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DYNAMICS OF INTERACTION CHARACTERISTICS ON FOOT – SHOE INTERFACE IN RUNNING LOAD REGIME

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SUMMARY

The aim of this study has been to determine whether any changes in plantar pressure distribution occur in competitive distance runners during the stance phase of continuous steady running and continuous accelerating running depending on increasing fatigue and loading intensity. Furthermore to show a practical significance of tensometrics for running technique and running economy evaluation, as well as, for prevention of structural and functional changes of foot resulting from an extreme loading. Non-homogenous group of five distance runners – two competitive male runners, two competitive female runners, and one recreational male runner participated in this pilot study. The analysis of plantar pressure distribution during the stance phase at initial and final stage of continuous run was performed by using Novel Pedar-X system. One male competitive runner and one female competitive runner underwent continuous, gradually increasing loading, during which changes in plantar pressure distribution and foot contact time were observed depending on increasing running speed. The other subjects – competitive male runner, competitive female runner, and recreational male runner underwent continuous steady loading, during which changes in plantar pressure distribution and foot contact time were observed depending on increasing fatigue. No changes in plantar pressure distribution have been detected in any of the competitive distance runners during the continuous accelerating and continuous steady run. However, significant change in terms of shifting peak pressure areas forward to the forefoot has occurred in context of increasing fatigue during the continuous steady run in recreational runner. The foot contact time during the continuous steady run has changed only in female competitive runner.

Key words: stance phase of running, biomechanics, tensometrics, Pedar-X system, pressure distribution, foot-shoe interface

INTRODUCTION

Since the foot is structurally very complicated, the pattern of its movement during the stance phase of running is also very complicated. The analysis of foot movement reaction to load during the stance phase of running is therefore difficult. As far as the mechanical efficiency of running is concerned, one of the most effective and most commonly used approaches is detection of the mechanical interaction of foot with the ground. However, not many studies have been done on mechanical reaction of foot to changes during prolonged continuous loading, such as a change of the running speed or rate of fatigue in connection with intensity of loading.

At the present time, three main methods of detecting the mechanical interaction of foot with the ground are used in competitive sport. The changes rising during the stance phase of running can be detected and analyzed visually, by means of electromyography, or through scanning changes in plantar pressure on the ground. A combination of these methods can often bee seen in practice.

One of the most commonly used systems for providing optical records is Qualysis, which has been used in work of MacLean, Davis, & Hamill (2009) to obtain 3D data during running in 12 female runners. Using this eight-camera optoelectric system that uses reflection of infrared radiation from reflective markers positioned on different body parts, force platform, and special software analyzed the influence of different running shoe midsole composition and custom foot orthotics on foot kinetics and kinematics during the stance phase of running. Optoelectric record of movement is ideal for investigating a movement during athletic performance or training. In competitive athletes, where physical limits or movement optimization are important factors, it can be used to improve technique of particular movement and reach a better performance, as well as, to understand mechanisms of various injuries, thereby facilitates their prevention.

Similar system used earlier Butler, Davis, & Hamill (2006). By means of six-camera motion analysis system, force plate, and uniaxial accelerometer placed on the distal, anteromedial part of the tibia studied the influence of an arch type (low arch vs. high arch) and running shoe type (motion control vs. cushioning shoe) on foot biomechanics during the stance phase of running in 40 recreational male and female runners. Retroflective markers were placed on several different spots either directly on the skin or on the shoe to track the movements of different parts of lower extremity. Since the shoe could distort the results of calcaneal movement, windows were cut in the heel counter of the shoe, so that calcaneal markers could be placed directly on the skin over the calcaneus. The results of this study have suggested that the type of a running shoe may have an influence on foot mechanics during the stance phase of running, however the influence of arch type may not be significant.

Hasegawa, Yamauchi, & Kraemer (2007), evaluated relationship between rearfoot, midfoot, and forefoot strike patterns and a level of running performance. Using two video cameras positioned 15 cm above the ground observed an actual foot strike pattern in 415 runners, including elite runners and Olympians, during a half marathon race (Figure 1). This optical analysis of stance phase during the running performance not only allowed to evaluate changes in terms of inversion and eversion of foot at the foot strike, but also to measure a contact time. These characteristics then could be evaluated with one another.

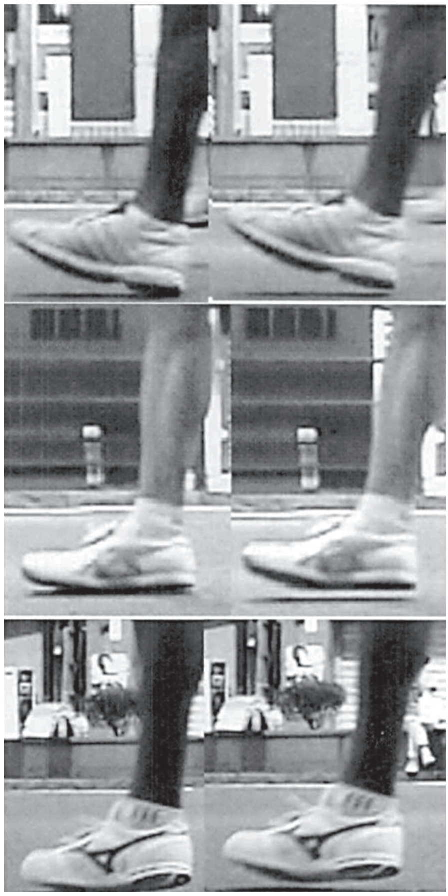

Figure 1. Sample picture of foot strike patterns: Rearfoot strike (men: third place at 15-km point), midfoot strike (women: first place at 15-km point), and forefoot strike (21st place at 15-km point) from top to down (Hasegawa et al., 2007).

Different device for analyzing particular phases of running stride used in their study Auvinet, Gloria, Renault, & Barrey (2002). By means of portable, non-invasive accelerometric system identified specific events in the gait cycle on the cranial-caudal, anterior-posterior, and median-lateral acceleration curves in seven competitive middle distance runners. In order to obtain the analysis of running strides, 3D lumbar acceleration recordings were synchronized with a video recording. Initial contact, mid stance, and toe-off phase were easily identified on obtained acceleration curves (Figure 2). This apparatus, that is composed of recording device, computer program for processing the accelerometric signal, and sensor that is fixed into a semi-elastic belt, which is fastened around the runner's waist, does not require additional technical equipment and provides important information about spatio-temporal characteristics of runner's stride. Thus, it could be very useful for outdoor analyzing of running style.

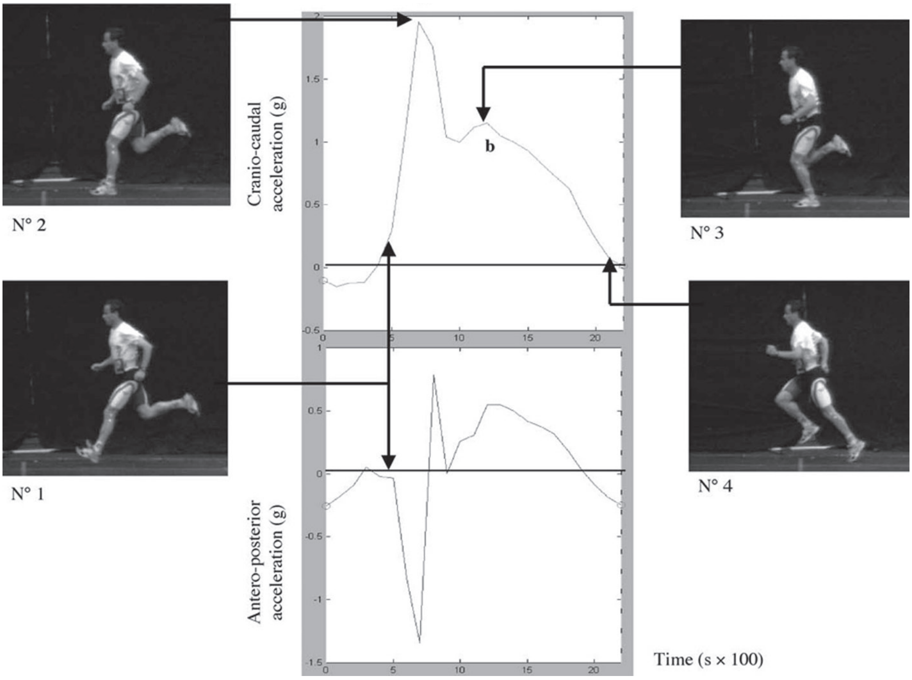

Figure 2. Cranial-caudal and anterior-posterior acceleration curves and synchronised images at specific stages of the gait cycle: initial contact (No. 1), foot flat (No. 2), mid-stance (No. 3), and toe-off (No. 4), identification of maximum loading impact (a) and thrust (b). (Auvinet et al., 2002).

An invasive laboratory method used Arndt et al. (2007) in order to accurately describe the movements in intrinsic articulations of the foot. Four male subjects participated in this study. Using a set of reflective markers mounted on intracortical pins drilled into the bones (tibia, fibula, calcaneus, talus, navicular, cuboid, medial cuneiform and metatarsals I and V) an accurate kinematic description of the intrinsic articulations of the foot during the stance phase of slow running was obtained (Figure 3).

Kinematic data were recorded and processed by 10 camera motion analysis system synchronized with the force platform for recording the ground reaction forces. Based on this analysis, a movement of particular segment relative to the proximal segment was determined. Calculations showed a little limitation of the foot movements due to inserted pins. Although, this method is very accurate, it is not applicable in training of distance runners.

Different approach chose Erdemir, Sirimamilla, Halloran, & van den Bogert (2009) who used a robotic system and computed tomography to analyze a foot tissue deformation at different levels of three-dimensional loading in human foot specimen. The apparatus enabled to load the foot in various directions at all three dimensions, as well as, to load its segments separately. The aim of this study was to quantify mechanical properties of the foot, in order to provide valuable data for development of computational models for movement analysis and detailed simulations of tissue deformation.

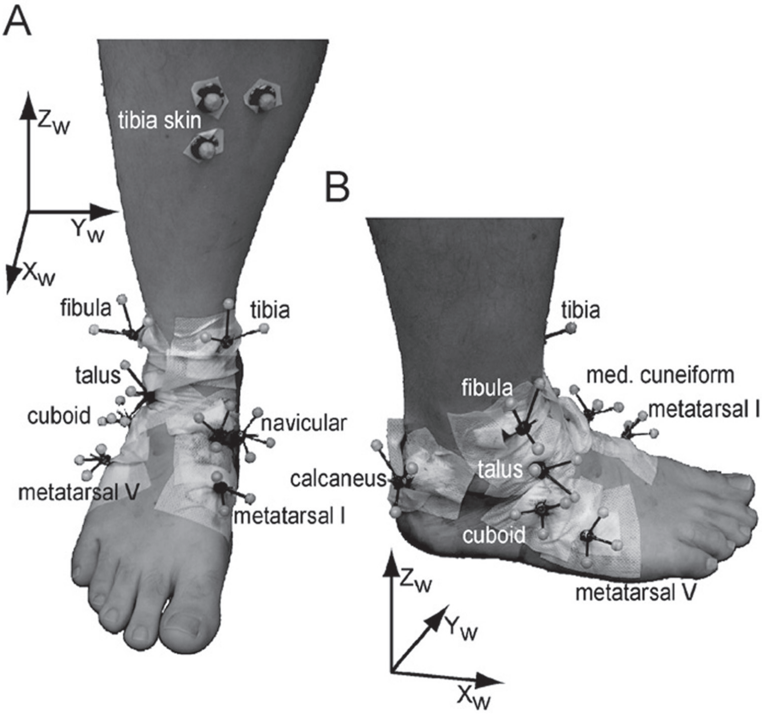

Figure 3. Inserted marker arrays, tibia skin-markers and the global coordinate system (Arndt et al., 2007).
(A) Frontal view, also illustrating the three skinmarkers on the tibia used for the CMC calculations (coefficient of multiple correlations) for comparing the running style before and after the insertion of markers.
(B) Lateral view.

Tensometric methods

Tensometric methods are broadly used in competitive sport. By means of analysis of pressure exerted by foot, they enable to create a graphic representation of the foot loading and its course during the stance phase of running. Thus, they can provide very useful feedback in effort to assume a more effective running technique, they provide information about the loading of the foot, as well as, the entire musculoskeletal system, and are able to diagnose some imbalances during loading that could lead to injury. Equipment of Kistler company, one of the world leading producers of pressure sensors, tensometric and dynamometric appliances, was used in study of Hagen & Hennig (2009). 20 experienced male runners participated in this study which had the purpose to evaluate the influence of various shoe lacing on some kinetic and kinematic characteristics of foot in stance phase of running. Plantar pressure distribution was scanned by using piezoelectric force platform that was able to provide 2D, as well as, 3D image of plantar pressure distribution, simultaneously in-shoe plantar pressure distribution was scanned by piezoelectric

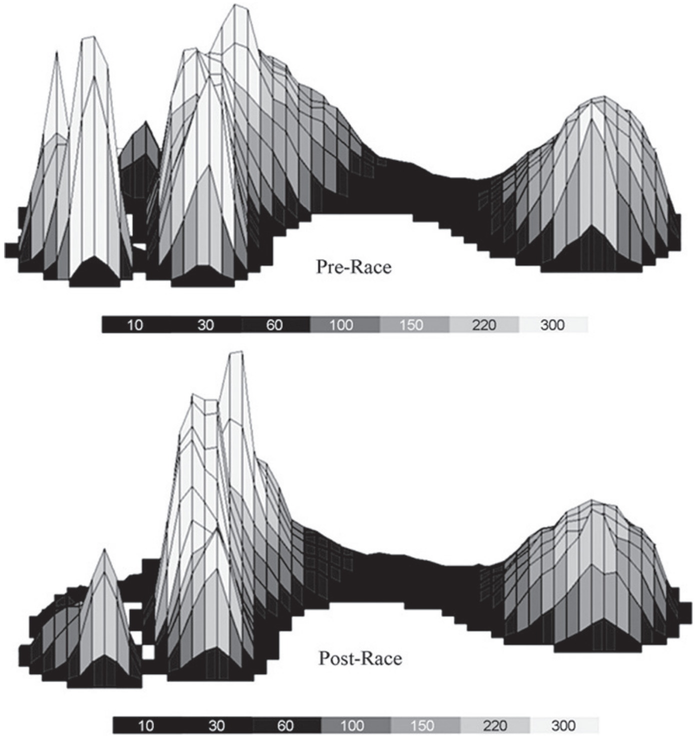

Figure 4. Plantar pressure distribution [kPa] of a male runner during walking pre- vs. post-marathon race (age 52 years; BMI: 24 and 7; finishing time: 4 h and 15 min) (Nagel et al., 2008).

transducers placed on 7 parts of the foot (medial and lateral heel; lateral midfoot; first, third, and fifth metatarsal heads; hallux). In order to obtain a detailed kinematic analysis, these devices were combined with goniometer and miniature accelerometer fixed to the lower leg over the medial aspect of the tibia.

Nagel, Fernholz, Kibele, & Rosenbaum (2008) studied the effect of distance running on plantar pressure distribution by using a capacitive platform. 200 recreational runners participated in this study. Their plantar pressure was measured during walking before and after a marathon race. After the race, peak pressure and impulse values were higher in the forefoot regions and reduced under the toes (Figure 4). These results indicate that a load shift from the toes to the metatarsal heads exists during a marathon race. This suggests that an increased loading of the metatarsal bones after a long run could be a cause of metatarsal stress fracture.

Fong et al. (2008) used a pair of portable pressure insoles Pedar-X system, produced by Novel company, that can be inserted in the shoes and enables an accurate measurement of plantar pressure distribution during walking, running, and other activities, to create a three-pressure-sensor (3PS) system for monitoring ankle supination torque during sport motions. 3PS was developed for the purpose of ankle sprain prevention. It significantly contributes to development of an intelligent shoe that would be able to analyze the ankle supination torque, and if necessary, initiate corrective action. Five male subjects participated in the initial experiment. First, the ankle joint torque was calculated by means of pressure insoles for measuring the plantar pressure at 99 regions covering the whole plantar area and 12 reflective markers placed on hallux, distal first metatarsal, distal fifth metatarsal, proximal first metatarsal, proximal fifth metatarsal, navicular, medial calcaneus, lateral calcaneus, heel, lateral malleolus, tibial tubercle, and lateral femoral epicondyle, either on skin or shoe surface, during various motions including walking, running, cutting, vertical jump-landing and stepping-down from a block. Based on this analysis, only three positions out of 99 pressure regions were found to be essential to reconstruct the ankle supination torque (Figure 5a). These locations were approximately at the fourth/fifth metatarsalphalangeal joint, the third

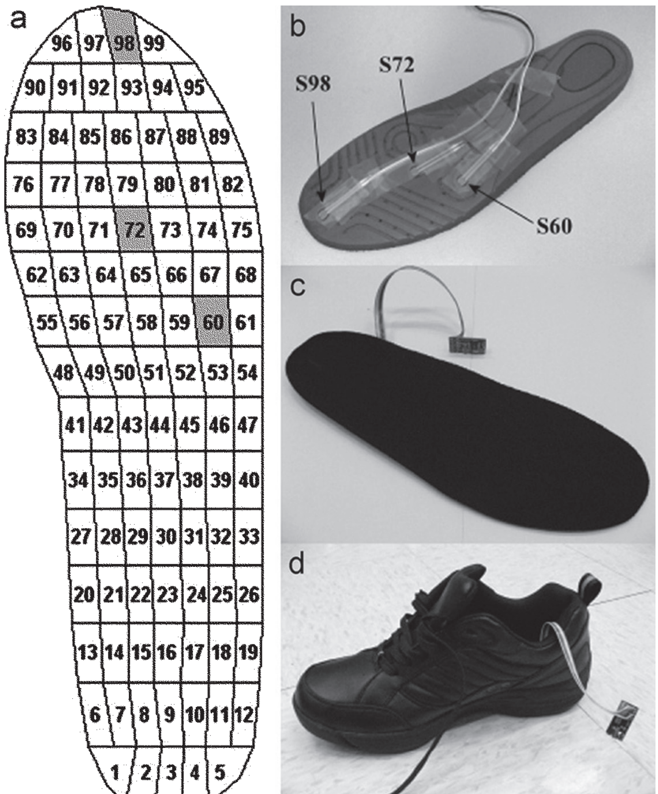

Figure 5. (Fong et al., 2008).
(a) Location of the three pressure sensors (in right foot) required for the reconstruction of the ankle supination torque in the initial test.
(b) Three individual pressure sensors attached to the required position beneath an insole.
(c) The top side of the instrumented insole.
(d) The sport shoe with the instrumented insole used in the validation test in this study.

metatarsalphalangeal joint, and the second/third distal phalange. Consequently, these three locations were equipped with circular pressure sensors beneath the insole (Figure 5b). It has been shown that the 3PS system is able to calculate the ankle supination torque during various dynamic sport motions with very high accuracy. Since it is very small it can be easily implanted into a sport shoe (Figure 5c,d). Furthermore, this system is very inexpensive, thus could be utilized in various loading conditions including various kinds of athletic training.

METHODS

Inhomogeneous group of 5 runners at age 23 to 40 years participated in this study. 4 of them were competitive middle distance and long distance runners (age 23–32 years) and one was a recreational runner (age 40 years). All the competitive runners were specialized on track running, however, in spring and fall in several recent years participated in some 6–10 km cross country races at national and international level. Subjects' basic characteristics are in table 1. The purpose of this study was to determine, whether any changes in plantar pressure distribution occur in competitive runners during the stance phase of continuous steady running and continuous accelerating running depending on increasing fatigue and loading intensity. Also, the aim of this study was to show a practical significance of tensometrics for running technique and running economy evaluation, and show the options of its application in prevention of structural and functional changes of foot resulting from an extreme loading. An analysis of plantar pressure distribution was accomplished in each of the runners during the stance phase at the initial and final stage of continuous running by using Pedar-X system produced by Novel co.

Pedar-X system is a device that is able to detect and analyze pressure distribution between the foot and the ground during the foot loading with frequency 50 Hz. By means of this system, plantar pressure distribution can be recorded and depicted, as well as, some other spatio-temporal characteristics during the stance phase of walking or running.

The system consists of two elastic tensometric insoles, recording device with a built-in Bluetooth system and a flash memory storage, and software for processing data. The insoles, that are inserted in the shoes, cover the entire sole area. The area of each insole is divided into 99 fields equipped with pressure sensors for actual pressure measurements. Both insoles are connected via a cable with recording device which is fixed to a subject's waist by an elastic band. Pedar-X system can be connected with a PC via an optical USB cable. The device is also able to communicate with a desktop or laptop PC through Bluetooth signal. Internal memory storage for collecting data has capacity 32 MB. This capacity, at scanning frequency 50 Hz, allows to collect data of about 1 hour of continuous activity.

In order to process collected data, version 19.3.30 of Pedar-X Standard software was used in this experiment. It has various features for quick collecting, evaluating, and presenting data recorded by the tensometric system. Among others, it allows running and viewing of an obtained record in real time or tracing a detailed course of every step from the moment of the first contact to the moment of the last contact of foot with ground. For more detailed analysis, the area of the insole is divided into 7 segments: medial heel, lateral heel, midfoot, medial forefoot, lateral forefoot, the first toe, and the other toes. The software then enables to analyze all measured variables for each of the segments separately, as well as, generally. Also, it enables to watch the detected data directly on PC screen or globally process and analyze it by using the database program unit – Novel database essential.

After inserting the insoles in the shoes, left and right tensometric devices were calibrated. All subjects were tested in neutral type of training shoes. In all the competitive runners, the testing was scheduled for the beginning of racing period. In order to prevent distorting of results due to accumulated fatigue, the testing was conveniently scheduled in their training plan, so that they had a day off or just an easy workout at least a day before the testing. Measurements were conducted during continuous 10 km (male runners) or 6 km (female runners) run on treadmill. Before the measuring had been started, each subject ran 2 km warm-up distance which also enables to control a functioning and proper fastening of all parts of the device. Two subjects – one male and one female runner underwent gradually increasing loading. Another two subjects – one mail and one female runner underwent steady loading. Finally, one subject – recreational runner also underwent steady loading. These results were used as a control data set.

Based on their actual fitness, the individual loading intensity was determined in each subject. In those subjects that underwent gradually increasing loading, the loading mode had been previously designed, including initial and final running speed. The objective of this was to make a subject run the initial part at very low – subliminal intensity and the final part at high – submaximal intensity insuring a high degree of fatigue, which was determined by measuring the level of lactic acid in capillary blood taken from the subject directly after the test had been finished. In subjects undergoing steady loading, the individual running speed was assessed, so that the subject could run the prescribed distance with gradually increasing fatigue that would reach submaximal degree at the end of testing. The level of fatigue was controlled by measuring the heart rate in regular intervals during the run.

During the test, the detected data was directly collected and saved in the internal memory storage of the portable device for data collecting and saving that was connected with tensometric insoles via a cable. Consequently, collected data was transferred by means of Bluetooth signal to the hard drive of a PC and by using software Pedar-X Standard processed and interpreted. Finally, a section of 500 steps (250 left and 250 right foot) was selected in each subject from the initial and the final stage of the run, and statistically tested and analyzed using the database program unit Novel database essential. Consequently, maximal and average values of observed variables were obtained from the number of steps.

Observed variables

Following variables were observed in each of the subject:

- **Plantar pressure distribution**
  Changes were evaluated visually on a graphic spatial representation created by software using 8-degree color scale corresponding with individual pressure levels, and on graphic picture of trajectory of the center of mass during the stance phase.

- **Overall average maximal pressure**
  Changes were evaluated by means of numeric values and the graphical representation. A change greater than 15 kPa was determined as objectively significant.
- **Average maximal pressure in seven plantar segments** (medial heel, lateral heel, midfoot, medial forefoot, lateral forefoot, the first toe, and the other toes)
  Changes were evaluated by means of numeric values and the graphical representation. A change greater than 15 kPa was determined as objectively significant.
- **Contact time**
  Changes were evaluated by means of numeric values. A change greater than 10 kPa was determined as objectively significant.

All the observed variables were evaluated on right and left foot respectively, at the initial and the final stage of testing.

Loading characteristics in objects are in table 2.

Table 1. Basic characteristics of subjects

Subject	P.F.	P.D.	M.P.	D.G.	A.T.
Sex	female	male	female	male	male
Age (years)	27	24	23	32	40
Height (cm)	168	180	157	173	179
Weight (kg)	56	70	49	62	74
Racing distance	1500 m	1500 m	5000 m	3000 m steeplechase	Recreational runner
Personal best	4:30,79	3:50,55	16:53,99	8:34,97	–
Personal best of the season	4:39,00	3:51,10	16:53,99	–	–
Duration of specialization (years)	10	11	9	20	–
Maximal heart rate	–	–	180–186	177–185	187–192

Table 2. Loading characteristics

Subject	P.F.	P.D.	M.P.	D.G.	A.T.
Loading distance (km)	6	10	6	10	10
Loading mode	Increasing Intervals: 2 km – 2 km – 1 km – 1 km	Increasing Intervals: 2 km	Steady	Steady	Steady
Running speed (min/km)	4:30 – 4:20 – 4:10 – 4:00	4:00 – 3:45 – 3:30 – 3:20 – 3:10	3:50	3:30	5:30
Heart rate (tepy/min)	–	–	Interval 1km 169 – 177 – 179 – 179 – 180 – 183	Interval 1km 157 – 163 – 163 – 166 – 169 – 172 – 176 – 177 – 176 – 177	At the end of testing 170
Lactic acid (mmol/ml)	3.1	8.1	–	–	–

RESULTS

Plantar pressure distribution

In three competitive runners (P.F., P.D. and M.P.), no changes in plantar pressure distribution were observed at the final compared to the initial part of loading (Figure 6). Only in subject D.G. an alteration of plantar pressure distribution on left foot was observed in the final part of testing. The area of maximal pressure moved from lateral part of forefoot medially. More expressive changes of the plantar pressure distribution were observed only in recreational runner A.T. whose areas of maximal pressure in both feet moved in final stage of the run forward – from the heel to the forefoot (Figure 9). These result indicated that the character of loading had no effect on the plantar pressure distribution in competitive runners.

Maximal pressure

Of three subjects undergoing steady loading, no increase in maximal pressure on left and right foot was detected in subject D.G. at the final stage of testing. In recreational runner A.T., the increase in maximal pressure was detected only on right foot, as a result of increased pressure at medial part of the forefoot (Figure 10, 11). On the other hand, decrease in maximal pressure on left foot was detected in subject M.P. in consequence of decreasing pressure at medial part of the forefoot, in comparison with the initial part of testing (Figure 7, 8). In subject P.F. who underwent increasing loading, only a little increase of maximal pressure on left and right foot in final stage of testing was observed. This was caused by increased pressure at medial part of the forefoot. In subject P.D., the value of maximal pressure at the final stage of the increasing load increased only on left foot due to significant increase of pressure during toe off. The results suggest that degree of fatigue did not significantly influence the plantar pressure distribution, and that increasing running speed may result in increased plantar pressure.

Contact time

Reduction of contact time was observed in both competitive runners (P.F. a P.D.) who underwent increasing loading at the final stage of testing. In two subjects (competitive runner D.G. and recreational runner A.T.) who underwent steady loading, no change in contact time was detected at the final part of testing. On the other hand, reduction in contact time was observed in competitive runner M.P. who also underwent steady loading. The results indicate that increasing running speed is associated with reduction of contact time, and that increasing fatigue is not related to reduction of contact time but rather to its extension.

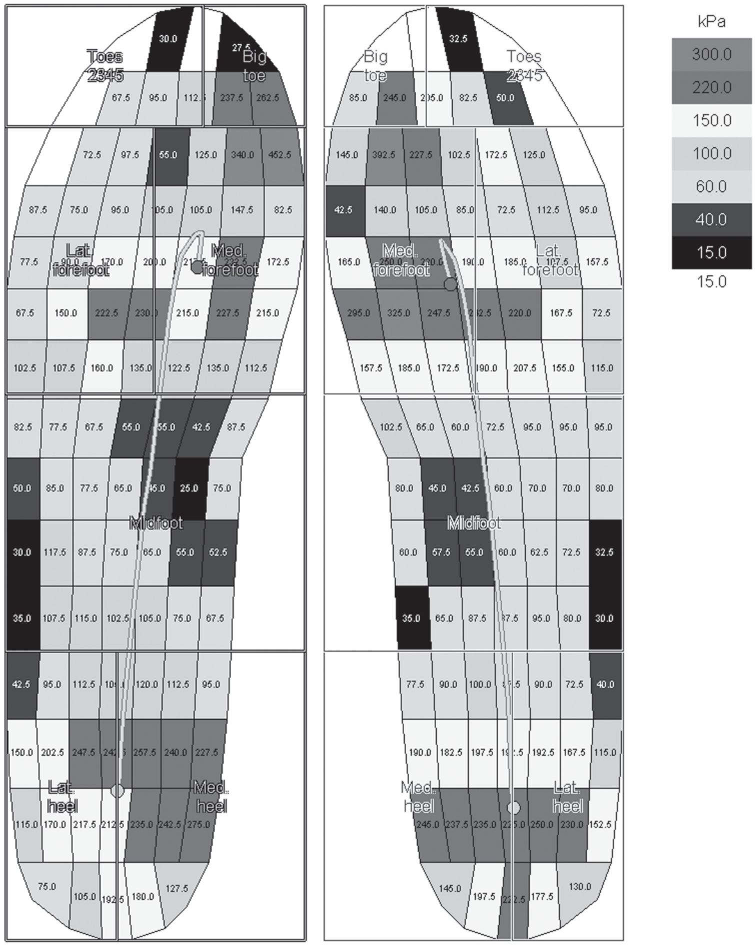

Figure 6a. Plantar pressure distribution at the initial stage of testing in subject M.P.

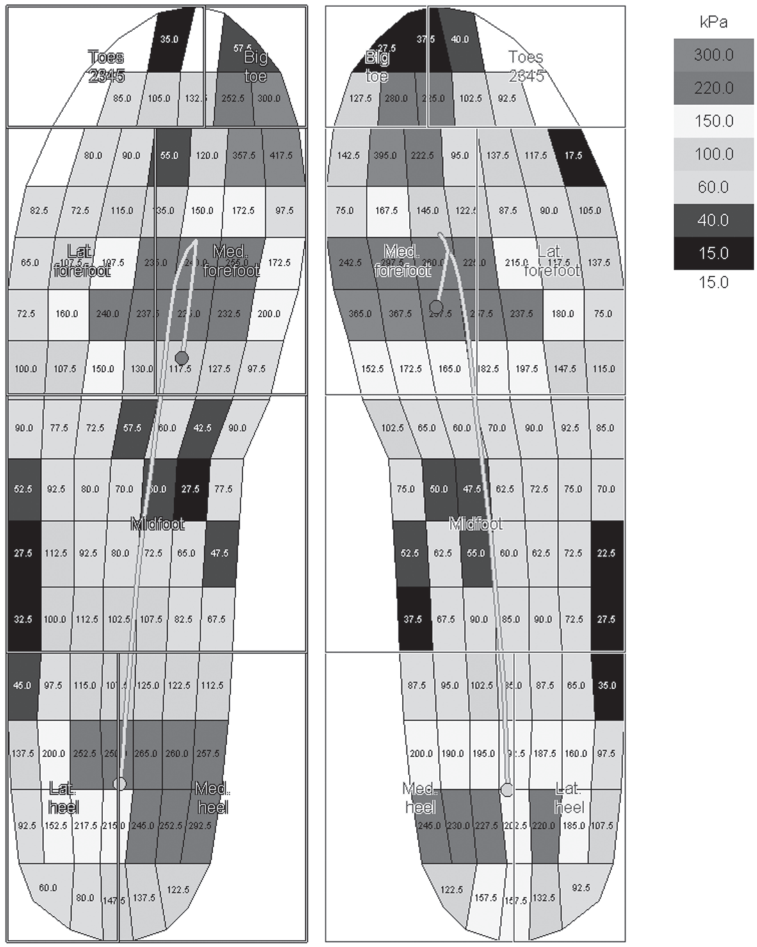

Figure 6b. Plantar pressure distribution at the final stage of testing in subject M.P.

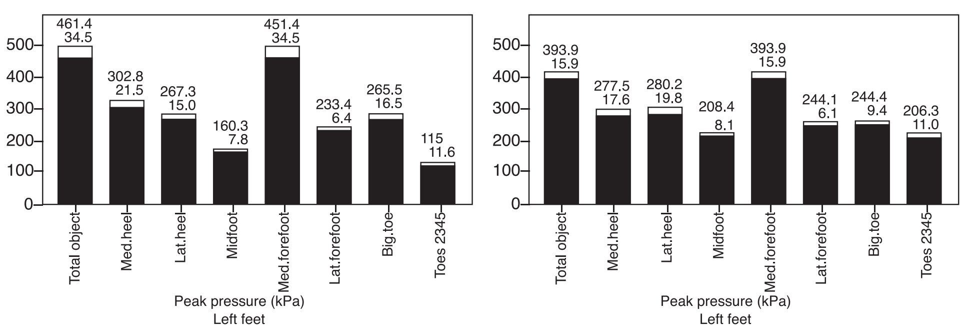

Figure 7. Values of maximal pressure in particular segments of left and right foot at the initial stage of testing in subject M.P.

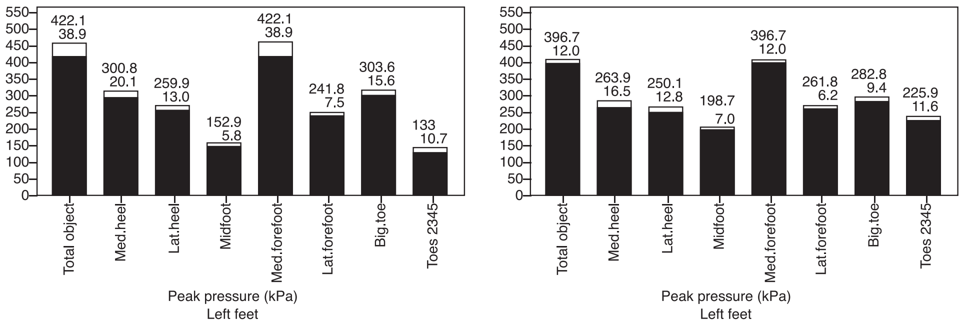

Figure 8. Values of maximal pressure in particular segments of left and right foot at the final stage of testing in subject M.P.

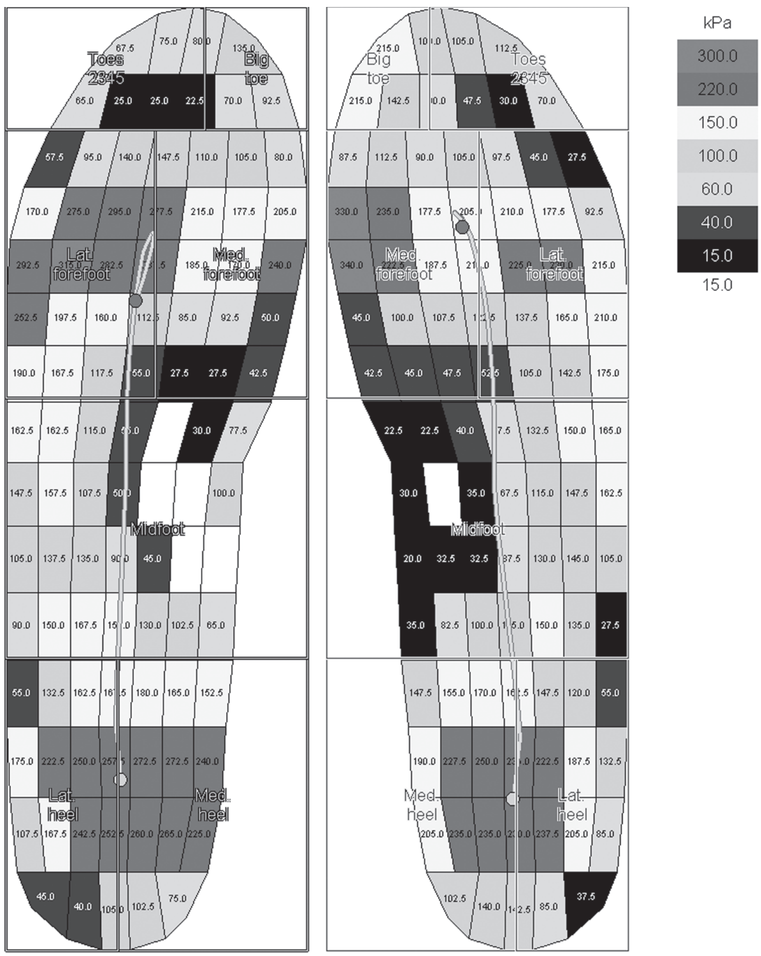

Figure 9a. Plantar pressure distribution at the initial stage of testing in subject A.T.

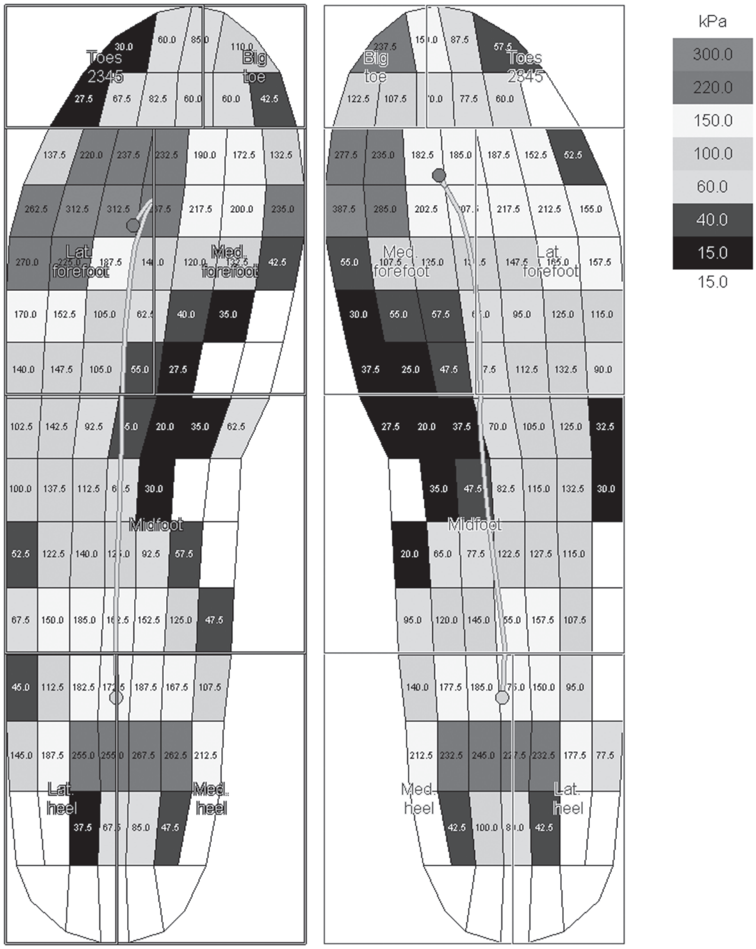

Figure 9b. Plantar pressure distribution at the final stage of testing in subject A.T.

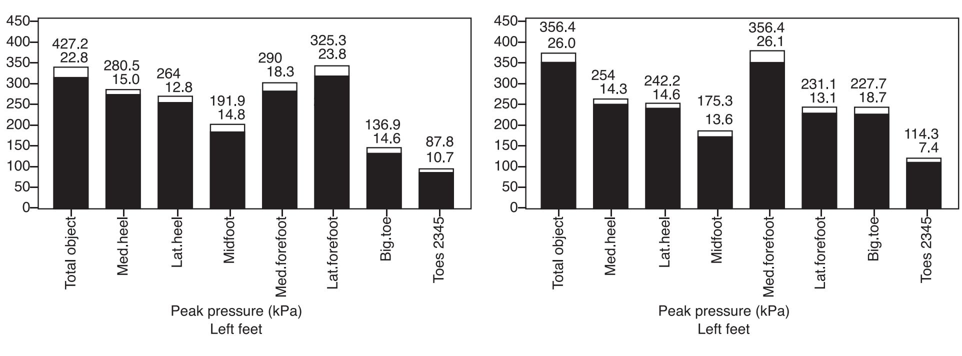

Figure 10. Values of maximal pressure in particular segments of left and right foot at the initial stage of testing in subject A.T.

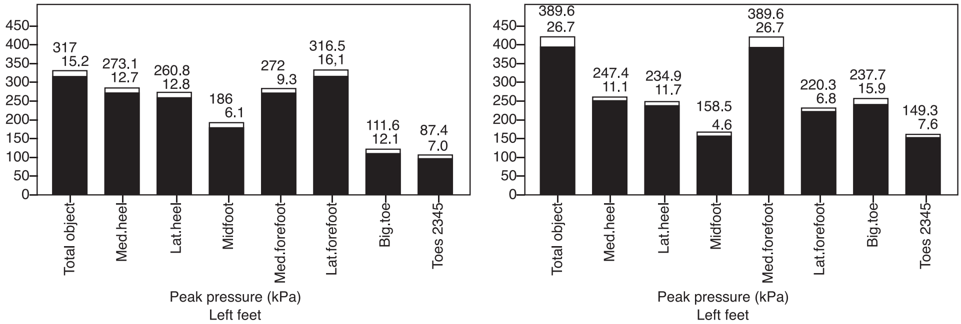

Figure 11. Values of maximal pressure in particular segments of left and right foot at the final stage of testing in subject A.T.

DISCUSSION

In the experimental group of this pilot study, male and female runners of different ages and racing experience, were included. One of the biggest problems in terms of the objectivity of testing was the tensometric device itself. It had to be carried during the entire testing. First, it was tensometric insoles that were inserted into shoes instead of the original insoles, then cables for connecting the insoles with recording device that were fixed by elastic bends to lower extremities of a subject, and finally the device for collecting and storing data, which was fixed to a subject's waist. Although, this device, as stated by manufacturer, weighs only 400 g, it could affect running technique and distort observed variables. Especially, when it was not positioned in the middle of a subject's back but rather on the side, which happened in most of the subjects.

Another substantial problem was testing procedure on treadmill in the laboratory environment. Running technique, as well as, pressure and temporal characteristics of stance phase can differ on treadmill from those in running outdoors. In order to get more objective information, similar experiment should be carried out in outdoor conditions, either on track, or on various kinds of surfaces and various course profiles.

Distortion of obtained values can also be caused by the shape of tensometric insoles that not always conform to an individual anatomical shape and size of subject's foot. This might be cause of spots of very low or zero pressure occurring at peripheral parts of the sole during the experiment in some of the subjects.

An important factor with regard to the objectivity of results is concededly the type of shoe. Some characteristic of shoe, such as the hardness of midsole or properties of insole, may influence kinetics and kinematics of the foot during the stance phase of running (MacLean, Davis, & Hanilo, 2009).

The results of testing may even be affected by a way of lacing and its tightness (Hagen & Hennig, 2009). During the experiment all the subjects underwent loading in neutral training shoes, which means without any motion control components. Nevertheless, during testing, each subject wore shoes from different producer, thus the effect of different shoe characteristics could not be excluded. To maximize the objectivity of detected data, all subjects would have to be tested in the same shoes made in the same year and with the same degree of wear-out.

In subjects who underwent gradually increasing loading, the aim was to them run the initial part of the test at very low intensity and the final part at high intensity corresponding to racing speed at the testing distance. In order to get the information about a degree of fatigue, an assessment of lactic acid was done in these subjects directly after finishing the test. In subject P.F. and P.D. the values 3.1 mmol/l and 8.1 mmol/l respectively were obtained. Especially in subject P.F., the degree of fatigue at the end of testing cannot be considered as high. Nevertheless, if we want to observe an association of changes in plantar pressure distribution with running speed, the fatigue could significantly distort the results. For next work it would be therefore convenient to eliminate increasing fatigue by progressively accelerating intervals of running with a sufficient resting period between the intervals.

In subjects who underwent steady intensity loading, the aim was to assess such intensity of loading that would ensure a gradually increasing fatigue during the test. This was controlled by recording heart rate in regular intervals. The purpose of this was to make a subject run the initial part of the test at relatively low degree of fatigue and the final part at high degree of fatigue. In all subjects, it was reached a gradual increasing heart rate with final values at submaximal level. Despite, in competitive runners, in which no changes in plantar pressure distribution were detected, the degree of fatigue may not be high enough to evoke such changes. For next work on relation of plantar pressure distribution to fatigue in competitive runners, it would be convenient to set a higher intensity of loading or prolonged loading.

With regard to a low number of subjects participating in this pilot study, the results cannot be generalized for competitive runners or general population.

CONCLUSION

Many technologies in presented studies are still limited to the laboratory conditions and equipment hence they cannot be used in an actual training conditions. Some others, such as Pedar-X system may be used in almost any outdoor conditions. This makes them very suitable for testing in specific loading situations such as in training of competitive athletes.

Based on observations made during this experiment we came to a conclusion that competitive runners were able to keep their individual running technique in spite of a high degree of fatigue. Therefore, we recommend either long continuous loading at high intensity that would simulate racing conditions as the most convenient method to obtain valuable information about the plantar pressure distribution in competitive runners.

Last but not least, the benefit of the tensometric device Pedar-X can be seen in prevention of structural and functional changes of foot developed in consequence of prolonged and inadequate load. This apparatus allows to diagnose some imbalances in motion control and symptoms of immoderate load. The significance of this tensometric technology is exceptional in terms of analyzing symmetry between left and right foot. Suggested investigation not only contribute to assumption and maintenance of the efficient running technique, but it has been shown it is also important for improvement of foot injury prevention.

The results of this study are used in the learning process at the Faculty of Physical Education and Sport.

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DYNAMIKA INTERAKČNÍCH CHARAKTERISTIK ROZHRANÍ NOHA–BOTA V ZÁTĚŽOVÉM REŽIMU BĚHU

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SOUHRN

Cílem studie bylo zjistit, zda u výkonnostních běžců dochází ke změnám distribuce tlaku chodidla na podložku v průběhu oporové fáze souvislého rovnoměrného a souvislého stupňovaného běhu v závislosti na rostoucí únavě a intenzitě zatížení. Dále bylo cílem ukázat na praktický význam tenzometrie pro hodnocení techniky a ekonomiky běhu a možnosti jejího využití pro prevenci strukturálních a funkčních změn nohy vlivem extrémní zátěže. Jedná se o pilotní studii, které ze zúčastnila nehomogenní skupina pěti běžců – dvou výkonnostních běžců, dvou výkonnostních běžkyň a jednoho rekreačního běžce. U každého z probandů byla provedena analýza distribuce tlaku chodidla na podložku v průběhu oporové fáze na počátku a na konci souvislého běhu pomocí

Pedar-X systému společnosti Novel. Jeden výkonnostní běžec a jedna výkonnostní běžkyně absolvovali souvislé, rovnoměrně stupňované zatížení, přičemž byly sledovány změny distribuce tlaku chodidla na podložku a změny doby trvání oporové fáze v závislosti na zvyšující se rychlosti běhu. Zbývající probandi – výkonnostní běžec, výkonnostní běžkyně a rekreační běžec absolvovali souvislé rovnoměrné zatížení, při kterém byly sledovány změny distribuce tlaku chodidla na podložku a změny doby trvání oporové fáze v závislosti na zvyšující se únavě. V průběhu souvislého stupňovaného ani souvislého rovnoměrného běhu nedošlo u žádného z výkonnostních běžců ke změně distribuce tlaku chodidla na podložku, ale ke změně ve smyslu posunu oblastí nejvyššího tlaku z paty na přední část chodidla došlo v souvislosti se zvyšující se únavou v průběhu souvislého rovnoměrného běhu u rekreačního běžce. Doba trvání oporové fáze se v průběhu souvislého rovnoměrného běhu změnila jen u výkonnostní běžkyně.

Výsledky této studie jsou využívány v pedagogickém procesu na FTVS UK Praha

Klíčová slova: oporová fáze běhu, biomechanika, tenzometrie, Pedar-X systém, distribuce tlaku, rozhraní noha–bota

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