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**Original Research**

# The Immediate Effect of Medical Insoles on Kinematic Variables of Lower Limb Joints in People with Ankle Sprains during Running

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## ABSTRACT

Ankle sprain is one of the common injuries among athletes and the general public. It seems that limiting the range of motion of ankle inversion can have positive effects on reducing the recurrence rate of ankle sprains. Therefore, the aim of this research is to use medical insoles to prevent excessive ankle movements. 10 soccer players with ankle sprains participated in this research. Kinematic data were collected using a motion recording system including four Vicon cameras and light-reflecting markers with a sampling rate of 100 Hz in two conditions running with and without insoles. Then the peak range of motion of inversion/eversion, dorsiflexion/plantarflexion, abduction/adduction in the ankle and flexion movements, internal/external rotation, abduction/adduction in the knee and flexion/extension movements, internal/external rotation and abduction/adduction in the hip joint in two conditions, with and without medical insoles was evaluated. Repeated measurement analysis of variance was used for intragroup comparison with a significance level (P<0.05) for statistical analysis. The results of this research showed that medical insoles reduce ankle dorsiflexion (p=0.036, d=1.14), inversion (p=0.003, d=1.44) and abduction (p=0.007: d=1.6). Also, the use of insoles decreased the internal rotation of the knee (p=0.04, d=0.61). Therefore, the use of insoles reduces the kinematic risk factors of ankle sprain and helps the stability of the ankle joint during running. As a result, the use of medical insoles can be suggested as a suitable therapeutic intervention to prevent ankle sprains.

**Keywords**: Lateral Ankle Sprain, Kinematic, Insole, Running

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## INTRODUCTION

Lateral ankle sprain is one of the common injuries among athletes of various disciplines and the general public [1,2]. Lateral sprain of the ankle can result in the development of a multitude of motor-behavioral impairments, including stiffness of the lower limb, changes in the joint movements of the lower limb joints, and a decrease in the strength of the muscles [3-5]. Unfortunately, 80% of patients who develop an ankle sprain for the first time continue to experience symptoms and recurrent injuries [3]. In addition, approximately 30-40% of people with acute ankle sprains develop chronic ankle instability (CAI) [6]. Functional ankle instability (FAI) is a subtype of chronic ankle instability [6,7]. This injury is characterized by symptoms such as frequent twisting of the ankle, pain, swelling, and impaired postural control [7,8]. In the long term, lateral ankle sprains may lead to instability, osteoarthritis, reduced quality of life, and reduced ankle joint function [8,9]. In other words, lateral ankle sprain can significantly affect a person's ability to participate in daily activities and sports [8,10]. Approximately, the treatment costs of ankle sprains in the United States are 2.6 billion Euros and 208 million Euros in Europe [11]. This treatment cost is very high for an injury that is easy to prevent [12,13]. One of the best ways to prevent ankle sprain injury is to identify the injury mechanism [12,13]. Therefore, identifying the mechanism of injury or reoccurrence of ankle sprain injury is of clinical importance to prevent this injury. For the first time, Garrick (1977) introduced the mechanism of lateral ankle sprain injury by combining movements of inversion, plantarflexion and internal rotation [14]. The findings of other researchers stated that an increase in inversion and internal rotation with and without plantarflexion causes lateral ankle sprain [15,16]. Various studies have shown that walking speed, stride length, and double support time decrease following lateral ankle sprain injury [17]. Also, people with ankle sprains have greater plantarflexion and hindfoot inversion than normal people [16,18]. Foot orthoses, including orthopedic insoles, are a common treatment intervention for people with lateral ankle sprains due to their versatility, comfort, and affordability [19]. Previous studies have shown that foot orthoses can improve postural stability in lateral ankle sprain patients by providing proprioception and neuromuscular stimulation [20]. On the other hand, medical insoles help to maintain the alignment of the soles of the feet. Haddadi (2017) [21] showed that semi-rigid and soft orthoses improve the dynamic stability of lateral ankle sprain patients after a 4-week treatment period. Likewise, Abbasi et al (2019) [22] found that orthopedic insoles with textured surfaces could increase the reach distance in the star balance test for lateral ankle sprain patients, implying that foot orthoses are associated with improved balance in patients with lateral ankle sprain. But so far, there has been no research on the effect of medical insoles on the kinematic variables of lower limb joints in people with ankle sprains. Previous research showed that insoles in different groups reduce the range of motion of ankle inversion, ankle dorsiflexion, knee internal rotation, and hip adduction. But so far, there has been no research on the effect of medical insoles on the kinematic variables of lower limb joints in people with lateral ankle sprains. Because one of the risk factors in the recurrence of ankle sprain is excessive inversion of the rear leg. Therefore, the purpose of this research was to investigate the effect of immediate use of insoles on the kinematic variables of lower limb joints in people with ankle sprains.

## MATERIAL AND METHODS

The present study is quasi-experimental and of laboratory type. In this study, 10 soccer players with functional ankle instability were selected as the experimental group. 10 subjects were chosen in group according to $\alpha = 0.05$, $\beta = 0.2$ (statistical power 80%) based on the power calculation method of Erdfelde et al 2007 (23). The mean and standard deviation of age, height, and mass of the subjects were (23.5 ± 1.63 year), (173.4 ± 2.36 cm), and (76.3 ± 6.81 kg), respectively. Criteria for inclusion in the experimental group were: obtaining a score above 26 on the ankle function evaluation questionnaire, a history of severe sprains of the external ankle, a history of feeling ankle instability during the last 6 months, and also the exclusion criteria were: There is a difference of more than 3 mm between the length of the two lower limbs, history of surgery, and skeletal abnormalities. All subjects were right-handed and right-footed, which were

measured by throwing the ball for the hand and hitting the ball for the foot, respectively. Subjects were advised to refrain from strenuous physical activity for 48 hours prior to the test. Before doing the test, the purpose and method of the study were explained to the subjects after which they signed the consent form to participate in the study.
In this questionnaire, 12 5-item questions are presented, which are scored based on the Likert scale with numbers from 0 to 4, and the maximum overall score of this tool is 48, and a score above 26 indicates a limited ankle function [24].
Kinematic data were collected using a motion recording system including four Vicon cameras and light reflecting markers with a sampling rate of 100 Hz. To record and analyze running kinematic data, a 3D analysis device (Vicon (100Hz) (Motion Lab Systems, Inc. 15045 Old Hammond Highway, Baton Rouge, LA 70816 USA) and four T series cameras were used. The left and right lower limbs were identified using light reflecting markers with a diameter of 14 cm. Markers are on the superior anterior and superior posterior iliac spine, the upper third of the right thigh (cluster of four markers), the lower third of the left thigh (cluster of four markers), the end of the thigh on the external epicondyle, the upper third of the right leg (cluster of four markers), the lower third of the left leg (four-marker cluster), the heel (on the shoe), the external ankle, the head of the second metatarsal (on the shoe) and the head of the fifth metatarsal (on the shoe) were installed on both the right and left sides. Subjects were placed in an anatomical position when markers were installed. Two Kistler force plates (Kistler AG, Winterthur, Switzerland) with dimensions (400 x 600 mm) synchronized with the motion analysis system were used to calculate kinetic and kinematic data. In this research, force plate was used to determine the phases of walking (heel contact and toe off).
During running, the kinematic data of both legs were recorded and the kinematic data of the dominant leg were analyzed. In order to coordinate with the test conditions, each subject runs around the laboratory for about 5 minutes. Then, each subject ran 6 times at normal speed (subjects were required to cover a 20-meter path in 7 seconds). Considering that running speed was measured by motion analysis cameras and statistically no difference in running speed was observed between the two conditions of running with and without soles, it can be said that this was controlled and did not affect the results of this research. In the present study, the type of shoes (ASICS design) was selected for all subjects according to their foot number (Figure 1).

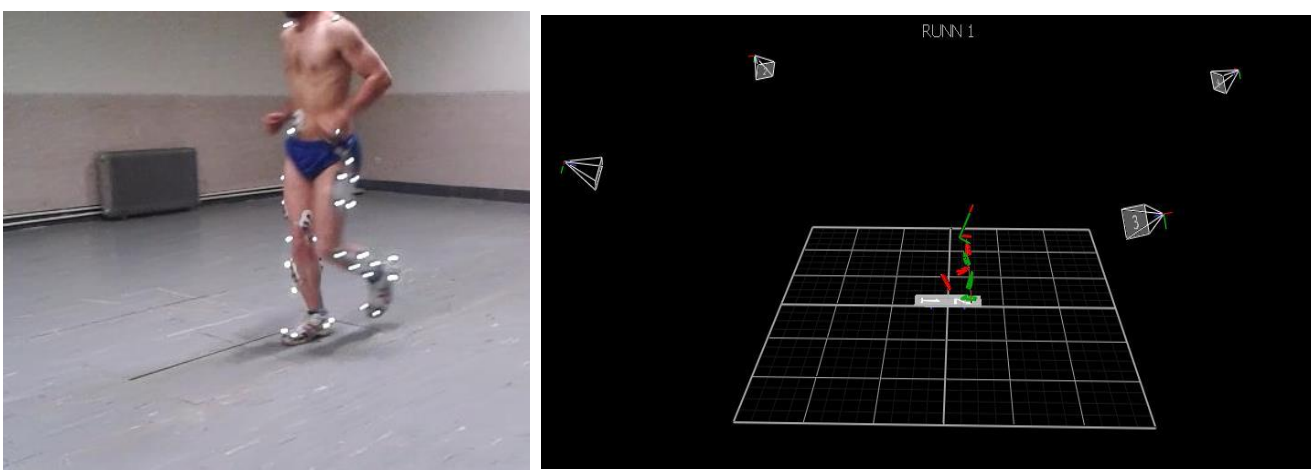


Fig 1. Lower limb markers and nexus software workstation

The insole of the shoe used in this study was made according to the feet of individuals and by a technical orthopedist. The insole used in this research is of semi-rigid type (shore A 53, polipropilen) and the peak height of the internal length arc in this insole was 15 mm and its posting degree was 8 (Figure 2).

Fig 2. Medial and posterior views of insole

## Data processing

Kinematic data were filtered using fourth order Butterworth low pass filter, zero lag with a cutoff frequency of 6 Hz. The obtained force plate signals were smoothed using a level 4 Butterworth low-pass filter with zero lag difference with a cut-off frequency of 20 Hz (25). Visual 3D software was used for kinematic data processing. This software calculates the stance phase data during running in the form of 101 points in an interpolated way. In the ankle joint, dorsiflexion, inversion, and internal rotation of the foot were identified with a positive sign. In knee and hip joints, flexion, adduction and internal rotation movements were identified with a positive sign.

## Statistical analysis

For the statistical analysis of the data, the Shapiro-Wilk test was first used to check the normality of the data distribution. Due to the normality of the data distribution, the analysis of variance with repeated measures was used to compare the data during two conditions of running with and without medical insoles. All analyzes were performed at a significance level of 0.05 using SPSS version 22 software. The following equation was used to calculate the effect size (d). Effect size values were interpreted as follows. If $d<0.20$ is a minor effect size, $0.5>d\geq0.20$ is a small effect size, and $0.8>d\geq0.50$ is a high effect size [26].

$$\text{Effect size } (d)=(\text{Mean2}-\text{Mean1})/(\text{average of SDs})$$

## RESULTS

The findings did not show any significant difference in running speed between two conditions with and without medical insoles. The results showed that the overall effect of the medical insole factor (p=0.011) and the joint factor (p=0.002) were significant. The results related to ankle range of motion are summarized in Fig 3. As can be seen, the use of medical insoles reduces ankle dorsiflexion (p=0.036, d=1.14), inversion (p=0.003, d=1.44) and abduction (p=0.007, d=1.6). In other words, insoles caused a 105% reduction in ankle dorsiflexion, 135% in ankle inversion and 22% in ankle abduction, respectively.

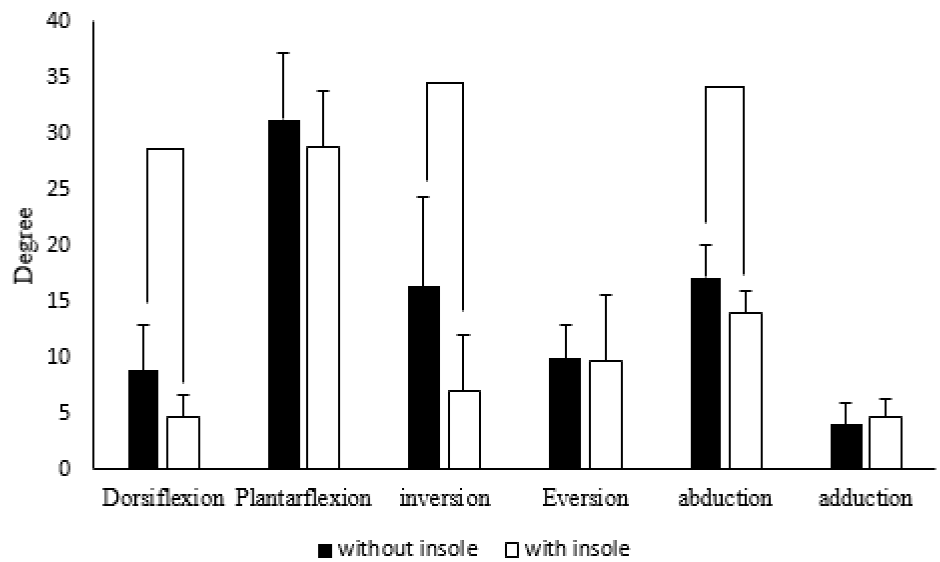


Fig 3. Three-dimensional kinematics (mean ± standard deviation) of the ankle joint in degrees during two conditions of running with and without soles

The results related to the range of motion of the knee and hip joint in two conditions of running with and without medical insoles are given in Table 1. The findings of the present study showed that there is no significant difference in knee flexion (p=0.07, d=0.42) and knee abduction (p=0.52, d=0.30) in two running conditions with and without medical insoles. But insoles have caused a 41% reduction in knee internal rotation and this reduction was statistically significant (p=0.04, d=0.61). But using insoles in hip flexion (p=0.07, d=0.42), hip adduction (p=0.07, d=0.42), hip external rotation (p=0.07, d=0.42) and hip internal rotation (p=0.07, d=0.42) did not make a statistical difference.

Table 1. Three-dimensional kinematics (mean ± standard deviation) of the knee and thigh joints by degrees during two conditions of running with and without insoles

| | **Without insole (Mean±SD)** | **With insole (Mean±SD)** | **P Value** | **Effect size** |
|---|---|---|---|---|
| Knee flexion | 40.81±5.83 | 38.32±5.96 | 0.07 | **0.42** |
| Knee abduction | 6.16±3.71 | 5.03±3.61 | 0.52 | **0.30** |
| Knee internal rotation | 12.24±7.23 | 8.68±4.34 | 0.04 | **0.61** |
| Hip flexion | 44.79±4.26 | 46.45±5.07 | 0.11 | **-0.35** |
| Hip adduction | 7.12±3.8 | 7.62±3.7 | 0.478 | **-0.13** |
| Hip external rotation | 3.46±1.95 | 2.35±1.51 | 0.18 | **0.64** |
| Hip internal rotation | 19.15±7.95 | 16.57±10.97 | 0.637 | **0.27** |

## DISCUSSION

The purpose of this study is to investigate the effect of medical insoles on the three-dimensional kinematics of lower limb joints in people with lateral ankle sprain. In the present research, the subjects' running speed was examined in two conditions, and no significant difference was observed between the two conditions. Also, the same shoes according to the size of the feet were considered for the subjects. Therefore, it can be said that the effect of running speed and shoe type was controlled in the present study and any change in the range of motion of the joints was due to the use of insoles. The results of this research showed that the use of medical insoles reduces ankle dorsiflexion. Kraus (2023) showed that the use of braces reduces the ankle dorsiflexion range of motion [27]. In addition, Simon Lack et al reported in 2014 that using insoles reduces ankle dorsiflexion [28]. Past research has shown that people with ankle sprains have greater dorsiflexion than healthy people [29]. Increased dorsiflexion is known as a compensatory mechanism to maintain joint stability [29,30]. In this way, with the increase in talo-crural dorsiflexion, it is placed in a tightly packed position, and this condition increases the stability of the ankle joint [28-30]. In addition to increasing ankle dorsiflexion, tibialis anterior muscle activity is also effective in increasing joint stability in people with lateral ankle sprain. The increase in tibialis anterior activity is directly related to ankle dorsiflexion [31]. Various researches have shown that the use of medical insoles reduces the activity of the tibialis anterior muscle in activities such as walking and landing. This article can be justified in the way that the use of insoles has increased joint stability, as a result, the tibialis anterior muscle needs less activity [30]. Dingenen et al (2015) people with ankle sprains have better muscle nerve control when using insoles, as a result, joint stability improves in these people using insoles [32]. The findings of the present study showed that the use of insoles significantly reduces ankle inversion. Previous research has mentioned excessive inversion as one of the risk factors in ankle sprains [33]. And they have shown that if the inversion of the rear foot is above 10 to 15 degrees at the moment of heel strike during running, it increases the chance of ankle sprain [34]. The increase in inversion at the moment of heel strike makes the line of action of the ground reaction force not pass through the middle of the joint, but tends to pass through the inner part of the joint [34,35]. Increasing the deviation of the ground reaction force from the center of the joint means increasing the moment arm (the vertical distance of the force from the point around which the object rotates) [34]. An increase in force and a larger moment arm causes a stronger inversion in the shortest possible time and causes excessive tension in the lateral ligaments of the ankle joint [34,35]. Considering that ligaments have viscoelastic properties, that is, their loading response is time-dependent, if force is applied to them slowly, there is a possibility of a more appropriate response from the ligaments, and the faster the force is applied, the more likely they are to be injured and torn [35]. The present study showed that the use of medical insoles can significantly reduce ankle inversion in heel strike. In other words, medical insoles reduce the moment arm of the ground reaction force. On the other hand, Hosseini et al showed that the medical insole reduces the ground reaction force [36]. Since the use of medical insoles reduces ankle inversion, on the other hand, by reducing ankle inversion, the moment arm of the ground reaction force is also reduced. As a result, the insole reduces the chance of ankle sprain injury happening again. Since the different parts of the foot work together as a continuous movement chain, the decrease or increase of inversion of the rear foot is related to the decrease and increase of abduction of the forefoot. The results of this research showed that insoles reduce the inversion of the rear foot, and since the reduction of ankle inversion is related to the reduction of the abduction of the forefoot, as a result, the insole reduces the abduction of the front leg. The results of the present research showed that insoles reduce the internal rotation of the knee. Knee internal rotation in combination with knee valgus is one of the risk factors of knee injuries including ACL tear and osteoarthritis [27,29]. In various researches, the relationship between the direction of the ground reaction force vector and the increase in internal rotation of the knee has been pointed out [34]. The more the direction of the ground reaction force vector is inwards at the moment of heel contact with the ground, it means that a bigger moment arm is applied on the joints of the lower limb. A greater distance increases the internal rotation of the knee, thereby putting more pressure on the anterior cruciate ligament. The use of insoles, due to the reduction of ankle inversion, has directly reduced the deviation in the direction of the ground reaction force vector at the moment of heel contact with the ground. Reducing the amount of deviation of the ground reaction force vector from the center of the joint or the passage of the ground reaction force vector from the center of the joints, reduces the amount of deformities and injuries of the lower limbs. In addition, Simon Lack et al reported in 2014 that the use of insoles reduces internal rotation of the tibia [28]. Barton et al in 2012 showed that increased tibial internal rotation increases the likelihood of patellofemoral pain [37]. The use of insoles did not show any significant difference in other variables studied in this research. One of the limitations of this research was the gender of the subjects of this research. Since only male subjects were used in this research, due to the anatomical differences between women and men, the results of this research cannot be generalized to the entire society.

## CONCLUSION

It seems that the use of medical insoles in the present study has been effective in improving the abnormal movements of the lower limb joints in people with lateral ankle sprain. The results showed that using insoles reduces ankle inversion, abduction and dorsiflexion. In other words, the use of insoles reduces the risk of kinematic factors of ankle sprain and helps the stability of the ankle joint during running. Therefore, the use of medical insoles can be suggested as a suitable therapeutic intervention to prevent ankle sprains.

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# تاثیر آنی استفاده از کفی طبی بر متغییرهای کینماتیکی مفاصل اندام تحتانی در افرادی با عارضه اسپرین مچ پا حین دویدن

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**چکیده:**
اسپرین مچ پا یکی از آسیب‌های رایج بین ورزشکاران و افراد جامعه می‌باشد. مکانسیم اسپرین مچ پا تاحدودی مشخص است. به نظر می رسد محدود شدن دامنه حرکتی اینورژن مچ پا باعث کاهش میزان وقوع اسپرین مچ پا می شود. بنابراین هدف از مطالعه حاضر استفاده از کفی طبی برای جلوگیری از حرکت اضافی پا می باشد. ۱۰ فوتبالیست با سابقه اسپرین مچ پا در این مطالعه شرکت کردند. داده های کینماتیکی با استفاده از چهار دوربین وایکان با فرکانس نمونه برداری ۱۰۰ هرتز در دو شرایط دویدن با و بدون کفی طبی جمع آوری شد. سپس دامنه حرکتی اینورژن/اورژن، دورسی فلکشن/پلانتارفلکشن، آبداکشن/آداکشن در مچ پا و دامنه حرکتی فلکشن، چرخش داخلی/خارجی، آبداکشن/آداکشن در زانو و هیپ مورد ارزیابی قرار گرفت. از آزمون آنالیز واریانس با اندازه گیری های تکراری با سطح معناداری($P<0.05$) برای مقایسه نتایج استفاده گردید. نتایج این تحقیق نشان داد کفی طبی باعث کاهش دورسی فلکشن مچ پا ($p=0.036, d=1.14$)، اینورژن ($p=0.003, d=1.44$) و آبداکشن مچ پا ($p=0.007, d=1.6$) می شود. همچنین، استفاده از کفی باعث کاهش چرخش داخلی زانو ($p=0.04, d=0.61$) شده بود. بنابراین استفاده از کفی طبی باعث کاهش عوامل خطر زا در بروز اسپرین مچ پا می شود و به حفظ پایداری مچ پا هنگام دویدن کمک می کند. با توجه به نتایج تحقیق حاضر استفاده از کفی طبی را می توان به عنوان یک ابزار برای پیشگیری از اسپرین مچ پا پیشنهاد کرد.

**واژه های کلیدی**: اسپرین جانبی مچ پا، کینماتیک، کفی، دویدن