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RESEARCH PAPER

Use a biomechanical experimental setup to analysis the reliability of force plate postural control parameters in chronic ankle instability patients, copers and healthy control

Somayeh Mohamadi [1,*], Mahyar Salavati[1], Amir Salar Jafarpisheh [2]

[1] *Department of Physiotherapy, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran*
[2] *Department of Ergonomics, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran*

Abstract

Ankle sprain is one of the most prevalent joint injuries in the lower extremity. Valid and reliable measurement techniques is essential for the collection of accurate and meaningful data about joint injuries such as ankle sprain. This case-control study is designed to evaluate the test–retest reliability of force plate measures and are compared the static postural control values in patients with chronic ankle instability (CAI), ankle sprain copers & healthy controls. Seventy-five patients (25 CAI, 25 copers & 25 healthy match controls) are asked to execute single-leg stance onto a force plate. Force plate parameters include, the center of pressure (COP) area, COP length, mean total velocity and sway index are measured for static postural control evaluation. To evaluate test–retest reliability, 20 participants of each group repeated the tests 6–8 days after the first session. Relative reliability of the force plate measures is assessed using interclass correlation coefficient (ICC) and absolute reliability using standard error of measurement (SEM), minimal metrically detectable change (MMDC) and coefficient of variance percent (CV%). Analysis of variance (ANOVA) is used to determine differences between three groups. Static postural control measures have high test–retest reliability, ranging from 0.73 to 0.88. Greater postural sway has been observed in the CAI compared with the coper ($P< 0.05$) and the matched limb of the control group ($P < 0.05$). The results are illustrated that the static postural control measures are reliable tests to evaluate functional performance of the patients with CAI, copers and healthy controls.

Keywords: Postural balance**;** Reliability and validity**;** Postural control**;** Chronic ankle instability**;** Balance**;** Postural stability**;** test**;** Ankle sprain

1. Introduction

Lateral ankle sprains are an extremely common injury among the physically active population [1]. Some individuals who are able to recover from sprain without residual symptoms, known as "copers" [2]. But approximately 30-75% of those who sustain a first time ankle sprain develop chronic ankle instability (CAI) with persisting symptoms including pain, giving way, dysfunction, and repetitive ankle injuries [1, 3]. It has been assumed that altered postural control is one of the factors attributed to CAI which involves an interaction between sensory, cognitive and motor systems [2]. It has been reported that the static postural control is a valuable measure

* Somayeh Mohammadi. Tel.: +982171732892; fax: +982122180109.
E-mail address: somayeh.mohamadi@ymail.com

of somatosensory integration [4]. On the other hand, measures instrumented of postural control have been used to predict ankle sprain risk and to evaluate sensorimotor deficits after acute first time index ankle sprains and in those with CAI [5]. Up to now, the various methods and measures which reported in the literature can make the interpretation of this extent of literature difficult [6]. Therefore, the static balance tests such as single leg stance on force plate are valuable methods to determine differences between CAI patients, copers and healthy control groups. To our knowledge, no study has evaluated reliability of the force plate data measures in CAI, copers and healthy controls. Since the reliability of outcome measures depends on patient's characteristics, further evaluation is needed to confirm the efficiency of force plate parameters in these populations. Therefore, the first purpose of this study is the surveying reliability of force plate data in CAI, copers and healthy controls. The second aim of the present study is the comparing the static postural stability in these three groups of people.

Here introduce the paper, and put a nomenclature if necessary, with the same font size as the rest of the paper. The paragraphs continue from here and are only separated by headings, subheadings, images and formulae. The section headings are arranged by numbers, bold and 10 pt. Here follows further instructions for authors.

2. Materials and Methods

2.1. Participants

A convenient sample including seventy-five people (male and female) volunteered to take part in this study according to G-Power software. Twenty-five patients with CAI and 25 copers are matched with 25 healthy controls based on age and body mass index (BMI). All participants are recruited through advertising in the university campus, hospitals, physiotherapy clinics and general community in Tehran province of Iran. All participants signed an informed consent form approved by the Human Research Ethics Committee of the Iran University of Medical Sciences in Tehran, prior to participation. Ethic Committee Code number: IR.IUMS.REC.1395.9211342211.

2.2. Inclusion and exclusion criteria

The CAI patients were defined according to an international ankle Consortium [7]. The subjects in the coper group were included if they had one episode of severe lateral ankle sprain within last year but they return to the daily activity without any recurrent ankle sprain or giving way [8]. An uninjured control group including 25 physically active individuals without history of ankle sprain.

The subjects in all three group had no history of any other musculoskeletal lower leg injury in the past 3 months, fracture or surgery.

2.3. Procedure

First, all sprained ankle participants are asked to complete the Persian versions of the following questionnaires: IdFAI [9], AII [10], FAAM [11] and FAOS [12] for categorizing participants to CAI or coper groups.

For the assessment of postural control, centre of pressure (COP) data is obtained using a fixed strain gauge Kistler (Type: 5691A) force platform and a Bertec AM-6701 amplifier (Bertec Corp., Columbus, OH) and low pass filtered with a cut-off frequency of 10 Hz. The COP kinetic data is collected with a sampling frequency of 100 Hz for better detection of movements of COP.

2.4. Static postural control evaluation

All subjects are asked to perform static postural control task which evaluated by the same expert evaluator. Subjects stood barefoot with their arms at the pelvic (akimbo position) and are instructed to simply look at a mark on the wall approximately 5 m in front of their faces. They are not permitted to move their limbs or head or to speak during the data collection period. Participants stood with the affected dominant leg on a special mark on the on the center of a 40 × 60 cm force platform for consistent foot placement across trials. Subjects are instructed to lift the contralateral limb and hold it in approximately 90˚ of knee flexion and 45˚ of hip flexion. Once they can hold this position, data collection is initiated with hit the computer keyboard (figure 1). If subjects lost their balance, touched down the non-standing-foot, or braced themselves on the nearby, the test is stopped and after a while repeated. All participants should hold the test position for 30 s during all trials. Each measurement is repeated three times, and average scores are used for analysis. One-minute rest is given between every test. Three familiarization trials are performed for each condition prior to data collection, to ensure participants fully understood the requirements of the tasks. A second data collection is conducted a week later at the same time of day, for the assessment of between-day reliability (n = 20).

The calculated COP parameters are COP area (cm2), maximal range of COP displacement (cm), mean total

velocity (cm/s) and sway index (cm). These COP parameters have been shown to be reliable measures for assessment of postural control in musculoskeletal disorders [13].

The study is approved by the Ethics Committee for Health Sciences Research involving human subjects, and the informed consent is obtained. All subjects who are willing to participate in the study, signed it.

These tests have been done in 2019, in the rehabilitation research centre of Iran University of medical science.

Figure 1: test position while doing tests on a force platform (experimental setup)

2.5. Statistical Analysis

Statistical analysis is computed using SPSS version 22 (SPSS Inc., Chicago, IL). Paired-sample t-tests are performed to determine the differences of the scores obtained at test and retest sessions and reliability of the performance measures between sessions. The interclass correlation coefficients (ICCs) for measurement of the absolute between-sessions reliability and the SEM (pooled standard deviation of all scores × the square root 1 – ICC) and within-subject coefficient of variation (CV%) are calculated for each parameter to estimate the relative between-sessions reliability. In addition, the minimum difference (MMDC= SEM× √2× 1.96) is calculated to determine the minimum threshold of measurement to ensure that differences between measurements are real and outside the error range.

The ICC value ranges for reliability interpretation are represented as follows: [14]

ICC Value < 0.5	Poor
0.5 ≤ ICC Value < 0.75	Moderate
0.75 ≤ ICC Value < 0.9	Good
ICC Value ≥ 0.9	Excelent

<0.5=poor, 0.5-0.75= moderate, 0.75-0.90= good, and >0.90 excellent.

For each ICC measurement, the 95% confidence interval is calculated to determine the amount of error associated with the measurement and take the sampling distribution into account.

The one-way ANOVA test, is done to examine difference in postural control between three groups. Data are presented as mean standard deviation (SD) and between groups p-value for significant differences and post hock Tukey test. The level of significance is set at $P \leq 0.05$ for all statistical tests.

3. Results

Demographic characteristics of all groups are shown in Table 1. No statistically significant difference is found for age, height and weight between the three groups (Table 1).

Table 1: demographics characteristics of the groups

Body Properties	Chronic Ankle Instability (n=25)	Coper (n=25)	Healthy (n=25)	p-value
Age (year)	30.84(6.19)	30.28(6.09)	31.04 (7.33)	0.99
Height (cm)	171.61(8.01)	173.57(10.50)	172.23(10.39)	0.78
Weight (kg)	74.52(10.66)	72.66(10.08)	71.91(8.99)	0.85
Body Mass Index (kg/m^2)	24.80(3.11)	24.11(1.89)	24.31(2.70)	0.64

The mean, SD, ICC, CI, SEM, MMDC and CV% for the postural control measures have been shown in Table 2. The ICC is higher than the acceptable level of 0.70 for most of variables. The CV% < 10% and ICC values of >75% have been shown to be demonstrative of good reliability for measures obtained during single leg stance.

Table 2: test-retest reliability force plate measures of single leg stance postural control in the three groups (n=20)

groups	Parameters	Trial 1 (mean+SD)	Trial 2 (mean+ SD)	ICC (95% CI)	SEM	MMDC	CV (%)
CAI	Area	17.01 (2.43)	17.12 (2.46)	0.89 (0.75-0.96)	0.81	2.24	14.28
	COP length	18.18 (3.03)	17.96 (3.00)	0.77 (0.70-0.89)	1.30	3.59	16.66
	velocity	1.31 (0.14)	1.30 (0.14)	0.93 (0.67, 0.98)	0.04	0.10	10.68
	Sway index	2.04 (0.29)	1.98 (0.26)	0.89 (0.74-0.95)	0.09	0.25	14.21
Coper	Area	13.99 (2.33)	15.01 (2.55)	0.70 (0.42 to .88)	1.34	3.70	16.65
	COP length	15.88 (2.64)	16.01 (2.94)	0.74 (0.50, 0.90)	1.42	3.94	16.62
	velocity	1.20 (0.15)	1.24 (0.16)	0.89 (0.58, 0.97)	0.05	0.14	12.5
	Sway index	1.73 (0.28)	1.77 (0.32)	0.81 (0.58-0.92)	0.13	0.36	16.18
healthy	Area	15.76 (2.62)	15.88 (3.13)	0.89 (0.74-0.95)	0.95	2.63	16.62
	COP length	16. 11(1.78)	16.12 (1.95)	0.91 (0.82 0.95)	0.56	1.55	11.04
	velocity	1.18 (0.17)	1.20 (0.19)	0.83 (0.79 0.87)	0.07	0.20	14.41
	Sway index	1.85 (0.23)	1.79 (0.22)	0.85 (0.68-0.94)	0.08	0.24	12.43

CAI: chronic ankle instability; COP: center of pressure; S.D: standard deviation; ICC: interclass correlation coefficient; SEM: standard error of measurement; MMDC: minimal metrically detectable change; CV: coefficient of variation;
Units of COP measures are as follows:; cm2 (area), cm (cop length), cm/s (mean total velocity), cm (sway index)

In the table 3, It is clearly shown that the means and standard deviations of COP parameters (area, COP length, velocity, sway index) and mean differences P values for each parameter. Moreover, in the post hoc analysis of one-way ANOVA, it is obviously illustrated that there are significant greater COP parameters in CAI group but there is no significant difference between copers and healthy control groups.

Table 3: the descriptive statistic of force plate data in three groups for between group comparisons using one way ANOVA (n=25)

COP parameters	CAI group Mean (SD)	Coper Mean (SD)	Healthy Mean (SD)	P-Value
Area	16.61 (2.50)	14.89 (2.68)	15.35 (3.21)	0.03
COP length	17.92 (3.43)	16.88 (3.33)	17.60 (3.36)	0.03
velocity	1.183 (0.21)	1.13(0.24)	1.11 (0.23)	0.01
Sway index	1.94 (0.44)	1.73 (0.33)	1.75 (0.43)	0.04

COP: centre of pressure; CAI: chronic ankle instability; SD: standard deviation

4. Discussion

The main purpose of our study is to investigate the test–retest reliability of force-plate derived parameters in CAI, copers and healthy controls. The results are suggested that the static postural control outcomes are reliable values in CAI, copers and healthy control groups. No significant differences (P >0.05) are observed between test sessions for all derived parameters. The results indicate high to very high relative reliability of COP area, COP length, mean total velocity and sway index. In the other words, this study established the relative and absolute reliability of some COP measures across three different groups, CAI, copers & healthy controls.

The findings of this study indicate that the single leg stance force plate–derived parameters are reliable indicators of performance in CAI, copers and healthy control groups.

Although there is no study to assess reliability of these parameters in CAI patients, the results of the present study may be comparable with the study by Salavati et al.[15] which demonstrated comparable results about force plate measurements especially for COP velocity in different musculoskeletal disorders. Also other researches has reported comparable values with moderate to high test–retest reliability for force plate parameters during single leg stance [16, 17].

In the study conducted by Brown (2007) , the CAI group demonstrated good reliability for the COP excursion length and velocity in the static and dynamic conditions and reliability of COP parameters in CAI group was better than the stable ankle group [18].

High test–retest reliability for all measures in the current study revealed satisfactory stability of the postural control measures over time in CAI patients and control groups. Thus, force plate data measures are reliable performance measure in CAI patients, coper and uninjured healthy controls.

According to the presented results, one of the most important results is that the CAI patients have significantly different balance measurement scores in comparison with the two other groups. The same findings was obtained in other studies with different samples and different study design, such as the studies of Wikstrom et al. [19], which showed that CAI subjects had greater COP measures in comparison with copers and matched healthy controls. One possible explanation for these result is that individuals with CAI failed to develop successful compensatory postural control strategies and this can lead to recurrent injuries and episodes of giving way to occur [19].

Furthermore, some other researchers reported that the static postural balance in CAI was worse than the controls [2, 20]. While other reported no difference in static postural control measures between CAI patients and controls [18, 21]. Brown and Mynark (2007) displayed no significant difference of mean total velocity between individuals with chronic ankle instability and subjects with stable ankles in static and dynamic conditions of postural control [18].

One explanation for this discrepancy is that, differences between individuals with CAI and stable ankles may remain undetected with single-leg stance tests and the task such as single-leg jump landing task may be more challenging in the individuals with CAI. Therefore, clinicians should incorporate more dynamic challengeable assessments when evaluating postural stability in individuals with CAI [21].

There are several limitations to our study such as our sample are among more severe category of ankle sprain individuals and also, the dynamic balance challenges are not surveyed. Therefore, further research may need to consider these factors to determine the evaluative and predictive value of the COP parameters in CAI patients and it is better that the comparison between CAI patients and coper counterparts are done.

5. Conclusion

- These findings suggest that sophisticated systems, such as the force plate, may offer reliable balance tests and as a gold-standard methods. Consequently, it can be clear, acceptable and standard tool for postural control assessment.
- The findings of this study indicate that force plate–derived parameters are reliable indicators to compare postural control in CAI patients with copers and their healthy controls.
- There is significantly different postural control performance between CAI, copers and control groups.

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