane, there was minimal to no lumbar movement, and the dowel and hurdle remain parallel. If any of the criteria were not achieved for a score of a 3, a score of 2 was given, and if the criteria for a score of 2 could not be achieved, a score of 1 was given. If the subject experienced pain during the movement, a final score of a zero was given for the hurdle step[1, 15, 18].

Descriptive statistics of the means and standard deviations of all data measured in this study were produced using PASW Statistics 18.0 (SPSS, Chicago, IL, USA). 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 group means. Differences between categorical variables were analyzed using the χ^2-test. Statistical significance was set at $p<0.05$.

RESULTS

Differences in COP excursion are presented in Table 2. Significant differences were observed between groups in comparisons of the COP path length, velocity, and area 95 in the hurdle step with the non-affected limb ($p<0.05$). However, there were no significant differences in the deep squat and hurdle step with the affected limb between the groups ($p>0.05$).

DISCUSSION

This study sought to investigate differences in postural control between CAI patients and healthy subjects. Impairments in feedback sensorimotor function have long been thought to be a consequence of an initial lateral ankle sprain and a mechanism of CAI. Recent research has indicated that central changes in sensorimotor function are present in patients with CAI[19]. CAI patients showed more postural sway compared with normal subjects in the hurdle step supported by the affected lower extremity. The area 95 represents the COP of the area formed by an oval shape about the center of the COP and is used to assess the spatial aspect of balance[17]. In the present study, the sway distance was longer, the velocity was faster, and the area 95 was wider in the hurdle step with the non-affected limb compared with that with the affected limb. This indicates that the CAI patient's ability to balance is deteriorated compared with that of a healthy subject[20].

The hurdle step also measures single-leg stability, as well as stability in the knees and hips. In a previous study, subjects with a unilateral chronic ankle sprain showed weakness involving the ipsilateral hip abductor due to CAI. After lower limb ligamentous injuries, dynamic postural stability of the lumbopelvic complex decreases[21]. This has an effect on postural control, and it also seems to have an influence on the COP path length, velocity, and area 95. These corrections, or postural sway, keep the COP within the base of support during the hurdle step[22]. Small postural sway adjustments can be used as ankle strategies in maintaining balance. During changes in balance, excessive lateral displacement of the center of gravity will result in increased COP path length[23]. When the ankle is unable to compensate adequately for this lateral sway, then a hip strategy is initiated, which helps to prevent the ankle from excessive inversion movement, and it has been suggested that altered sensation in the ankle joint can lead to muscle function changes in another, more proximal joint[22].

The deep squatting posture can be described as a sitting posture with ankle dorsiflexion, knee flexion, and hip flexion[24]. In this study, there was no statistically significant difference in the results from deep squat assessment of COP path length, velocity, and area 95 in healthy subjects and those with CAI. When deep squat assessment of the FMS, any of the criteria for a score of three are not achieved, performing the test with the board from the described FMS kit (2 inch) under the heels. Because of this influence, when removing the kit and to the assessment would have seemed the differences between the two groups. However, when there is no kit, lifting the heel higher than the full squatting position is known to shift the center of mass forward and the whole body is adjusted through segmental linkage coordination. When the heel was raised, this postural adjustment made stability critical. The tip-toe squatting condition places the center of pressure within a small area of the base of support (BOS), and the BOS length may influence subjects' ability to perform the squat movement[25].

This deep Squat evaluation seems difficult to determine the difference from the subjects because the operation using all of the both limb. It is possible to evaluate the deep squat with a WBB; however, this requires precise, symmetrical positioning of the feet and precludes the assessment of individual limb COP movements. Consequently, the force under each foot is typically measured independently, which requires a WBB[26]. Regardless of the lower extremity muscle activation pattern, these data suggest that supraspinal aspects of motor control are susceptible to CAI.

Significant differences in COP path length, velocity, and area 95 in the hurdle step with the affected lower extremity were identified as significant predictors of CAI patients and thus decreased postural stability compared with that of normal subjects. These findings help elucidate the factors contributing to CAI and may be helpful in the development of methods of preventing and treating CAI. The limitations of this study include the relatively small groups. Future research should study other functional movements.

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