Available online at www.sciencedirect.com

ScienceDirect

The Foot 18 (2008) 84–90

The Foot

www.elsevier.com/locate/foot

The relationship between the height of the medial longitudinal arch (MLA) and the ankle and knee injuries in professional runners

Z. Nakhaee [a], A. Rahimi [b,*], M. Abaee [c], A. Rezasoltani [b], K. Khademi Kalantari [b]

[a] *Red Crescent Institute, Birjand, Iran*

[b] *Rehabilitation Faculty, Shaheed Beheshti University of Medical Sciences, Tehran 1616913111, Iran*

[c] *Rehabilitation Faculty, Tehran University of Medical Sciences, Tehran, Iran*

Received 4 September 2007; received in revised form 22 December 2007; accepted 7 January 2008

Abstract

Background: Usually the rate of lower extremity's injuries in sports such as running is known to be correlated with the height of foot arches. Foot pressure measurement studies have shown controversial results in this issue, mainly due to the complexity of the foot structure. This study aimed to investigate if any relationship exists between the MLA height and the ankle/knee injuries in professional runners. It was also aimed to find out any association between the foot pressure patterns and the clinical navicular drop test in the subjects.

Materials and methods: Forty-seven professional runners were participated in this study and using the clinical navicular drop test, they were categorized into normal, low and high arch foot subjects. Using an Emed pedography platform (Novel, Germany), the maximum force, peak pressure and the contact area of their feet were studied in both static (single limb support) and dynamic conditions.

Results: The results of this study showed no strong correlation between the height of MLA and the rate of the ankle/knee injuries ($P = 0.58$). The correlation between the clinical navicular drop test and the modified arch index (MAI) was between 0.32 in static and 0.57 in dynamic tests.

Conclusion: The results of this study conveyed that having a lower or higher than a normal MLA is not a definite risk factor for sports-related injuries. This might be due to the complexity of the foot structure and its ability to accommodate with new situations routinely occurs in sport. Furthermore, although a high correlation was not found between the clinical navicular drop test and the foot pressure indices, due to the clinical entity of this test, the obtained association is relatively good. A significant correlation was found between the foot pressure distribution in single limb support (static) and the dynamic conditions, which provides an extrapolation of the results of this type static condition tests to the dynamic conditions.

Keywords: Medial longitudinal arch (MLA); Pedography; Foot pressure pattern; Ankle and knee injuries; Professional runners

1. Introduction

The capability of foot shock absorption as well as providing good body stability is mainly due to the fact that the foot structure is very complex [1]. Existence of too many small joints and three medial, lateral and transverse foot arches have granted the foot to be a very unique segment of the body. Different type of foot structures has shown to be an important factor in plantar pressure distribution pattern [2]. Any inappropriate foot plantar pressure distribution may increase the risk of tissue injuries leading to be as a source of pain. Increased walking speed results in increased plantar pressures but not vice versa and running is associated with overuse injuries rather than a direct relationship with plantar pressures and overuse injuries [3,4]. In closed kinematic chain activities such as running, the interaction between the foot and the ground determines the probability of occurring injuries in this area [5]. Despite having many common structural features, the shape and the biomechanical reactions of the foot differ greatly among individuals. The medial longitudinal arch (MLA) has been known as the source of many of these differences [6] and the existence of any relationship between the MLA height and the lower limb injuries has been studied in some research with controversial results [4,7,8]. The most common technique of foot type classification is

* Corresponding author. Tel.: +98 21 77810157; fax: +98 21 77561406.
E-mail address: arahimiuk@yahoo.com (A. Rahimi).

0958-2592/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foot.2008.01.004

categorizing them through its MLA heights using the clinical navicular drop test [6]. Due to the fact that this is a static test and a dynamic test is required to classify the feet during movements (walking/running) to measure the foot plantar pressure during both standing (single/double) and moving (walking/running) both indoor and outdoor activities. Using foot plantar pressure measurement systems is more common for this reason and as previous studies have shown [6,9] the modified arch index (MAI) is a good indicator of foot type to be a valid clinical means [6,9].

The primary purpose of this survey was to study the relationship between the height of the MLA and the rate of occurrence of the ankle and knee injuries in professional runners. In addition, studying the correlation between the clinical navicular drop test and the MLA, and finding any relationships between the indices obtained in both static and dynamic conditions were also the other aims of this study.

2. Materials and methods

The study included 47 professional[1] male runners from Shaheed Shiroodi Stadium, 2006, Tehran, Iran. Before conducting the test, a pilot study was carried out to prove the repeatability and reliability of the system with 10 normal subjects. Each test was repeated for six times and the average of the results was used in data analysis. The subjects were excluded if they were using any medical insoles, suffering from any malalignment of lower limbs or the spinal column, having a clinical history of the ankle or knee instability, any neurological or musculoskeletal disorders, any lower-limb corrective surgeries, or experiencing pain during the test.

Before starting the test, the participants signed in an informed consent form and then completed a self-constructed questionnaire indicating any injuries in running during last year. All measurements were taken from their predominant foot. Based on the results of their navicular drop test, the participants were assigned into one of the following groups: normal arch, high arch, or low arch. The subjects were asked to sit on a chair with the knee and ankle in 90° and the navicular tubercle of their foot was palpated on its greatest prominence and marked using a marker. Then, the examiner's thumb and forefinger were placed over the two sides of the ankle (tibiotalar) joint and by frequent inversion and eversion of the posterior part of the foot and ankle, the neutral position of the subtalar joint was determined and the foot was placed on the neutral position. The point at which the examiner felt the two sides beneath his thumb and forefinger had equal depths was set as the natural position of this joint and this position was used for measurement. Then, a prepared cardboard card was used to measure and mark the vertical height of the navicular bone in the non-weight bearing position. The foot placed on a small stool without any pressure, which is a modification of Brody's method [8,10].

[1] Three 2-h practice sessions per week.

Fig. 1. An Emed-X platform (Novel Electronics, Munich, Germany) used in this study.

This height was measured again in a full weight bearing position and marked on the same card. The difference between the initial and the second heights of this bone was labeled as the "Navicular Drop" index. According to Brody's (1982) definition, the normal range for the navicular drop is between 5 and 9 mm. A drop more than 10 mm is considered as low arch and less than 4 mm is known as high arch foot [11].

To calculate the foot pressure indices including MAI, an Emed pedograph platform system (Novel Electronics, Munich, Germany) was used in this study (Fig. 1). The system works through a calibrated capacitor sensors and connects directly to the computer through a USB port (four sensors per square centimeter, 100 Hz). Before conducting each static/dynamic test, the system was calibrated by the researcher and the subjects were familiarized with the system through walking on the platform at their self-selected speed for 10 min. To test in static condition, the subjects were asked to stand over the platform on one foot, imitating the midstance phase of a gait cycle, and lean on one hand over the wall. The subject just put their hand on the wall next to them without any deviation. All efforts were carried out for not having any deviations of the subjects to alter the results. After 5 s when the subject's postural sway diminished, the static data was captured. The data acquisition was repeated for six times and the average of the trials was calculated.

To test the dynamic situation, the free gait method was employed. Each subject stood 4 m away from the platform and while looking forwards passed over the platform in such a way that the predominant foot would be completely placed first on the platform. Similar to the static condition, this phase was repeated till six acceptable trials were recorded. Any trials in which the subject deliberately targeted on the platform, was excluded and the trial was repeated.

The data were processed using Novel-Diabetes application software, installed on the system. The software divides

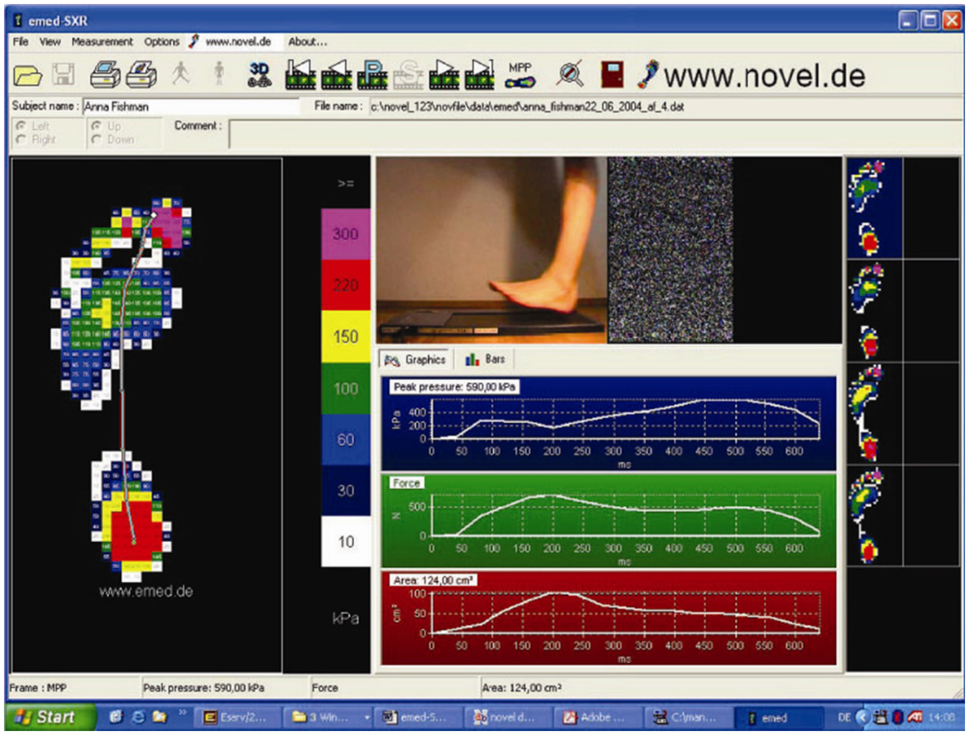

Fig. 2. A sample of the results derived from Emed-X.

the foot into 10 regions (masks) represented anatomically relevant areas of the foot. For each foot region, the temporospatial parameters, peak pressure, maximum force and the contact area were calculated (Fig. 2).

Based on the previous research, the MAI was calculated by dividing the values of maximum force and peak pressure in the midfoot region by the sum of these two variables in all regions of the foot (except toes) [6]. The arch index (AI) for contact area was also calculated using the same method. Data analysis was carried out using SPSS software, Version 11 and $P < 0.05$ was taken as the significant level.

3. Results

3.1. Repeatability of the Emed pedograph platform system

Before starting the test, 10 healthy subjects with normal arch height were asked to walk over the platform using the previously described method, as a pilot study. The whole test was repeated again in the afternoon of the same day and a week later. Intraclass correlation (ICC) of the indices including peak pressure, maximum force and contact area was calculated as shown in Table 1. The ICC between 0.85 and 0.91 is known as a good repeatability of the test and convinced the researchers to start the main test.

Table 1
The consistency of the results for Emed-X pedobarograph ($N = 10$)

	ICC
Peak pressure arch index	0.85
Max force arch index	0.89
Contact area arch index	0.91

3.2. Subjects characteristics, navicular drop and foot type classification

The characteristics of the subjects, navicular drop and the rate of injury in the subjects with different foot types have been shown in Tables 2 and 3. As the tables shown, the mean age was 21.4 ± 3 years old, height 180.3 ± 7 cm,

Table 2
Subjects characteristics and navicular drop values in healthy and injured subjects

Groups	Numbers	Age (years)	Height (cm)	Weight (kg)	Navicular drop (mm)
Healthy	30	21.33	180.46	69.08	5.3 ± 2
Injured	17	21.20	181.47	69.27	7.4 ± 2.5
P value	–	0.902	0.684	0.949	0.002[a]

[a] Significant difference.

Table 3
Foot type classification in healthy and injured subjects

Height of MLA	Healthy	Injured	Total
Normal	17	11	28
Low arch	2	3	5
High arch	11	3	14
Total	30	17	47

and weight 69.8 ± 8 kg; with a minimum 3 years running experience.

Table 2 shows the characteristics of the subjects in terms of the age, height and weight in the healthy and injured individuals and reveals that they were matched. An independent *t*-test showed that the mean navicular drop value for 30 (64%) healthy subjects was 5.3 ± 2 mm, which was significantly lower than that of 17 (36%) injured subjects who had a navicular drop value of 7.4 ± 2.5 mm ($P = 0.002$).

Table 3 reveals that based on the result of the navicular drop test, 28 (60%) subjects were within the normal limit and classified as normal group, of which 17 subjects were healthy and 11 subjects had a history of lower extremity injury. Five (11%) subjects had more than 10 mm navicular drop and classified as low arch group, of which two subjects were healthy and three subjects were in injured group. Finally, 14 individuals (29%) were classified as high arch group with less than 4 mm navicular drop, of which 11 subjects were healthy and three subjects were in injured group. There were totally 17 (36%) injured subjects with different foot types. A χ^2 test did not show any relationship between the rate of injury and their MLA height ($P = 0.58$).

3.3. The correlation between the MAI in dynamic and static conditions

A Pearson statistics analysis test showed that the correlation in peak pressure arch index between the dynamic and static conditions was 0.71. However, it was 0.78 for maximum force arch index and 0.87 for the contact area arch index between the static and dynamic conditions (Table 4) (Figs. 3–5).

3.4. The correlation between the navicular drop values and MAI in dynamic and static conditions

The correlation coefficients between the navicular drop values and the MAI in static and dynamic conditions have been shown in Tables 5 and 6, separately. It was between 0.44 and 0.57 in static and 0.32 and 0.57 in dynamic situations.

Table 4
The correlation between the modified arch index (MAI) in dynamic and static conditions ($N = 39$)

	ICC
Peak pressure arch index	0.71
Maximum force arch index	0.78
Contact area arch index	0.87

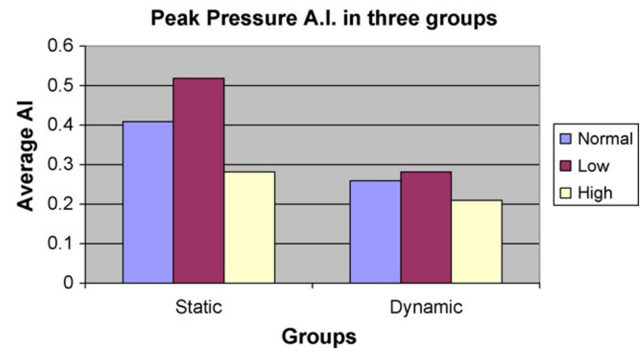

Fig. 3. The measurements of peak pressure arch index in subjects with normal, low and high arch feet.

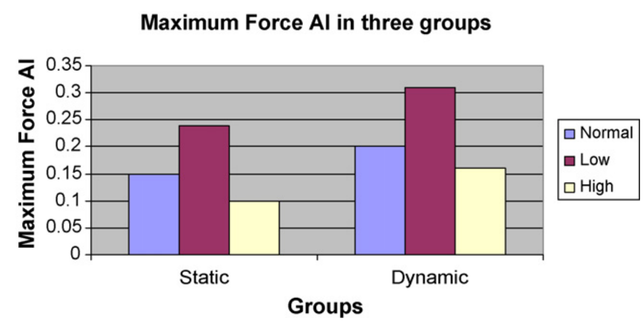

Fig. 4. The measurements of maximum force arch index in subjects with normal, low and high arch feet.

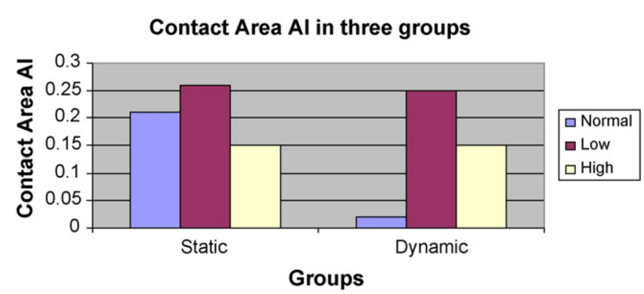

Fig. 5. The measurements of contact area arch index in subjects with normal, low and high arch feet.

Table 5
The correlation coefficient between the navicular drop values and the MAI in static condition ($N = 39$)

	Navicular drop
Peak pressure arch index	0.49
Maximum force arch index	0.57
Contact area arch index	0.44

Table 6
The correlation coefficient between the navicular drop values and the MAI in dynamic condition ($N = 39$)

	Navicular drop
Peak pressure arch index	0.32
Maximum force arch index	0.51
Contact area arch index	0.57

3.5. The comparison of the mean modified arch index in dynamic and static conditions

Using a single factor one-way ANOVA, the mean MAI values in the static and dynamic conditions were compared among the three high arch, low arch and normal arch groups. The results showed that in dynamic situation, the mean peak pressure arch index was not significantly different among the three groups ($P > 0.05$). However, in static condition, a significant difference was shown between the normal and high arch, and between the low arch and the high arch groups ($P < 0.05$). In terms of the mean maximum force arch index, there was a significant difference among the three groups in both the dynamic and static conditions ($P < 0.05$). The mean contact area arch index was only different between the normal and low arch groups, and between the low arch and high arch groups in both dynamic and static conditions ($P < 0.05$).

4. Discussion

Despite the meaningful difference between the average of navicular drop values in the injured and healthy groups, the main hypothesis of this study was not confirmed and no relationship was found between the rate of the ankle and knee injuries and the height of the subject's MLA. The results also showed that the most injured subjects were in the group with normal arch height and not in low or high arch subjects. In other words, most high arch subjects were in the healthy and not in injured group. A relatively good correlation was found between the navicular drop values and the modified arch index (MAI) variables. Some of the MAI parameters showed a significant correlation between the single limb support static and dynamic conditions.

The results of this survey were in agreement with some studies carried out in this area, but were contradicted with some others. In a similar study, Bennet et al. studied the navicular drop values of some healthy and sport-injured subjects and found a higher navicular drop amount in the injured runners relative to the healthy runners [7]. Many studies have been conducted to investigate any relationships between the navicular drop values and the rate of sports injuries in athletes, each with different techniques including foot printing, radiography and using anthropometric indices to describe the foot [5,7,9,11,12]. Michelson et al. reported that, contrary to the popular beliefs, pes planus is not a risk factor for lower extremity injuries in runners [11]. However, Burns et al. compared subjects with normal and high arch feet and concluded that high arch subjects had more foot pain characterized by high pressure-time integral under their rearfoot and forefoot [2].

These extensive controversies led the researchers of the current study to believe that the sources of these different viewpoints are highly likely due to the various methods employed by the researchers, as well as being the multifactorial nature of the mechanisms of the occurrence of injuries. These factors include footwear effects, having previous injuries, running terrain, the intensity and the type of trainings, etc. In 1982, Van Mechelen explained four etiological factors important in occurring running injuries including the existence of previous injuries, lack of running experience, competition, and running a long distance every week [13]. In details, the relationship between the occurrence lower extremity injuries and factors such as warm-up, gender, height, weight, body biomechanics, running frequency, performance level, type of shoes and using orthoses yet to be understood [14–17]. In the current study, all the participants were male and were matched in terms of age, height, weight and running experiences. The practice venue was also the same for all subjects. Based on the controlled studies in terms of the type, time and the intensity of trainings, Marti et al. and Macera et al. reported an equal risk of injuries in men and women [16,18]. Macera et al. and Walter et al. had also reported that age, height and weight have no relationship with the rate of running injuries, while weekly long distance running was an important factor related to the prevalence of injuries [18,19]. Marti et al., Macera et al., and Taunton et al. reported that the having a history of previous injuries is a main predictor of the occurrence of re-injury in runner athletes [14,16,18]. In 2003, Taunton et al. also reported no relationship was found between the rate of running injuries and the type of running terrains [14]. However, it seems that they failed to accurately measure the time and intensity of the training carried on the particular terrains.

In this study, the measurement of navicular height was carried out non-invasively through highlighting some landmarks on the skin. Although a high correlation was not found between the navicular drop values and the foot pressure measurements, the navicular test seems to be a valuable method in static evaluation of the foot. In agreement, Gilmour and Burns reported a −0.46 as the correlation index between the navicular height and the arch index [20].

In agreement with Morag and Cavanagh, the results of the current study showed no significant difference on the average dynamic peak pressure arch index among the three groups. Morag and Cavanagh had also pointed out that a foot with lower arch, and consequently greater contact area, would have higher midfoot peak pressure arch index, which would highly correlated with the calcaneus inclination shown in radiographic images ($r = -0.64$) [7]. Rosenbaum et al. also studied the relationship between the plantar pressure pattern and the static eversion angle of the calcanean bone. They reported that the higher calcaneus eversion angle in static position, the more pressure applied to the medial part of the midfoot in dynamic position, too [21]. Cavanagh et al. identified the arch related measurements as of the strongest predictors of dynamic plantar pressure patterns [22].

Comparison of the modified arch indices in the three groups in dynamic and static conditions showed that except the dynamic peak pressure arch index, the rest of the indices were different among the three groups. It is reasonable to assume that the maximum force value to be more sensitive than the peak pressure value related to the effective factors such as foot structure and arch heights. In terms of the static peak pressure and contact area arch indices, the observed difference was meaningful in both conditions between the normal arch and the high arch groups, and also between the high arch and the low arch groups. In spite of the existence of a meaningful difference between the high arch and low arch groups, the low arch and normal groups did not show a significant difference. This might be due to the fact that a significant difference between the low arch and normal groups may require an application of a force more than one body weight (i.e. replacing the ordinary walking with a running task) to become more apparent through kinematic changes in dynamic circumstances. In 2005, Burns et al. compared the temporospatial parameters and the peak pressure in normal and high arch individuals and found out that the contact area in the midfoot region was smaller in high arch individuals than in normal ones [23]. However, the peak pressure in the rearfoot region was more in high arch individuals than the normal ones. Sneyers et al. reported a higher peak pressure and relative loads in forefoot in high arch subjects than that in low arch subjects [24]. It could finally be stated that since the foot is a mediator between the body and the ground, its shape and structure should affect on the amount of foot plantar pressure. As a result, plantar pressure measurement might provide some direct information regarding the quality of the interaction of the different structures of the foot and the ground, and it can be used as a means of foot type classification.

Due to the complexity of the structure of the foot, a comprehensive analysis of the foot interaction with the ground during walking is very difficult. Using multi-segmental models of the foot, some researchers have succeeded to offer new information regarding the kinematics and kinetic of the forefoot, midfoot, and rearfoot and their interaction with ground during gait [25,26] and predict the dynamics of the foot function. Nachbauer and Nigg studied the height of MLA in standing position and arch flattening during running and reported no relationship existed between these two situations [27]. Cashmer et al. used a 3D gait analysis system and studied the behavior of the MLA in three conditions including sitting on a chair, single limb standing, and walking [28]. They studied three parameters including the length of the arch, the height of the arch and the supranavicular angle in these three conditions and found a significant difference among them. On the contrary, McPoil and Cornwall in 1996, and Hunt et al. in 2000 found that the static angle of the rear foot in the single limb stance may serve as a good clinical indicator for the maximum rearfoot eversion during walking [29,30].

The significant correlation of some of the MAI parameters between the static and dynamic conditions, found in this study, could be due to the similarity of the single limb stance and functional walking biomechanics. Thus, it is reasonable to assume that foot pressure measurements in the single limb stance might predict the foot functions in dynamic tasks such as walking. This may help researchers and clinicians to predict foot behaviors during simple single stance rather then complex movements during sports, but requires further research.

5. Conclusion

The results of this study did not support the idea of existence any relationship between the structure of the MLA and the prevalence of the ankle and knee injuries in professional runners. It seems that various factors such as different foot wears, training surfaces, experiencing previous injuries, the intensity and frequency of training sessions and also the type of trainings all might determine the probability of injury occurrence in athletes. This also indicates that using prophylactic ankle supports to prevent injuries in runners with abnormal arch height may not be helpful, although it may be of benefit when injury is present. This study shows an association between the maximum force/plantar pressure and arch height with further research indicated.

References

[1] De Cock A, Declercq D, Willems T, Witvrouw E. Temporal characteristics of foot roll-over during barefoot jogging: reference data for young adults. Gait Posture 2005;21:432–9.
[2] Burns J, Keenan AM, Redmond A. Foot type and overuse injury in triathletes. J Am Podiatr Med Assoc 2005;95(3):235–41.
[3] Burnfield JM, Few CD, Mahamed DS, Perry J. The influence of walking speed and footwear on plantar pressure in older adults. Clin Biomech 2004;19:78–84.
[4] Hreljac A, Marshall RN, Hume PA. Evaluation of lower extremity overuse injury potential in runners. Med Sci Sports Exerc 2000;32(9):1635–41.
[5] Williams DS, McClay IS, Scholz JP, Hamill J, Buchanan TS. High-arched runners exhibit increased leg stiffness compared to low-arched runners. Gait Posture 2004;19:263–9.
[6] Razeghi M, Batt ME. Foot type classification: a critical review of current methods. Gait Posture 2002;15:282–91.
[7] Morag E, Cavanagh PR. Structural and functional predictors of regional peak pressures under the foot during walking. J Biomech 1999;32:359–70.
[8] Brody DM. Techniques in the evaluation and treatment of injured runner. Orthop Clin North Am 1982;13(3):541–58.
[9] Bennett JE, Reinking MF, Pluemer B, Pentel A, Seaton M, Killian C. Factors contributing to the development of medial tibial stress syndrome in the high school runners. J Orthop Sports Phys Ther 2001;31(9):504–10.
[10] Cote K, Brunet M, Gansnder B, Shultz S. The effect of the pronated and supinated foot postures on static and dynamic postural stability. J Athlet Train 2005;40(1):41–6.
[11] Michelson JD, Durant DM, McFarland E. Injury risk associated with pes planus in athletes. Foot Ankle Int 2003;23(7):629–933.
[12] Mei-Dan O, Kahn G, Zeev A, Rubin A, Constantini N, Even A, et al. The medial longitudinal arch as a possible risk factor for ankle sprain: a prospective study in 83 female infantry recruits. Foot Ankle Int 2005;26(2):180–3.
[13] Van Mechelen W. Running injuries. A review of the epidemiological literature. Sports Med 1992;14(5):320–35.
[14] Taunton JG, Ryan MB, Clement DB, McKenzie DC, Lioyd-Smith DR, Zumb BD. A prospective study of running injuries. The Vancouver Sun Run "In Training" clinics. Br J Sports Med 2003;37:239–44.

[15] Taunton JG, Ryan MB, Clement DB, McKenzie DC, Lioyd-Smith DR, Zumb BD. A retrospective case–control analysis of 2002 running injuries. Br J Sports Med 2002;36:95–101.

[16] Marti B, Vader JP, Minder CE, Abelin T. On the epidemiology of running injuries: the 1984 Bern Grand-Prix study. Am J Sports Med 1988;16(3):285–94.

[17] Brunet ME, Cook SD, Brinker MR, Dickinson JA. A survey of running injuries in 1505 competitive and recreational runners. J Sports Med Phys Fitness 1990;30(3):307–15.

[18] Macera C, Pate R, Powell K, Jackson KL, Kendrick JS, Craven TE. Predicting lower extremity injuries among habitual runners. Arch Intern Med 1989;149:2565–8.

[19] Walter SD, Hart LE, McIntosh JM, Sutton JR. The Ontario cohort study of running related injuries. Arch Intern Med 1989;149:2561–4.

[20] Gilmour JC, Burns Y. The measurement of the medial longitudinal arch in children. Foot Ankle Int 2001;22(6):493–8.

[21] Rosenbaum D, Hautmann S, Gold M, Claes L. Effect of walking speed on plantar pressure patterns and hindfoot angular motion. Gait Posture 1994;2:191–7.

[22] Cavanagh PR, Morag E, Boulton AJM, Young MJ, Deffner KT, Pammer SE. The relation of static foot posture to dynamic foot function. J Biomech 1997;30(3):243–50.

[23] Burns J, Crosbie J, Hunt A, Ouvvrier R. The effect of pes cavus on foot pain and plantar pressure. Clin Biomech 2005;20:877–82.

[24] Sneyers CJ, lysens R, Feys H, Andries R. Influence of malalignment of feet on the plantar pressure pattern in running. Foot Ankle Int 1995;16(10):624–32.

[25] Leardini A, Benedetti MG, Catani F, Simoncini L. An anatomically based protocol for the description of foot segment kinetics during gait. Clin Biomech 1999;14:528–33.

[26] MacWilliams BA, Cowley M, Nicholson DE. Foot kinematics and kinetics during adolescent gait. Gait Posture 2003;17:214–24.

[27] Nachbauer W, Nigg BM. Effect of arch height of the foot on ground reaction forces in running. Med Sci Sports Exerc 1992;24(11): 1264–9.

[28] Cashmer T, Smith R, Hunt A. Medial longitudinal arch of the foot: stationary versus walking measures. Foot Ankle Int 1999;20(2): 112–8.

[29] McPoil T, Cornwall MW. Relation between three static angles of the rearfoot and the pattern of rearfoot motion during walking. J Orthop Sports Phys Ther 1996;23(6):370–5.

[30] Hunt AE, Fahey AJ, Smith Rm. Static measures of calcaneal deviation and arch angle as predictors of rearfoot motion during walking. Aust J Physiother 2000;46:9–16.