Influence of high heels on biomechanical parameters of the human gait

Vytautas Grigas[1], Kristina Kazlauskienė[2], Danguole Satkunskienė[3], Aurelija Zdanytė[4]

[1, 2, 3] Kaunas University of Technology, A. Mickeviciaus 37, 44244 Kaunas, Lithuania
E-mail: [1]*vytautas.grigas@ktu.lt,* [2]*kristina.kazlauskiene@ktu.lt,* [3]*danguole.satkunskiene@ktu.lt,* [4]*aurelija.zdanyte@stud.ktu.lt*

Abstract. The influence of the heel size on the kinematical parameters of human gait and the muscles activity is the topic of the research covered by this paper. The knee joint angle and electrical activity of the four muscles of human leg measured when walking on the treadmill with different speed on shoes hawing different height heel are analyzed.

Keywords: gait analysis, heel size, knee joint angle, muscles electrical activity.

Introduction

The feet is in continuous interaction with a shoe sole during walking, and the influence of the shoe heel, heightening the foot heel above the metatarsal heads, onto the gait biomechanical parameters is unquestioned [1]. When walking on a high heel shoes the whole posture is affected: the larger spine deflection appears, the center of mass displaces forward, so the maintenance of equilibrium is more difficult, the foot is deformed and foot pain arises [2]. A lot of the researches are carried out in this field during which a lot of high heel gait biomechanical parameters are investigated, but in most cases the muscles activity or motion kinematics is examined separately and in most cases the foot and ankle are in the focus [1–4].

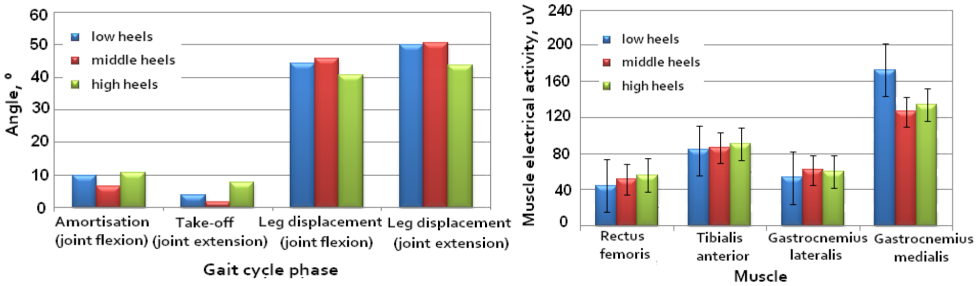
The knee joint angle and electrical activity of the four muscles of human leg when walking on the treadmill with different speed on shoes hawing different height heel are the aim of the research described in this paper.

Investigation of the influence of high heels on human gait

To evaluate the influence of the heel height on the gait biomechanical parameters the experimental research of the human gait when walking on a treadmill with two different speeds (3,2 km/h and 4,2 km/h) wearing shoes with low (20 mm), middle (50 mm) and high (90 mm) heels, was carried out (one 22 years old female, height 165 cm, weight 48 kg). The variation of the knee joint angle was measured together with a four muscles of human leg electrical activity by means of electromyograph Myotrace-400 (Noraxon, USA) by using appropriate sensors (goniometer and EMG sensors). The measurement data were transmitted to a PC via Bluetooth and processed by MR-XP 1.07 MT404_Clinical Application Protocol software (the EMG signal has been divided into periods corresponding separate steps and filtered). Reliability of results has been checked by using SPSS Statistics software (statistical significance level $p<0,05$).

To evaluate the effect of a height of a shoe heel on the variation of knee joint angle the one cycle of total 20 measured for every regime of gait (heel height, speed of walking etc.) is extracted and the phases of motion are segregated. It can be seen that the largest amplitude is obtained for knee flection and extension phases during leg displacement. The dependencies of the knee joint angle amplitude in for different phases of the gait cycle on the heel height when walking on the treadmill with 3,2 km/h speed is shown on Fig. 1, a.

In the first half of cycle (amortization and take-off phases) the high heels (90 mm) leads to increment of the knee joint angle amplitude, and in the second half (knee flection and extension phases during leg displacement phase) – to the reduction. The 50 mm heel height seems to be optimal with regard to the knee joint angle, because in this case the gait is smoothest. The change of knee joint angle amplitudes when walking with increased (4,2 km/h) speed (the reduction of duration of the gait cycle leads to decrement of joint angle amplitude in flection and extension phases) seems to be inconsiderable.



a b

Fig. 1. Dependencies of the gait biomechanical parameters on shoe heel height when walking with the 3,2 km/h speed: a – knee joint angle amplitude; b – muscles electric activity

To evaluate the effect of heel height on a leg muscles the electrical activity of Rectus femoris, Tibialis anterior, Gastrocnemius lateralis and Gastrocnemius medialis was measured by using Myotrace-400 with non-invasive, surface EMG sensors (having area 30–100 mm^2), sticked on the skin at the abdomen of the corresponding muscle. The gait regimes (heel heights, speed of walking) were the same as for knee joint angle measurements.

It was obtained, that when walking with a 3,2 km/h speed the electrical activity of Rectus femoris and Tibialis anterior grows with increment of the heel height (from the 42 to 56 μV and from the 82 to 92 μV correspondingly, see Fig. 1, b). That means that with a higher heel the more neurons are active in these muscles, because the larger force should be generated: for Rectus femoris – when straightening shin and flexing thigh, and for Tibialis anterior – when straightening feet. Such activation of neurons causes more intensive tiredness of muscles in comparison with walking on low or middle height heels shoes. The specific activity of Gastrocnemius medialis is also clearly seen: it is almost twice larger than for other muscles: the 172 μV for low heel (20 mm) shoes, 134 μV – for high heel (90 mm) and the lowest – 126 μV – for middle height (50 mm) heels shoes. The increment of walking speed leads to even larger difference in various muscles electrical activity.

Conclusion

The experimental research of the influence of heel height on the biomechanics of gait has confirmed the general negative effect of the high heels, however the influence of the heel height on the knee joint amplitude differs depending on the phase of joint movement (the 50 mm heel height is optimal during initial phases). The electrical activity of muscles unambiguously rises with increasing heel height, and increment of the speed of walking leads to higher activity of muscles and hereby – their tiredness.

References

[1] **Hansen A., Childress D.** Effects of shoe heel height on biologic roll-over characteristics during walking. J Rehabil Res Dev 2004; 41: 547–554.

[2] **Amit Gefen, M. Megido-Ravid, Y. Itzchak, M. Arcan.** Analysis of muscular fatigue and foot stability during highheeled gait, Gait and Posture, ISSN : 2230-9543 IJECT Vol. 3, 2002

[3] **Ásdís Árnadóttir, Inga Hrund Kjartansdóttir, Sigríður Katrín Magnúsdóttir.** Lower limb muscle activity. Electromyographic measurements of walking in high-heeled shoes compared to walking in trainers, 2011, http://skemman.is/handle/1946/9123

[4] **Sung-woo Park and Kunwoo Lee.** Simulation of biomechanical influence of high heels heels on musculoskeletal system of foot and ankle, in Proceedings of ISB2009, Cape Town, South Africa, Jul., 2009.