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# Effect of Shoes' Heel Height on the Energy Cost during Jogging

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**Abstract:** The purpose of this study is to examine the changes of energy cost during a high-heeled continuous jogging. Thirteen healthy female volunteers jointed in this study with heel height of the shoes varied from 1, 4.5 and 7 cm, respectively. Each subjects jogged on the treadmill with K4b2 portable gas analysis system. The results of this study showed that ventilnation, relative oxygen consumption and energy expenditure increased with the increase of heel height and these values shows significantly larger when the heel height reached to 7 cm. Present study suggest that wearing high heel shoes jogging could directly increase energy consumption, causing neuromuscular fatigue.

**Keywords:** Energy cost, high-heeled shoes, jogging

## INTRODUCTION

In today's society, fashionable footwear designs are now becoming increasingly complex and incorporating high heels. Footwear purchase is dictated by fashion and not a sense of comfort; for many people fashion surpasses the need of comfort (Gu *et al*., 2010a). But high heeled shoes have come under much speculation as one of the causative factors for forefoot pain and discomfort. Dawson *et al*. (2002) reported that a prevalence proportion of foot problems in women were associated with wearing high-heeled shoes. A study in Netherlands found that 60% of women suffered foot problems directly caused by shoes (Postema *et al*., 1998). Studies on high heel shoes effect have become a hot issue in biomechanical field (Postema *et al*., 1998; Esenyel *et al*., 2003; Gu *et al*., 2010b). Biomechanical studies showed that walking in high-heeled shoes may alter lower-extremity joint function (Esenyel *et al*., 2003), raise the peak pressure in the fore foot (Mandato and Nester, 1999) and alter the load distribution on the media foot region (Eisengardt *et al*., 1996). However, few investigations available to discuss the detailed features of energy cost with high-heeled shoes.

People are often being in a hurry state to adapt to quickening of life pace. Therefore, jogging with high-heeled shoes becomes an unavoidable situation. Energy coast information about jogging under high-heeled shoes condition would be important to the modern life women. It has been shown that heel height change could adjust lower limb musculature differently during locomotion (Gu *et al*., 2010b). Conversely, the variety in lower limb muscular activity (Bourgit *et al*., 2008) could change the energetic requirements. The purpose of this study is to examine the changes of energy cost along a continuum of heel heights to understand the physiology level alteration after heel heights variety.

## MATERIALS AND METHODS

Fifteen young healthy females jointed in this study voluntarily without any injury likely to influence the jogging gait. They had no cardiovascular or neuromuscular disorders, either. The average age of the subjects was 22.75±0.83 years, average height was 165±1.22 cm and average weight was 54.75±3.11 kg. Foot size of subjects is 37 EUR and fit for the experimental shoes. All subjects habitually wore flat-heeled shoes and possess treadmill jogging experience.

Three shoes (Fig. 1) were used in the study. One was a common sneaker weighing 358 g with whole outsole height 1.2 cm (flat heels). One was a stiletto-heeled shoe weighing 366 g with heel height 4.5 cm (low heels). And the other one was a stiletto-heeled shoe weighing 368 g with heel height 7 cm (high heels).

The difference of heel height made up the three experimental conditions. The order of presentation of the conditions was randomized across subjects. Energy cost data were collected by K4b$^2$ portable gas analysis system (COSMED, Rome, Italy), recognized as an accurate and valid device for measuring oxygen uptake (McLaughlin *et al*., 2001).

Firstly, subjects were informed whole experiment process. Before the test, subjects were given 10 minutes warm up stage, putting on the K4b$^2$ portable gas analysis system, to adapt the feeling with the face mask. The treadmill speed was gradually increased to 6.5 km/h; five min in each of the test shoes jogging

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Fig. 1: Subjects jogging on the treadmill with gas analysis system; S illustrates shoes of three different heel heights used in the study (From left to right: A flat, a low and a high heel)

at 6.5 km/h were collected. The analysis software of K4b$^2$ portable gas analysis system could record many indexes of cardio-pulmonary function and energy cost of each breathing. Minute Ventilnation (VE), relative Oxygen consumption ($VO_2$) and Energy Expenditure (EE) in 10 sec' steady state were chosen in this study.

Statistical analyses were carried out using SPSS19.0 statistical analysis software and data were presented as means and SD. Analysis of variance (ANOVA) was employed to study the effects of heel height and Turkey test was used for post hoc comparison with the level of statistical significance was set at the 5% level.

## RESULTS AND DISCUSSION

Table 1 showed the value of VE, $VO_2$ and EE with each testing shoes during treadmill jogging. It clearly described that these indexes were highly elevated when the heel height increased. Compared with each other, there was a significant difference between flat heels and high heels ($p<0.05$). In contrast with flat heels condition, all indexes in treadmill jogging with low heels increased around 25%. While the raising percentage of VE, $VO_2$ and EE between high heels and low heels was not so obvious, just 12.98, 8.79 and 10.12%, respectively.

The main finding of the present study was that relative oxygen consumption and energy expenditure increased with the increase of heel height, particularly in 7 cm high-heeled shoes which shown a significant difference compared to flat heel. This increased energy cost of jogging may result from the biomechanical changes imposed by the heel height. When jogging in the most comfortable situation, human body's physical function was present the most economy state. But high-heeled shoes had restricted knee and ankle range of motion, increasing knee flexion (Anna *et al*., 2012). Furthermore, the foot wearing high-heeled shoes would naturally place in plantar-flexed position, which could lead to stride length shorten (Wu and Li, 2003). In order to maintain the fast speed and specific posture, the stride frequency must increase during jogging, which would increase the energy cost in turn.

Table 1: Index of VE, $VO_2$ and EE in flat heels, low heels and high heels condition

| | VE l/min | $VO_2$ ml/min/Kg | EE Kcal/min |
|---|---|---|---|
| Flat heels | 33.57±8.16 | 24.63±6.84 | 6.51±1.81 |
| Low heels | 41.42±8.25 | 29.71±5.22 | 7.83±1.49 |
| A Increased % | 25.40±11.02 | 25.69±22.00 | 24.72±21.15 |
| High heels | 46.54±8.18***** | 32.02±4.12***** | 8.54±1.19***** |
| B Increased % | 12.98±4.53 | 8.79±8.01 | 10.12±7.11 |

* $p<0.05$ significantly difference comparing to flat heels. A Increase % = (data in low heels condition *vs* data in flat heels condition); B Addition % = (data in high heels condition *vs* data in low heels condition)

Wang *et al*. (2008) found that the footwear's weight was highly related to the energy cost. The weight of experimental shoes in this study was controlled at the same level to focus on the heel height effect only. While increased impulse in the forefoot with high-heeled shoes may contribute to elevate energy cost (Eisengardt *et al*., 1996). In this case, muscular functional activities of lower extremity weakened (Wu and Li, 2003) and muscular endurance reduced (Gu *et al*., 2010a). During high-heeled locomotion, which more likely caused fatigue. There was another interesting result was that the increasing percentage of all indexes between flat heel and low heel was higher than this value between low heel and high heel. While low heel' height was 3 cm higher than flat heel, high heel' height was just 2.5 cm higher than low heel. This means the important index to energy cost was the foot posture changing from normal to plantar-flexed. After the plantar-flexed degree increase, the energy cost variety not as notable as former condition. Although energy cost during jogging with high-heeled shoes is higher than the flat heel condition, it doesn't encourage female to do exercises with high-heeled shoes for losing weight effectively. Because the foot stability would be impaired (Gu *et al*., 2010a) attributing to get injuries such as ankle sprain (Hsue and Su, 2009) easier during high-heeled locomotion.

## REFERENCES

Anna, M., O. Łukasz and M. Piotr, 2012. The influence of heel height on lower extremity kinematics and leg muscle activity during gait in young and middle-aged women. Gait Posture, 35: 677-680.

Bourgit, D., G.Y. Millet and J. Fuchslocher, 2008. Influence of shoes increasing dorsiflexion and decreasing metatarsus flexion on lowerlimb muscular activity during fitness exercises, walking andrunning. J. Strength Cond. Res., 22: 966-973.

Dawson, J., M. Thorogood, S.A. Marks, E. Juszczak, C. Dodd, G. Lavis and R. Fitzpatrick, 2002. Theprevalence of foot problems in older women: A cause for concern. J. Public Health Med., 24(2): 77-84.

Eisengardt, J.R., D. Cook, I. Pregler and H.C. Foehl, 1996. Changes in temporal gait characteristics and pressure distribution for bare feet versus heel various heel heights. Gait Posture, 2(4): 280-286.

Esenyel, M., K., Walsh, J.G. Walden and A. Gitter, 2003. Kinetics of high-heeled gait. J. Am. Podiatr. Med. Assoc., 93(1): 27-32.

Gu, Y., X. Ren, J. Li and M. Rong, 2010a. Plantar pressure distribution during high-heeled Latin dancing. Int. J. Exp. Comput. Biomechan., 1(3): 296-305.

Gu, Y.D., J.S. Li, G.Q. Ruan, Y.C. Wang, M.J. Lake and X.J. Ren, 2010b. Lower limb muscles SEMG activity during high-heeled Latin dancing. Proceeding of IFMBE, 6th World Congress of Biomechanics (WCB 2010), Singapore, August 1-6, 31: 198-200.

Hsue, B.J. and F.C. Su, 2009. Kinematics and kinetics of the lower extremities of young and elder women ding stairs ascent while wearing low and high-heeled shoes. J. Electromyogr. Kines., 19: 1071-1078.

Mandato, M.G. and E. Nester, 1999. The effects of increasing heel height on forefoot peak pressure. J. Am. Podiatr. Med. Assoc., 89(2): 75-80.

McLaughlin, J.E., G.A. King, E.T. Howley, D.R. Bassett and B.E. Ainsworth, 2001. Validation of the COSMED K4b2 portable metabolic system. Int. J. Sport. Med., 22: 280-284.

Postema, K., P.E.T. Burm, M.E. Zande and J. Limbeek, 1998. Primary metatarsalgia: The influence of a custom moulded insole and a rocker bar on plantar pressure. Prosthet. Orthot. Int., 22: 35-44.

Wang, Y.X., J.S. Li and J.Y. Wang, 2008. Biomechanical research of sport shoes energy regression design. Zhejiang Sport Sci., 30(5): 106-109.

Wu, J. and J.S. Li, 2003. A research on kinematics on young girls' walking with high-heel shoes. Shanghai Sport Sci. Res., 24(3): 9-11.