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## Research Paper:

# Effects of Six-week Hopping Exercise on Time to Stabilization and Perceived Stability in Athletes With Chronic Ankle Instability During Single-leg Jump-landing

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## ABSTRACT

**Introduction:** To examine the effects of a 6-week hopping exercise program on time to stabilization and perceived stability among athletes with chronic ankle instability. This is a randomized controlled trial.

**Materials and Methods:** A total of 28 basketball players with chronic ankle instability (Mean±SD age; 22.67±2.88 y, Mean±SD weight: 80.47±8.48 kg, Mean±SD height: 186.82±3.09 cm) participated in this study and were randomly divided into two equal groups of 14 people each: 1. Experimental; and 2. Control. The experimental group performed hop exercises 3 times per week for 6 weeks. The control group received no intervention. Time to stabilization for anterior-posterior and medial-lateral components of ground reaction force, as well as ankle joint function assessment tool were found before and immediately after the exercise program. Descriptive statistics, independent t-test, and paired sample t-test were used to analyze the data at the significance level of 95% ($\alpha \leq 0.05$).

**Results:** The 6-week hopping exercise program led to a significant decrease in the time to stabilization of medial-lateral and anterior-posterior of ground reaction force and also a significant increase in the score of ankle joint function assessment tool ($P<0.05$).

**Conclusion:** Given the effectiveness of hopping exercises, postural control deficit, and time to stabilization in sport exercises, it is suggested that these selected exercises be used in training and rehabilitation protocols.

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## Introduction

Ankle sprain is one of the most common injuries in sports. Although it may initially look like a minor injury, it can cause serious damage to the skeletal muscle and impose a high cost on the health system [1]. The cost of treatment and diagnosing lateral ankle sprain was nearly $2 billion in 1984, which reached over $4.5 billion in 2015. It also has an incidence rate of over 2.15 per 1000 persons per year, which constitutes more than 50% of all injuries reported in high school and college games in the United States [2].

The other complications of acute ankle sprain include pain, joint laxity, and frequent ankle "giving way". Chronic ankle instability may be due to one or a combination of mechanical and functional deficits, such as ligament injury, muscle strength deficiency, delayed muscle reaction time, and or weak proprioception leading to poor balance control [3]. In general, patients with chronic ankle instability spend a longer time to reach stabilization on the affected leg and, they experience more postural sway in single-leg standing [4-7].

Time to stabilization is the time required to achieve equilibrium for both medial-lateral and anterior-posterior directions after landing. It is used to evaluate the dynamic stability, i.e. the ability to quickly achieve stability is a positive and conservative one. Besides, since most ankle sprain injuries, which occur unintentionally, are due to landing, the landing task is an effective and functional assessment method for evaluating this variable. Results of the previous research have shown that patients with chronic ankle instability have longer stability time than healthy individuals, and this delay leads to impaired postural control and intensifies the risk of re-injury [8-10].

So far, the common rehabilitation protocols used for chronic ankle instability consisted of balance exercises using the wobble board [11]. Although these exercises have a positive effect on the reaction time of the lower limb muscles [12], they use less functional approach and more static situations and are incompatible with the nature of exercise tasks (which is dynamic) [13, 14]. Furthermore, based on the approaches used, the incidence of re-injury in patients with chronic ankle instability is high. This condition necessitates using therapeutic protocols for its reduction [2]. Nowadays, applying the functional training approach and the principles of therapeutic practice are considered for faster rehabilitation given the specific needs of different sports. The use of plyometric exercises in this approach is also crucial [15]. Hopping is one type of plyometric and basic exercise that covers a wide range of plyometric exercises. In this regard, sports fields such as basketball can be considered a functional approach since basketball is played with jumping and landing as their main components [15]. Based on these points and the necessity of providing rehabilitation protocols to reduce risk factors in the patients with chronic ankle instability, the present study aims to investigate the effect of hopping exercises on the time to stabilization and perception of instability in the athletes with chronic ankle instability.

## Methods

In the present study, the statistical population consisted of male basketball players with chronic ankle instability. A total of 28 participants were randomly selected and divided into two groups of 14 players each as the experimental and control groups (Table 1). The inclusion and exclusion criteria were determined based on the International Ankle Consortium [16]. These criteria included: 1. Having at least one lateral ankle sprain causing swelling, pain, and dysfunction of the ankle at least 12 months before the research; 2. Having at least 2 ankles "giving way", six months before the research; 3. Obtaining scores less than 90% in the foot and ankle ability measure and 80% of this instrument's sports tool; 4. Obtaining scores less than 24 of Cumberland ankle instability tool; and 5. Negative talar test and anterior drawer test related to the diagnosis of mechanical ankle instability [16]. The exclusion criteria included having a history of lower limb surgery, visual impairment, chronic musculoskeletal injury, or acute lower limb injury 12 months before the study [16]. Also, we observed all the ethical and legal aspects of the participants, which included voluntary participation, the privacy of information, and their anonymity. Before conducting the study, all participants read and signed the informed consent form.

### Study intervention

The exercise program used in this study consisted of 6 types of hopping exercises of sides to sides hopping, anterior and posterior hopping, figure-of-4 hopping, hopping forward, and figure-of-8 hopping done three times per week for six weeks [17-20]. Exercise intensity increased from 80 to 160 foot-contact per week. Also, the exercises progressed first in a double-leg and then, single-leg manner. Also, to increase the difficulty and intensity of the exercises, the hand position was changed from freestanding to the position on the chest and back exercises. Exercise levels were varied every week from the gym floor to artificial grass and gymnastics mats.

The participants had 10 min to warm up at the beginning of each exercise session. We should mention that the exercises were performed as hopping and stability exercises in the first three weeks [21]. From the third week on, a 2-Hz rhythm hopping exercise was performed using a metronome [1, 18, 19].

### Jump-Landing task

To perform the single-leg jump-landing task, the participants were asked to stand on a 40cm high box with their healthy feet, so that the injured leg was bent over and hands were resting on the pelvis. Then, they landed on the force plate with the help of the healthy foot.

After landing, the participants had to maintain their balance on the injured foot for 10 s. The examiner showed the participants the correct form of the intended task and, then, the participants performed the task at least three times to feel comfortable in performing it. The successful trial was recorded, and the participants had a 60-s rest between each trial. The jump-landing task was performed on both feet. Errors considered in executing the jump and landing task included failing to keep the balance of a single leg for 10 s, dislocating or hopping, stepping down the stairs instead of jumping and landing, and incomplete landing with incomplete contact with the force plate.

### Assessing time to stabilization

To evaluate the time to stabilization, the researcher used an AMTI force plate of 40*60 cm, so that the participants were standing on the box and performing the single-leg jump- landing task. Then, force plate data were extracted using Cortex software (Model 2.5.0.1160) in the form of Excel sheets, and MATLAB content software was used to continue the process and determine the time to stabilization. The anterior-posterior and medial-lateral components were examined separately to calculate the time to stabilization. In each component of this force, the range of the basic changes of the ground reaction force was first examined. After determining the range of the changes and when the ground reaction force reached this point, it was considered as the time to stabilization. Three successful trials were evaluated for each individual.

The last 8-10 s of each trial was used to evaluate the range of the ground reaction force changes. The range of reference changes was only estimated based on healthy foot trials by the smallest absolute value of ground reaction force range over the last 2 s of each trial for both posterior-anterior and medial-lateral forces (divided by individual bodyweight for normalization). Then, the mean value of all three trials for one person and the total mean of all 14 persons on the healthy foot was calculated as the total value of the mean range of anterior-posterior and medial-lateral force changes. Afterward, three standard deviations of this total mean were added to the total mean of the reaction force changes to create the range of a normal change of ground reaction force. To normalize the data, this value was multiplied by the participant's weight in Newton. The resultant values of the total change range of ground reaction force in the anterior-posterior and medial-lateral directions were 0.0191 and 0.0134, respectively. For each participant and trial, the unbounded third order polynomial diagram was matched on the ground reaction force data over 10 s. The time to stabilization was the time when the polynomial diagram first intersected the horizontal line point of the change range. Then, the average time to reach stability for all three successful trials in the injured leg was calculated as the time to reach stability in the anterior-posterior and medial-lateral directions [8, 22, 23].

### Ankle joint functional assessment tool

All participants completed an ankle function assessment tool to assess their perception of ankle instability and function. The ankle function assessment tool consisted of 12 questions to understand the degree of instability in different studies and has high validity and reliability (intraclass correlation coefficient=0.94) [24, 25]. The participants were asked to choose the closest option to their ankle status. There were five options for each question ranging from 0 to 4. Most scores were given to the best conditions for understanding the stability and function of the participant's ankle. The highest score for each question was 4 and the lowest score was 0. Descriptive statistics, independent t-test, and the paired sample t-test were used for data analysis at a 95% significance level (α= 0.05). The Hedges effect size was also used to determine the effect size of the exercises, where<0.4 indicated low effect size, 0.41–0.7 moderate effect size, and >0.71 large effect size [26].

## Results

The results of the independent t-test showed that the experimental and control groups in the pre-test were the same regarding the dependent variables and demographic information (Table 1). Results of the paired t-test demonstrated significant improvement in the time to stabilization in the two components of anterior-posterior and medial-lateral ground reaction force and

**Table 1.** The individual characteristics and independent t-test results

| Variables | Mean±SD | | t | P |
|---|---|---|---|---|
| | Groups | | | |
| | Experimental | Control | | |
| Height (cm) | 187.96±7.93 | 185.69±7.28 | 0.789 | 0.437 |
| Weight (kg) | 82.59±9.51 | 78.35±7.02 | 1.340 | 0.192 |
| Age (y) | 22.78±3.09 | 22.57±2.76 | 0.193 | 0.848 |
| Time to achieve anterior-posterior stability | 1.37±0.06 | 1.36±0.05 | 0.347 | 0.732 |
| Time to achieve medial-lateral stability | 1.48±0.17 | 1.47±0.18 | 0.183 | 0.934 |
| Perception score of ankle instability | 17.14±3.08 | 16.71±2.64 | 0.395 | 0.696 |

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ankle joint function tool score after six weeks of hopping exercise (Table 2). The results of the post-test independent t-test showed that the experimental and control groups had a significant difference in anterior-posterior (P=0.041) and medial-lateral (P=0.001) stability and ankle function tool score (P=0.002). Time to stabilization showed a decrease of 0.05 s in the anterior-posterior component and 0.39 s in the stability component as well as an increase of 7.01 points in the ankle function tool scores after exercises; however, these values were almost i in the control group.

## Discussion

The results of the present study showed that six weeks of hopping exercise improved the time to stabilization and the perception of instability in athletes with chronic ankle instability. It is necessary to achieve faster post-landing stability for preventing ankle injury. Numerous studies have reported that patients with chronic ankle instability have a deficiency in the time to stabilization [3] and the results of this study suggested that this factor could improve after hopping exercise. Few studies have been conducted so far to investigate the effect of non-functional exercises on the time to stabilization in patients with chronic ankle instability. The results of the present study were consistent with those of Huang et al. [27] and Han et al. [28] but inconsistent with those of Ridder et al. [29] and Fitzgerald et al. [13].

Huang et al. [27] investigated the effect of six weeks of plyometric and integrated (plyometric and balance)

**Table 2.** The paired t-test results for variables of time to stabilization and perception of ankle instability

| Variables | Steps | Mean±SD | | t | P | Effect Size (95% CI) |
|---|---|---|---|---|---|---|
| | | Pre-test | Post-test | | | |
| Time to achieve anterior-posterior stability | Experimental | 1.37±0.06 | 1.31±0.05 | 5.837 | 0.001 | -1.43 (-2.26,-0.6) |
| | Control | 1.36±0.17 | 1.36±0.06 | -0.486 | 0.635 | |
| Time to achieve medial-lateral stability | Experimental | 1.48±0.17 | 1.08±0.06 | 8.369 | 0.001 | -2.10 (-3.02,-1.18) |
| | Control | 1.47±0.18 | 1.48±0.17 | -0.766 | 0.457 | |
| Perception score of ankle instability | Experimental | 17.14±3.08 | 24.21±6.58 | -3.396 | 0.003 | 0.90 (1.68,0.12) |
| | Control | 16.71±2.64 | 17.42±3.36 | -0.785 | 0.447 | |

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exercises on lower limb biomechanics in patients with chronic ankle instability, in which the kinematic time to stabilization was one of the variables investigated. The results of their study showed that both plyometric and integrated exercises decreased the time to stabilization in knee flexion motion in internal single-leg drop-landing. On the other hand, we should note that two medial-lateral drop-landing tasks were used in this study, given that most of the previous works have examined the time to stabilization in patients with chronic ankle instability during jump-landing task without direction, creates difficulty in drawing conclusions for this study. Also, these exercises were only effective in decreasing medial landing and did not affect the lateral landing. The time to stabilization was also studied given the joint movement, rather than the ground reaction force in these participants.

Han et al. [28] studied four weeks of rubber band exercises as a perturbation force among the patients with a history of an ankle sprain. Their results showed that these exercises improved stability in these participants. The reason for the consistency of the present study with those works is that this type of exercise increases one's ability to reach balance more quickly. We can say that hopping exercises also improve muscle strength and, thus, the time to stabilization. Also, considering the approach of using stretching to cause disturbance on the other foot, we can state that to achieve stability after each hopping performance, one needs to overcome the disturbance created after each hopping and, by repeating this over six weeks, one gains the ability to achieve faster stability.

De Ridder et al. [29] examined balance exercises with an emphasis on home-based therapy on postural control and the degree of instability in the participants with chronic ankle instability. The results of their study showed that eight weeks of balance exercise improved the scores of stability perception tools, but did not have a significant effect on postural control assessed through the time to stabilization. The reasons for the non-significant results in this study might relate to inadequate exercises to improve postural control during the performance task. The exercises used in this investigation consisted mostly of static exercises. The differences between the results of these two studies could be attributed to the dynamic and functional nature of the hopping exercises used in the present study.

Similarly, Fitzgerald et al. [13] failed to obtain significant results at the time to stabilization during landing tasks, as they used one- and two-leg static balance exercises. Keeping the balance is related to many factors, one of which is the proprioception. Given the impact of hopping exercises on joint position sense and dynamic balance [18, 19], one of the possible reasons for the improved time to stabilization is the increased proprioception. Given the joint movement at the end of the range of motion during the hopping movements, the hopping exercises can help improve the sensory information of the joint receptors activated at the end of the range of motion and enable the individual to achieve a faster state of stabilization. Also, given the impact of these exercises on the star test's reach distance and its increase, we can state that in addition to clinical tests such as the star test, these exercises provide better performance in functional tasks such as jump-landing and time to stabilization which is considered as the basic skill in sports. On the other hand, considering the effect of exercises with stretch-shortening cycle such as hopping on the structural nature of muscle tissue and strength improvement, these exercises improve the time to stabilization in the patients with chronic ankle instability by increasing strength and balance in the lower limb muscles.

Balance is defined as maintaining the center of gravity within the base of support. With regard to the hopping exercises used in this study, individuals should maintain balance during the disturbances caused by hoping to achieve stability after hopping and also maintain balance for sequential hopping. Based on the theories of motor control, changes are caused in motor cortex maps by repeating motor patterns and these patterns replace the previous ones and enable the individuals to maintain faster balance and stability.

The results of the improvement in ankle function tool scores are consistent with those of Rozzi et al. [24], Clark and Burden [30], McKeon et al. [21]. Rozzi et al. [24] who stated that doing balance exercises using Biodex improves the ankle performance evaluation questionnaire score. Also, Clark and Burden [30] examined the effect of balance board exercises on the perception of ankle functional instability through a questionnaire and the results indicated improvement in the score of a performance evaluation questionnaire after doing these exercises. In this regard, McKeon (2008) examined hopping exercises on balance and performance of the patients with chronic ankle instability and his results showed that hopping to stabilization improved the score of self-report ankle performance questionnaire. However, the questionnaire used in this study was different from the present one.

Improvement in ankle instability score in this study is remarkable based on the effect size achieved because improvement in one's perception of ankle instability sta-

tus can be influenced by the effect of this type of exercise interventions for preventing injury. The results of this study were consistent with those of previous research [11, 21] that used hopping exercises as a part of their exercise program, except that the results of the present study had more effect than self-report questionnaires.

This outcome may be because the current exercise program had a greater impact on one's performance by using a functional approach. Also, according to the results obtained from the time to stabilization in this study, after the jump-landing task with faster control of ground reaction forces, these changes improved the scores of perception of instability and performance.

## Conclusion

Doing six weeks of hopping exercises improves the time to stabilization and perception of the degree of instability measured by the ankle performance evaluation questionnaire in the patients with ankle instability. This type of exercise can be used to improve the problems of patients with chronic ankle instability. We should mention that this research, similar to all other studies, had some limitations. Given that the study sample consisted of only the male gender, it is difficult to generalize the research results to different skill levels of athletes and ordinary people and females.

## Ethical Considerations

### Compliance with ethical guidelines

All research processes and methods was approved by the Institutional Review Board of Tehran University.

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### Authors' contributions

All authors equally contributed to preparing this article.

### Conflict of interest

The authors declared no conflict of interest.

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