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RESEARCH PAPER

Biomechanical differences between individuals with chronic ankle instability, copers and healthy controls in the countermovement jump on the force plate

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Abstract

To evaluate the counter-movement jump task in chronic ankle instability (CAI), copers and healthy subjects. Seventy-five subjects (25 CAI, 25 coper and 25 healthy) participated in the present study. Time to stabilization (TTS) and dynamic postural stability index (DPSI) after counter-movement jump-landing task on a force plate in both legs of each participant were assessed. To compare those three groups, One-way Analyses of Variance (ANOVA) with Tukey post hoc test was used. Pair t-test was utilized to demonstrate the probable changes within group. Using one-way Analyses of Variance (ANOVA) with Tukey post hoc testing, the CAI group displayed significant difference in the medial/lateral (ML) TTS and also DPSI in the vertical plane, and in the composite score than the healthy and coper groups. No significant difference was found between dominant and non-dominant legs in each group based on Pair t-test. Significant different dynamic postural stability was demonstrated in CAI group compared with copers and healthy control. It can be suggested that dynamic postural control strategies should be take into account in their rehabilitation programs. No difference between landings on dominant or nondominant leg can suggest central mechanisms for functional ankle instability.

Keywords: ankle, sprain, postural control

1. Introduction

Lateral ankle sprain is one of the most prevalent lower extremity injuries especially in physically active population [1]. A large percentage of individuals with a history of lateral ankle sprain demonstrated residual symptoms such as activity induced pain, recurrent swelling, ankle's giving way and repetitive injuries for more than one year and then identified as chronic ankle instability (CAI) [2]. The copers were determined as completely recovered people without any giving way or other related symptoms [3].

The previous studies described dynamic postural control deficit in subjects with CAI [2, 4-6]. According to the literature, the mechanism of ankle sprain injury may be attributed to dynamic tasks [5]. Some tests were used to evaluate the postural stability in individuals suffering from ankle sprain [5] but, in many studies static postural stability was measured and it seems that static balance tests may not be sensitive

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enough to find small variations of postural control and lower challenges in sensorimotor systems [6]. Counter-movement jump test is considered a reliable measurement tool to evaluate the dynamic postural stability deficits [7-9].

In the numerous studies, CAI individuals were compared with the healthy counterparts and few investigations were conducted on coper subjects [7, 10, 11] to detect the postural control deficits using static tests more than dynamic ones [8]. Also, much ambiguity was found to assess the role of leg dominancy in postural stability [12]. Due to the important role of dynamic postural stability in individuals with CAI, the main purpose of this study was to evaluate and compare individuals with CAI, healthy subjects and copers using counter-movement jump test. Therefore, the second purpose of the current study was to compare the dynamic stability parameters between dominant and non-dominant legs.

2. Materials and Methods

2.1. Participants

In the present case-control study, 75 subjects (males and females) participated and allocated through the random sampling method and according to G-Power software. Twenty-five individuals with a history of CAI and also 25 copers were matched with 25 healthy controls based on age and body mass index (BMI). All participants were recruited through advertising in the university campus, hospitals, physiotherapy clinics and general community in Tehran province of Iran.

2.2. Inclusion and exclusion criteria

The inclusion criteria of participants in the CAI group were considered as having a previous severe lateral ankle sprain for at least past three months without any pain, swelling, redness or inflammation in the time of evaluation, recurrent giving way or instability in the ankle that was confirmed by the proposed questionnaires for instability [10]. 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 [13]. The subjects in the control group had no history of any musculoskeletal lower leg injury in the past 3 months, fracture or surgery.

The exclusion criteria of participants in the present study were considered as follows: any history of previous surgery in the neuro-musculo-skeletal systems of the lower limbs, lower extremity fractures, and acute lower limbs injury in the previous three months, visual or cognitive disorders.

2.3. Procedure

The ethical approval was received from the ethical committee of Iran University of medical sciences. All subjects who were willing to participate in the study, received consent form and signed it. Then, all individuals suffering from lateral ankle sprain completed the following questionnaires: 1) Identification of Functional Ankle Instability (IdFAI), 2) Ankle Instability Instrument (AII), 3) Cumberland Ankle Instability Tool (CAIT), 4) Foot and Ankle Ability Measure (FAAM) and 5) Foot and Ankle Outcome Scores (FAOS) [10].

All tests were performed in the Rehabilitation Research Laboratory of Iran University of Medical Sciences. A subject’s body weight was recorded as the average of vertical ground reaction force (GRF) variations during a five second static stance on the force plate before data collection (2). Time to stabilization (TTS) and dynamic postural stability index (DPSI) after counter-movement jump-landing task (CMJT) was applied to evaluate dynamic postural control. All measurements were made in barefoot. Three trials were performed to record each outcome measure. All Tasks were conducted in a random order. For the CAI and coper groups, the injured dominant leg was tested and compared with subject’s dominant leg in the control group. Comparison with the nondominant leg was performed for evaluation of functional instability. In the present study, dominancy was defined as having at least 2 of the 3 following tests: a balance recovery after a posterior push, a step up onto a box, and kicking a ball with maximum accuracy through a goal [14].

2.4. Dynamic postural control evaluation

The force plate which reliability and validity of its data was checked before, utilized in the present study in the landing zone to collect kinetic data with the frequency of 500 Hz [15]. The CMJ consists of an initial downward movement toward squat position, followed by immediate upward movement lead to taking off with forceful hip, knee, and ankle extension, and then, landing on the ground. Subjects stood on the force plate and looked straight forward, then they were instructed to jump as high as possible with both legs and to land one time on the evaluative leg (dominant limb in control group and affected dominant limb in CAI and coper) and one time on another leg in the center of the force plate while hands placed on the hips (Akimbo position), the free foot was flexed at the knee joint without touching the stance leg (figure 1).

After landing, all subjects were asked to stabilize themselves quickly and remained in a single-leg stance for 30 seconds without any sway. The above tasks were performed three times with considering 60 seconds' rest between trials. Failed trials due to having sway and loss of balance (e.g., free foot touched the floor or hands detached from hips) were excluded from data collection. The average of the three successful trials were used for further analysis.

The TTS and DPSI in the medial/lateral, anterior/posterior and vertical directions were calculated and analyzed using the above-mentioned tasks.

2.5. Statistical Analysis

Statistical analysis was performed in SPSS version 21 (SPSS Inc, Chicago, Illinois 60606, U.S.A.). The one-way ANOVA test and the Tukey post hoc test were used to identify the probable differences between groups and pair t-test was calculated to detect probable differences between dominant and non-dominant legs in each group. The level of significance was set at 0.05.

3. Results

In the present study, 75 subjects were participated. The demographic characteristics of the participants were demonstrated in 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 findings of one-way ANOVA tukey post hoc test are provided in Table 2.

Table 2. One-way ANOVA Tukey Post hock test for maximum reach distances in the three groups. The results of pair t-test to compare dominant and non-dominant legs within groups is demonstrated in Table 3. No significant differences were found for maximum reach distance between the dominant and non-dominant legs in all three groups ($p<0.05$).

1. Discussion

The present study compared CAI group and copers with healthy subjects for dynamic postural stability using CMJ task in three directions. The primary finding of this study demonstrated that individuals with CAI reported more medio-lateral TTS, DPSI and vertical SI compared with LAS copers and control group. In the present study, a larger composite and vertical DPSI scores were reported in individuals with CAI than copers and control group. These scores alteration indicated that the dynamic stability was seemed to be worse in CAI group. The results were accompanied with the findings of the previous studies reported the higher postural stability scores in individuals with CAI compared with the control group [2, 4, 5]. One of the speculative hypotheses for greater postural stability scores, is that CAI individuals may develop impairments in feedback neuromuscular control or fail to develop compensatory changes in feed-forward neuromuscular control or both [2].

Table 2: Tukey Post hock test of One-way ANOVA for stability indices in the three groups.

Dependent variables	*Groups*	*Mean differences*	*p-value*	*95% confidence interval*
ML-TTS	Healthy vs coper	0.44	0.34	0.31-0.1.25
	Healthy vs CAI	0.65	0.02*	0.28-0.1.33
	Coper vs CAI	0.68	0.02*	0.31-1.45
AP-TTS	Healthy vs coper	0.55	0.20	0.21-1.31
	Healthy vs CAI	0.44	0.35	0.32-1.20
	Coper vs CAI	0.11	0.93	0.65-0.87
V-TTS	Healthy vs coper	0.45	0.30	0.29-1.20
	Healthy vs CAI	0.48	0.30	0.31-1.25
	Coper vs CAI	0.15	0.82	0.55-0.77
DPSI	Healthy vs coper	0.06	0.85	0.19-0.30
	Healthy vs CAI	0.36	0.003*	0.11-0.61
	Coper vs CAI	0.40	0.001*	0.16-0.66
ML- SI	Healthy vs coper	0.02	0.68	0.04-0.09
	Healthy vs CAI	0.03	0.55	0.04-0.09
	Coper vs CAI	0.05	0.15	0.01-0.12
AP- SI	Healthy vs coper	0.03	0.24	0.01-0.07
	Healthy vs CAI	0.01	0.82	0.03-0.05
	Coper vs CAI	0.02	0.56	0.02-0.06
V-SI	Healthy vs coper	0.05	0.14	0.02-0.12
	Healthy vs CAI	0.10	0.01*	0.19-0.45
	Coper vs CAI	0.12	0.01*	0.20-0.46

Abbreviations: TTS: time to stabilization, ML: mediolateral, AP:anteroposterior, V: vertical, DPSI: dynamic postural stability index, SI: stability index, SEBT: star excursion balance test, PM: posteromedial, PL: posterolateral.

According to the results, the TTS scores were reported to be larger significantly in the frontal plane than the sagittal and vertical planes in individuals with CAI. The probable explanation for this increased score was attributed to the ligamentous injury and the subtalar and talocrural joints instability [16]. In addition, a significant correlation was found between anticipatory contraction and perfect dynamic postural stability [2]. Little or no anticipatory lower leg muscles contraction was reported in individuals with poor TTS. Therefore, the impaired dynamic stability determined in individuals with CAI, might be due to the weak anticipatory contraction. The findings of the present study were in agreement with the results described by Ross [17] and Wright et al [18]. They indicated that TTS-ML was longer in the individuals suffering from FAI than the control group [17, 18]. However, in the study conducted by Brown et al, no difference was found in TTS-ML measures between groups [19]. According to the results, the unchanged TTS scores in two groups were attributed to the study protocol and analyses.

The joints, muscles and ligamentous mechanoreceptors were damaged due to the ankle sprain; therefore, the lower extremity muscles activity and ankle joint's mechanical stability were changed [14]. In addition, less effective hip strategy was used to create balance and compensate the neuromuscular deficits instead of ankle strategy because the proprioception has been impaired. Some previous studies demonstrated the increased activation of hip muscles and decreased ankle muscles' activity in individuals with CAI during a single leg stance task. Finally, the impaired lower extremity muscles recruitment might be influence on the CMJ findings and performance in individuals with CAI [4].

Table 3: The results of pair t-test in dominant and non-dominant legs within groups.

	Groups	CAI (mean±SD)	coper (mean±SD)	healthy (mean±SD)
ML-TTS	dominant side (right)	0.15±0.04	0.08±0.02	0.08±0.01
	Non-dominant side (left)	0.16±0.05	0.09±0.02	0.08±0.01
	p-value			
AP-TTS	dominant side (right)	0.12±0.02	1.44±0.38	0.11±0.02
	Non-dominant side (left)	1.44±0.38	1.44±0.38	1.44±0.38
	p-value			
V-TTS	dominant side (right)	0.28±0.11	1.44±0.38	0.26±0.05
	Non-dominant side (left)	0.31±0.11	1.44±0.38	1.44±0.38
	p-value			
DPSI	dominant side (right)	0.35±0.14	1.44±0.38	0.28±0.07
	Non-dominant side (left)	0.37±0.16	1.44±0.38	0.27±0.07
	p-value			
ML-SI	dominant side (right)	2.01±0.83	1.44±0.38	1.70±0.42
	Non-dominant side (left)	1.98±0.79	1.44±0.38	1.72±0.44
	p-value			
AP-SI	dominant side (right)	1.66±0.67	1.44±0.38	1.44±0.38
	Non-dominant side (left)	1.63±0.65	1.44±0.38	1.42±0.36
	p-value			
V-SI	dominant side (right)	2.62±0.94	1.44±0.38	1.83±0.54
	Non-dominant side (left)	2.65±0.96	1.44±0.38	1.85±0.55
	p-value			

Abbreviations: TTS: time to stabilization, ML: mediolateral, AP:anteroposterior, V: vertical, DPSI: dynamic postural stability index, SI: stability index, SEBT: star excursion balance test, PM: posteromedial, PL: posterolateral.

Therefore, neuromuscular control, as measured by dynamic postural stability, seems to be important in maintaining joint stability [20] and therefore, changing the postural control in CAI group is considered to be an important indicator of ankle joint instability and lead to recurrence of ankle sprain. In addition, no significant difference was found between copers and control group and this means that purely ankle sprain may not be considered as an important indicator, but, some structural, biochemical and genetic problems may prone people to progress the sprain recurrence [21].

The second purpose of the present study was to determine if participants' dominant and non-dominant legs might be influence in the ability of individuals to control of the posture using CMJ among the three groups. The biomechanical differences found between the dominant and non-dominant ankle joints during physical activities might be related to the physiological and anatomical symmetries or asymmetries of lower extremities. Some disagreements were found in previous studies due to the following variables: side-to-side limb length differences, weight, long bones' shape and strength, standing and supine quadriceps angle, rear foot angle, size and shape of foot print, tibial torsion, navicular drop, pelvic angle, hip anteversion, femoral anteversion, tibiofemoral angle, anterior knee laxity, and genu recurvatum. Therefore, the presence of asymmetry in the SEBT was determined as the function of an acute or chronic injury and not seemed as a result of functional leg dominance [12].

A potential limitation in the present study was considered as a lack of information about muscles activity and joint function. Therefore, the electromyography and kinematic assessment of the lower extremity muscles and joints was not included in the present study. Also, the most subjects with severe or high-grade ankle sprain had injury in their dominant leg.

Future studies will be needed to use the electromyography and kinematic evaluations in the procedures and also, individuals with different grades of ankle sprain will be included.

4. Conclusion

In conclusion, dynamic postural stability was reported to be differed significantly in individuals with CAI compared with copers and healthy controls. The neuromuscular control training programs can be used in CAI individuals as the crucial part of their rehabilitation program.

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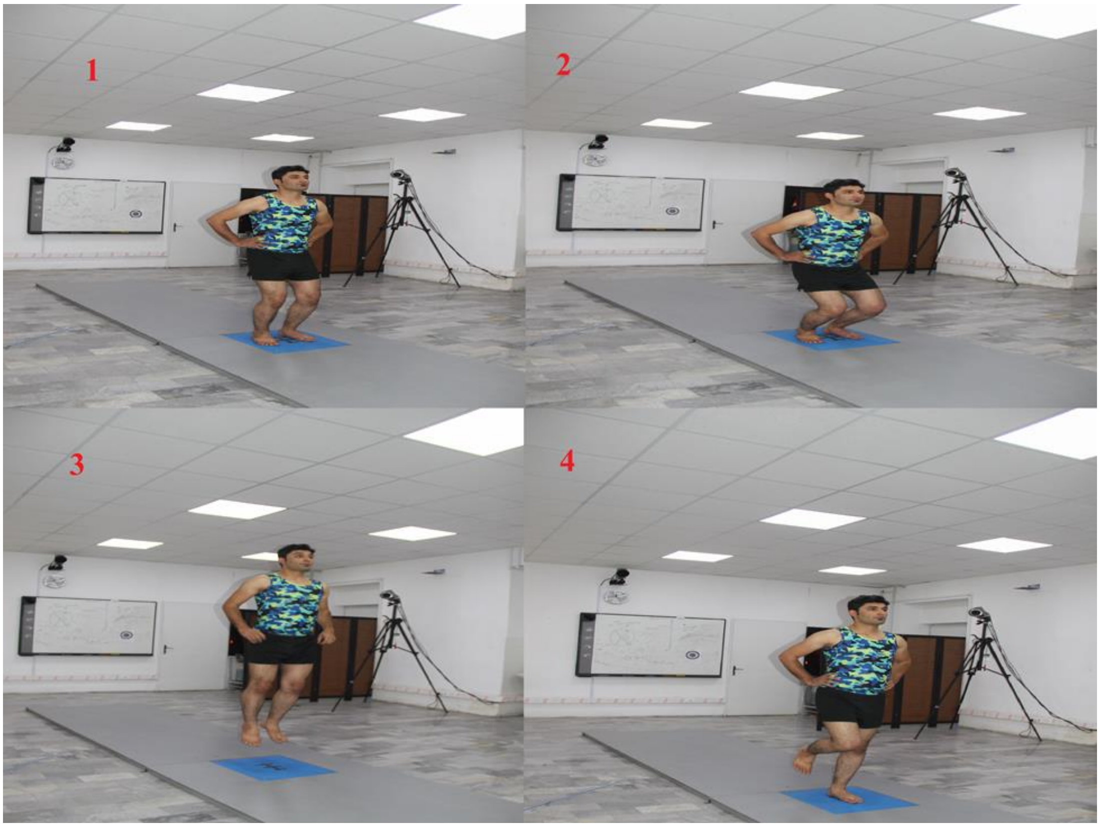

Figure 1: counter movement jump test position while doing test on a force platform (experimental setup)