EXTREME LOADINGS OF LOCOMOTOR SYSTEM IN THE RUNNING

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Abstract

Walking and running are natural way of human motion. Today running is effective aerobic exercise to maintain vital human functions, mostly cardiovascular and breathing functions. Modern human’s lack of movement results in numerous health problems and generally reduce the quality of his life. The impact of regular physical exercise on the body is proven beyond any doubt; but we can also see the growing negative effects of physical exercise, which are typically a result of the unadjusted and too demanding exercise programs. Walking and running are human’s the most effective and health activities, but running can have large load on joints, bones, tendons, ligaments and muscular system. The negative effects of physical exercise are manifested in the form of overload which often leads to injuries. Running injuries and their development takes place at the beginning relatively unnoticed, obvious symptoms with pronounce consequences for the runner occur relatively late.

Key Words: biomechanics, running, technique, extreme loadings

Introduction

Running as a physical activity is genetically determined. The basic running structural unit is double step. Within the cycle running cycle alternates support and flight phase. Support phase begins at the moment when the foot strikes the surface and ends when the foot leaves the ground. Moment of leaving foot from support delimits both phases. When foot touches the ground with heel is the first support, and when the take off is done with finger is called last support. Between a supporting phase is the flight phase. The distance between the two phases defines the stride length. In addition to the frequency step is the most important step length parameter of running. Step length and step frequency are in inverse proportion and are individually conditioned. They depend on runner’s characteristics and capabilities. At higher frequency is smaller stride length and vice versa. Parameter stride length depends on the morphological characteristics of runners, especially the length of the lower extremities, from the ground reaction force, contact time and take off angle. The average stride length of the recreational runner is 100 to 150 cm, a top runner 150 to 220 cm. Frequency step, which is manifested by the number of steps per unit time depends on the intra and inter muscular coordination and operation of the central nervous system that regulates the movement of agonist and antagonistic muscle groups (Mero, Komi, Gregory, 1992; Novacheck, 1997; Komi, Nicol, 2000). The relationship between length and step frequency steps is largely automated and fixed in locomotor central nervous system (Enoka, 2003). Human running technique is very individual and independent with stage of training.

The mechanics of running

Maximum load on human body is created the first and last support phase (Figure 1), vertical reaction force is between 2000 to 2500N, during sprint even up to 3500 N (Cavagna, Komarek, Mazzoleni, 1971; Mero, Komi, Gregor, 1992, Škof, Strojnik, 2007). Gait reaction forces are three times smaller (Novacheck, 1997). The main difference between walking and running is flight phase, which do not exist in walking. During walking the human body is always in contact with one foot on the ground. The foot is one of the most loaded segments of the locomotor system during running. The foot has 26 bones of different shapes and features, 19 muscles and more than 100 ligaments. In the course of 10 km, the foot strikes the ground about 5,000 times, the average stride length of 2 m. With average runner’s mass (70 kg) and regarding to the number of steps, we can conclude that the total absorption reaction of surface forces for each foot is 3430 kN. This force is then transmitted to the knee and hip joint. Undoubtedly, these burdens are on the borderline of human adoptive capacities. Runner’s reaction force depends on the running technique, how foot is placed on ground in the moment of the first contact (Figure 2). We differentiate three types (Novacheck, 1997, Hasegawa et al., 2007, Lieberman et al., 2009, Daoud et al., 2012): with heel (RFS rear-heel foot strike), mid foot (MFS mid-foot strike) and fingers (FFS fore foot strike). Hasegawa et al., (2007) found that 75% of marathon runners use RFS (Figure 3), 24% MFS and only 4% FFS. Which of the run models are the most effective researches up to date did not give a single answer (Lieberman et al., 2009). Superior results were achieved during the marathon runners with all three types. Placing foot is closely related to the function of modern running shoes, which are constructed according to the latest knowledge of biomechanics and functional anatomy of the foot. The basic task of running shoes is the mechanical protection of the feet, partial neutralization of reaction forces and injury prevention. Rear – foot strike means in terms of burden "shock" to the ankle, knee and hip joint.
Reaction force in this case is oriented in the opposite direction of motion of body center of gravity. In part, this force is absorbed by running shoes sole, which must be appropriately thick and elastic. In terms of biomechanics of running a more efficient technique is to place foot in the first contact to the front outside part (Figure 4). In this mode, the foot like a spring partially neutralizes the reaction force. Contact with the front foot, however, requires proper coordination and activation of agonist and antagonist muscles (m. tibialis and m. gastrocnemius medialis and lateralis). M. Gastrocnemius muscle provides necessary preactivation needed for proper foot stiffness (Komi, Nicol, 2000). When are muscles activated 50 milliseconds before touchdown, less energy is lost than a passive setting foot on the heel. Efficiency and economy of running is not only dependent on the production of chemical energy, but also on the amount of mechanical -elastic energy that is generated in the eccentric phase (the first phase of foot contact with the ground). Economic running technique is combination of efficiency of chemical and elastic energy. According to researches (Mero, Komi, Gregor, 1992; Komi, Nicol, 2002; Enoka 2003) the proportion of chemical energy and, elastic energy is 75:25 %. During evolution walk and run have helped man to survive in raw nature. The man ran and walked barefoot for about four million years. Only in the modern era has started using shoes. Running shoes are little more than sixty years old, which is in context of the history of time. Running shoes have changed the technique of running. Barefooted man ran through the front foot and by exploiting the elasticity of muscles, tendons and ligaments (Lieberman et al., 2009). Today's modern runner sets foot on the heel and exploits the elasticity of the lower part of running shoes. The basic functions of running shoes are absorption of impact forces at the feet with ground, stabilization of ankle and foot and provide a good grip (friction). It is important that the front part of the sole is rigid enough, which prevents excessive foot supination and plantar fascitis development.

**Extreme loadings in the running**

Despite the fact that running is one of the most effective and healthy human motor activity, it can also have high impact on locomotor system, especially for joints, tendons, ligaments and muscle system of lower extremities (Hartmann, Mester, 2000; Halson, Jeukendrup, 2004; Muijka, 2009). The negative effects of sports training show as "collateral damage" in the form of various injuries. The first type of injury is acute one that occurs immediately with the known mechanism of injury and place. The second type chronic injuries are primarily due to overload of the motor system, in particular segment of the lower extremities. Chronic injury is taking place in the beginning usually completely unnoticed, obvious symptoms with noted consequences for the runner occurs relatively late. First signs of chronic injuries are attributed to bad warm up, excessive load, unfavorable external influences; runner continues with sports activity, problems are not heavy and there is no sign of injury (Urhausen, Kindermann, 2002). To the difficulties which are associated with overload syndrome runners react late or too late. On muscle, tendon, ligament, cartilage, bone, nerve and blood vessel is continuous load which can cause micro-trauma and micro-stress. The most common external causes of overload syndrome are: improper motor preparation, running technique, rapid changes in the intensity of training, inadequate configuration of the terrain, frequent one-sided load, inadequate rest and recovery, inadequate climatic conditions and inadequate equipment. The internal causes of overload syndrome may be genetic or acquired. In general the morphologic characteristics of the body manifest different level of asymmetry. The reason may be also the biochemical change in the organism. Important role play age and gender as well. It is important to identify and analyze causes and act accordingly. The entire process of eliminating both external and internal causes of overloading the motor system requires a team approach with work-oriented specialists. These are coaches, physiotherapists, masseurs, doctors, orthopedic surgeons. Kinesiology profession and science can play a key role in early identification and prevention of the occurrence of overload syndrome. This applies to all those athletes, who use running in their sport (weather monostructur or polystructur). Achilles tendon is undoubtedly the most critical part in runners (Figure 5). Painful Achilles tendon may remove athlete from training for several months. Achilles tendon is a thick fibrous bundle which connects muscle gastrocnemius lateralis and medialis, and soleus with heel. Tendinopathy is one of the most common injuries in runners. Tendinopathy means painful and swollen Achilles tendon accompanied by reduced functionality, which can cause tendinitis (inflammation) or paratenonitis (inflammation of the fascia). Tendinopathy occurs approximately 2–6 cm above tendon insertion. Tendon pain occurs due to the high forces and long-lasting load. With tendinopathy microscopic tears occur in tendon and fascia. On tendon scar tissue begins to accumulate. The basic function of the Achilles tendon is the transmission of force generated by muscle to bone, besides it also works as shock-absorber against external forces and prevents muscle's damage. This feature requires appropriate elasticity, flexibility and tensile strength. Achilles tendon load in sprint can reaches 9 kN and 2.6 kN with slow running (Urhausen, Kindermann, 2002; Lieberman et al., 2009). At peak forces tendon can partly or totally breaks. Tendon partly can break up the first degree (when are interrupted 5% to 50% fibers) and the second degree (when are interrupted 50% to 80% fibers). Point of complete rupture occurs when tendon extends 10% to 20% of initial length.
Figure 1: Vertical ground reaction force in the touch-down (Impact Peak) and take-off phases (Active Peak) (http://www.google.si/imgres?q=site+foot+biomechanics+running)

Figure 2: The differences in the development of the ground reaction force – the rear foot and fore foot techniques (http://www.google.si/search?num=10&hl=sl&site=imghp&tbm)

Figure 3: Over 70 percent of marathon runners use the heel-strike technique.
Conclusion

In the recreational sport running and walking are the most common aerobic sports activities. Running is an integral part of many competitive sports. Walking and running are natural forms of exercise, one of the most appropriate ways of maintaining good physical fitness and wellness. There is ample evidence that walking and running reduces stress, lowers blood pressure and total blood cholesterol levels. These are all important reasons for the popularity of walking and running as a regular form of recreation, which in recent years continually growing. Nevertheless running have indisputably proven positive impact on human, in recreational and competitive sport we have noticed growing negative effects of wrong sport training, which usually results from unadjusted and to demanding exercise programs.

Many injuries are also associated with different running content. Running can have also high load, especially for joints, ligaments, tendons and muscles of the lower extremities.

References

EKSTREMNO OPTEREĆENJE LOKOMOTORNOG SISTEMA KOD TRČANJA

Sažetak
Hodanje i trčanje su prirodni način ljudskog kretanja. Danas je trčanje učinkovita aerobna vježba za održavanje vitalnih funkcija, naročito kardivaskularnih i dišnih funkcija. Suvremenom čovjeku nedostatak kretanja rezultira brojnim zdravstvenim problemima i općenito smanjuje kvalitetu života. Pozitivan utjecaj tjelesne vježbe je dokazan izvan svake sumnje, ali i također možemo vidjeti rastuće negativne učinke tjelesne vježbe, koji su obično posljedica nepriлагođenih i prezahtjevnih programa vježbanja. Hodanje i trčanje su tipično ljudske i najučinkovitije zdravstvene djelatnosti, ali trčanje može prouzročiti veliki teret na zglobovima, kostima, tetivama, ligamentima i mišićnom sustavu. Negativni učinci tjelesne vježbe se očituju u obliku preopterećenja što često dovodi do povreda. Ozljede u trčanju i njihov razvoj odvija se na početku relativno nezapaženo, a očiti simptomi s vidljivim posljedicama javljaju se relativno kasno.

Ključne riječi: biomehanika, trčanje, tehnika, ekstremna opterećenja

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