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RUNNING BIOMECHANICS AND SELECTION OF SPORTS SHOES IN BENEFIT TO AMATEUR ATHLETES

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ABSTRACT
Biomechanical analysis of running is a powerful tool in favor of professional and amateur sports. Through it, data can be obtained to be used to improve sports performance and prevent running injuries. For our study we used „Templo motion analysis software" and „Coach`s eye", app to make video recording of the participants. This software package and application developed to analyze in detail the biomechanics of human movement. Randomly selected amateur runners were photographed, and angles of foot pronation were measured when running with different types of shoes.
The angle of dorsiflexion in the ankle joint at the moment of contact of the foot with the surface, as well as the angle between the hip and the lower leg in this moment.
The hypothesis of the study is that the use of biomechanical analysis of running techniques in training and the selection of appropriate shoes for the purposes of the particular athlete, will positively affect the athletic performance and will help prevent injuries. 304 amateur runners take part in the research. Conclusions: The biomechanical analysis of the technique, the selection of suitable running shoes will help the training of runners and running prevention.

Key words: running, biomechanics, movements, sports shoes, amateur athletes

INTRODUCTION

Running is a natural-applied motor activity. After getting up and start walking, the child naturally starts running.

Amateur running as an activity is a social phenomenon. In addition to its accessibility, we often associate it with a community of people united by one idea - a healthy and active lifestyle. Running differs from walking in the presence of swing phase - there is a moment when no part of the body interacts with the surface.

It is necessary to clarify the impact of different forces on the body during running, to understand how individual technique affects the results, to prevent injuries and to achieve sports longevity.
- Internal forces - muscle strength, elastic forces from tendons and ligaments (potential energy)
- External forces – gravity force, air resistance, inertial forces.

Movement is always the result of the interaction between internal and external forces when the body is in stance or swing. In athletic practice, we distinguish mainly dynamic forces that cause movement. Each manifestation of dynamic forces leads to the emergence of inertial forces (equal in magnitude and reverse in direction). Contact with the ground when stepping creates gravity reaction force, opposite to the inertial force. In order to move forward, the body must apply muscular force, to activate the musculoskeletal system in counteraction to the resulting friction forces. The degree of energy loss, of amortization, depends

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on the response of the musculoskeletal system - how the foot will meet the support, whether the body has adequate muscles.

Proper running biomechanics is associated with economical and synchronized movements of the components of the kinetic chain. An important element of this chain is the foot, as a connection between the surface and the body.

The technique is determined by the running cycle (running stride), which is conditionally divided into two periods:stance and swing

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Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

During the period of stance, the foot with one of his part is in contact with with the ground. During the swing such contact is absent. The stance period is divided into the following three phases: initial contact **(Figure 1 and Figure 5),** mid stance **(Figure 2)** and propulsion **(Figure 3).** The amortization starts from the first touch of the foot to the mid stance – in this part have the greatest impact forces (from the initial contact to the the moment of vertical when the runner`s center of mass is perpendicular to the ground).

The repulsion starts from the moment when the center of body mass cross the vertical and ends at the toe off moment from the ground. Stance ends when the foot is no longer in contact with the ground. Toe off marks the beginning of the swing phase of the gait cycle.

From this moment the swing period begins, which continues until the next ground contact **(Figure 5).**

Thus described running gait is characterized by the kinematic components cadence (running step frequency) and amplitude (running stride length). In different running disciplines the running speed is different and therefore the individual parameters of these components are different.

Speed is created in the rear separation phase - ie in repulsion, and is lost in the absorbation phase. The timing of toe off depends on speed. Less time is spent in stance as the athlete moves faster (10). In this sense, the target of the runner is to reduce the importance of amortization and with the help of adequate, economical and synchronized movements of the neuromuscular apparatus to make movement (running) (9).

Nowadays, there are many devices that can measure various indicators during running - including biomechanical. From the point of view of economy of movements cadence and stride length, the time of contact (ground contact), vertical oscillations (etc.) are important. Running cadence is measured by the number of steps for a minute, and the amplitude is determined by the length of the step. The optimal ratio of these two parameters determines the speed of running - the efficiency of neuromuscular work.

More experienced runners with rational technique have cadence of about 180 (number of steps measured per minute). This indicator is a relatively constant quantity and is a kind of criterion for the individuality of the runner. Usually the inexperienced maintain a low cadence (160-170 steps). Cadence is closely related to the time of contact of the foot with the ground. Reduction of the interaction - foot support leads to a decrease in the action of forces during depreciation. From a practical point of view, this means stepping short, fast and agile while running. This is related to the individual structure of the feet, as well as the muscles of the feet, calves, thighs, pelvis. However, short contact with the support requires more muscle strength, so the sprinters have powerful muscles of the pelvis, thighs, plantar flexors, elastic Achilles tendon, active plantar fascia.

When running has a longer duration, the onset of fatigue should be delayed, which, in addition to improving the functional capabilities of the body, is associated with adequate and economical technique, selection of appropriate shoes. In this sense, keeping the energy during running depends on the effective work of muscles, joints and tendons, combined with rational technique, and appropriate running shoes.

Hypothetically, shoes can change the way of run. There is no one shoe suitable for every foot and the choice is a matter of preferences, individual characteristics, sports experience, beliefs and knowledge of the runner. According to some studies, modern running shoes can support cushioning and stabilization, through the included materials and the construction of the sole, and the upper part (mesh).

Will the specialized running shoes affect the way of stepping, will they help to correct deficiencies in the technique, will they soften the stepping (the impact of the forces in contact of the foot with the ground)?

Numerous scientific studies claim that about 80% of amateur runners step on the back of the foot (heel striking or raearfoot striking) when make the first contact with the ground.

The cartilages are adapted to withstand high compression forces and while the level of stress on the bone structures is in the normal range, no permanent damage is observed. However, repeated inadequate biomechanical loading over time can lead to cartilage degeneration or other structural and functional deficits. In order to preserve the function of the musculoskeletal system in the long run, it is necessary to minimize excessive stresses, to reduce the force and the possible wrong direction of the response of the forces in the "impact" of the foot with the support. Humans have evolved to pass long distances, but while million years ago they did it barefoot, with sandals or light shoes, since the 1970s we have witnessed the evolution of specialized running shoes.

A large percentage of mass running shoes have a raised heel (large drop), as a large percentage of amateur runners initial contact is with the back of the foot (RFS - rearfoot strike).

RFS (rearfoot strike) - The initial contact when stepping on the heel. Most often there is overstriding - stepping in front of the projection of center of gravity on the ground - red arrow **(Figure 6 and Figure 7).**

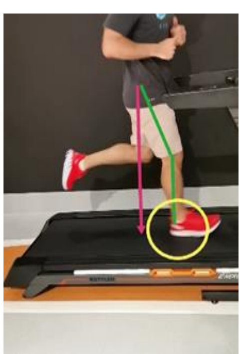

Figure 6.

Figure 7.

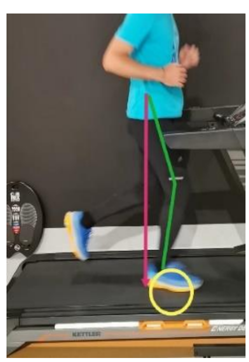

Figure 8.

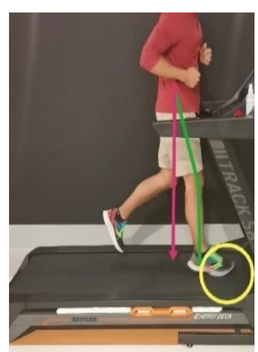

Figure 9.

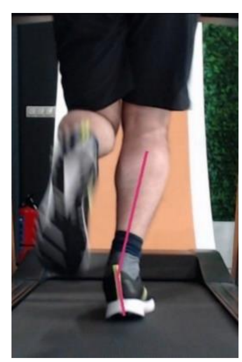

Figure 10.

MFS (midfoot strike) – The first ground contact is with part of the metatarsal bones covered by the ball, sometimes in combination with a small part of the heel **(Figure 8).** If the arch is "fallen", the foot tends to perform overpronation and the contact will have more area of the foot.

FFS (forefoot strike) - Contact with the fingers and part of (the heads of) the metatarsal bones. In many cases, when running at high speed, the foot interacts ground on the front (FFS), but when there is overstriding, such the stepping is inefficient from a biomechanical point of view **(Figure 9).**

RFS and FFS (when there is well expressed step forefoot, but not when running at high speed and stepping close to the body mass center projection on the ground) is most often associated with the so-called *overstriding* - overextension of the lower leg relative to the thigh at the time of contact - too large angle (marked in green in **Figures 6-9**).

When the foot contact with the ground, there is universal mechanism to perform pronation. The human ankle is a complex mechanical structure containing 28 bones, 33 joints (20 of which are actively articulated) and more than many muscles, tendons and fascia. Running largely depends on how this whole "complex" reacts in time of contact.

What is pronation, supination, overpronation?
Pronation - when the foot touches the ground, the arch of the foot begins to become flatter (elastic) to withstand the impact load. In addition, other joints in the kinetic chain are activated - ankle, knee, to help absorb the impact. Pronation is a natural reaction of the legs, but the problem is when the pronation is too pronounced (overpronation). Overpronation is usually due to weak muscles of the arch, lower leg, can be caused by overweight.

Supination - there are reverse stages in terms of pronation - return of the lower leg to the normal plane of work - adduction, ie. the foot ceases to interact mainly with the inner surface and the support shifts to the metatarsal bones (ie forward).

METHODS

For the purpose of the study, two studies were conducted with amateur runners.

The survey was conducted before a video analysis of running technique, when choosing sports shoes. One study is through a questionnaire related to sports experience. Responses were received from 304 athletes, 113 women and 191 men. Video analysis was performed with specialized software "Templo Motion Analysis Software", for 2D capture of pronation, as well as a video recording application - "Coach's eye".

A large percentage of participants are over 30 years old - approximately 90%. More than half of the respondents (51.9%) run over 100 km per month, 2/3 of the athletes have 3 or more running activities per week.

The investigation contains a question assessing the subjective perception of runners of the initial contact of the foot with the ground at the first contact while running. The following answers were received: 63.5% or 193 runners think they are MFS (midfoot strikers), 17.8 % or 54 runners - FFS (forefoot strikers), only 18.8% or 57 runners rate their running as RFS (rearfoot strike).

44.4% or 135 runners indicate that they have had running-related injuries in the last year. To the question "If you have running injuries, what do you consider to be the leading cause?" (you can specify more than one answer), the prevailing opinion is that this is primarily due to the lack and poor recovery (129 responses), the next most frequently cited reason is "disadvantages of running technique" – 102 runners, 86 responses have for " inadequate trainings to the possibilities - speed, intensity, rest…" and 52 runners answers for "wrong shoes".

The questionnaire contains the question "What running shoes do you prefer for your daily activities" and the following answers were received: neutral with a small drop - 42.1% or 128 runners, neutral with a large drop - 18.1% or 55 runners, minimalist - 7,7% or 24runners, with control of pronation- 4.3% or 13runners, with all kinds of running shoes 27.6% or 84 runners.

When determining pronation and running stride according to the first contact of the foot, the total range of motion in the ankle joint should be measured. Detailed measurement data are not the subject of this report.

76% of the surveyed persons are RFS, 11.5% - FFS and 12.5% - MFS. In summary, 36.7% of the surveyed persons (111 runners) have overpronation.

DISCUSSION

A large percentage of mass modern running shoes have a raised heel (large drop), as most amateur runners make the first contact with the heel (back of the foot). There are studies that show that placed at an angle in the shoe, the heel reduces about 7 times the force of the impact (1). At the same time, the plantar fascia, the Achilles tendon and the plantar flexors have a particularly important function when running. The high heel in the shoe reduces stress, but makes the tendons lazy and the muscles ineffective due to not using the full range of motion and elastic force. The human Achilles tendon and plantar fascia store a large percentage of the kinetic and potential energy. The function of the tendons to act as a spring reduces the work that the muscles have to do (2).

The strong longitudinal arch of the foot improves the spring mechanics of running by storing and releasing elastic energy. If the runner hits the ground an average of 500-600 times per kilometer, despite technological advances in the design of running shoes, his feet are under stress (3).

The raised heel also encourages the runner to RFS. There are studies comparing the economy of barefoot and shod runners (1, 4, 5).

The improved economy of running with minimalist shoes or running barefoot is probably due to changes in the biomechanics of the lower limbs and the exclusion of the heel at initial contact. Despite the hypothesis that running with neutral or minimalist shoes is biomechanically appropriate, there is no convincing evidence that this protects of injuries (6-8). The transition from shoes with a large drop to those with a small or minimalist one is associated with changes in biomechanics and need of period of adaptation. The correct running shoes should be recommended after analysis of the technique, measuring the angles of the ankle and knee, which are informative of the stability of the ankle and the adequacy of the muscles.

RESULTS AND CONCLUSIONS

Contacting on the front or back of the foot involves storing and generating forces of different volumes. When step is on the front, there is a shorter moment of contact, but the Achilles tendon and the arches of the foot reserve more elastic energy. When stepping mainly on the back, it is essential to work purposefully to correct the technique, as well as a good shoe to reduce vertical compression.

How bed running technique affects the injuries of runners is still controversial in the scientific literature.

A fallen arch, a large body weight or inadequate muscles can make the ankle unstable, limiting the dorsiflexion of the foot.

Running shoes with a raised heel can reduce the "impact", facilitate the work of the Achilles tendon and plantar fascia, but at the same time make them less efficient. The feeling of contact with the support is also reduced.

Forefoot striking runners are recommended to choose shoes with a small or zero drop, as their technique is economical and gentle on bones, joints and muscles.

Rearfoot runners often have a low arch of the foot and / or overpronation. When choosing shoes, they can bet on those with a raised heel and softening (the most common and easy choice, because these are the most common running shoes), but they can also move to a gradual reduction in the height of the heel (drop).

It is necessary to look for and eliminate the causes of inadequate stepping technique (contact). Most often these are weak muscles of the pelvis and thighs, as well as uncomfortable shoes. Insufficiently effective work of the hip muscles "causes" the leg to remain unfolded in the knee joint and to land on the heel, instead of "looking" for support under the projection of center of body mass on the ground.

Running shoes have suffered significant transformation in recent years. Nowadays, some of them are technical and engineering masterpieces - from varying degrees of softening, support, to minimalist. In track and field athletics, serious restrictive measures are already being taken with regard to the use of provenly advantageous running shoes.

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