대한물리치료과학회지
Journal of Korean Physical Therapy Science 2017; 24(3): 30-38
ISSN 1226－3672, http://dx.doi.org/10.26862/jkpts.2017.12.24.3.29

The Analysis of Variation on the Area of Shoes with EMG and Thermography of Lower Extremity

Cu-Rie Lee[1], Ph.D., Ed. · Keun-Jo Kim[1], Ph.D., P.H. · Jin Lee[2], Ph.D., P.T.

[1]*Dept. of Physical Therapy, Gimcheon University*
[2]*Dept. of Physical Therapy, Hyeon-Myeong Medical Center*

Abstract

Purpose: The purpose of this study was to find out changes in muscle activity and body heat of tibialis anterior and gastrocnemius muscles according to the area touching the ground through the areas of different heel heights using electromyography and infrared thermography. **Method:** This study was carried out for 15 healthy women. After walking for 30 minutes, the body temperature was measured in a standing state in front of the measuring instrument, and the distance between the treadmill and the thermography was about 50M, which may cause an error in measurement. **Result:** The results of the comparison of changes in muscle activity and body heat showed significant differences all in tibialis anterior, medial gastrocnemius muscle an lateral gastrocnemius muscle. The changes in body heat of tibialis anterior and medial gastrocnemius muscles according to the shape of the heel were lower as the area of the heel touching the ground was wider. **Conclusion:** This study was conducted to find out changes in muscle activity and body heat of tibialis anterior and gastrocnemius muscle depending on the area touching the ground through different heel areas.

Key words : Infrared thermography, Electromyography

Ⅰ. Introduction

As the social activities of women are activated, the time for walking and activities in various types of shoes is increasing. Stability and wearing sensation should be emphasized in shoes but there is not enough information on shoes and many women have a strong tendency to wear high-heeled shoes according to the beauty or fashion (Eun-Hye Go et al, 2008). Considering these cosmetic and fashion aspects, the most important thing for women to choose shoes is the design of their shoes (Sun-Hee Choi and Jong-Sook Chun, 2007).

Previous studies analyzed the back muscles, ankle muscles, femur quadriceps muscle affected by the height of the shoe rather than the shape of the heel of a shoe and especially studied and analyzed the problems due to

교신저자: 이진
주소: 서울특별시 중구 서소문로 120 현명의원 물리치료실, 전화: 02-3399-1634, E-mail: 3679@syu.ac.kr

increased waist load as the height of the shoes increases. In addition, we analyzed the studied the analysis by weight by varying the height of heels and analyzed by varying weights and the heights of the heels of the subjects.

A study on the effect of heel height on standing balance and ankle muscles presented the fact that the height of the shoes affects the balance or ankle muscles and the muscle activity of the ankle muscles increases as the height of the shoes increases through clinical experiments and presented the conclusion that the higher the height of the heel, the more instability of the ankle and the instability of the ankle degrades the movement and position sense of the joints (Deok-Won Oh et al, 2010).

The existing study depending on the form of shoe heel reported that although the shoes have the same heel height, if the area touching the ground changes depending on the shape of the heel, the impact on the human body is different due to the difference in the degree of burden on the load generated while walking. In addition, Chang-Min Lee and Eun-Hui Jeong (2002) reported that these various types of shoe heels vary the ground contact area with the ground surface, affecting the degree of muscle tension.

According to a study on foot pressure depending on sneakers, high heels, and kill heels, high heels and kill heels show the greatest pressure in the forefeet compared to sneakers and the narrower the area of footwear touches the ground, the more pressure is applied to the forefeet, middle feet, and back feet (Jae-Woong Song et al, 2009).

In a study on change of body heat after exercise of femur, the subjects were asked to exercise only one leg and then, the skin temperature of the front femur of both legs was measured and compared and it was found that the skin temperatures of the exercised legs and the non-exercised legs were both significant (Seon-Mi Kim et al, 1995).

As shown above, there are many studies based on the heel heights and studies depending on body weight, while there are only a few studies on the area touching the ground, so this study investigated changes in muscle activity and body temperature of the tibialis anterior, medial gastrocnemius muscle and lateral gastrocnemius muscle by varying the area touching the ground depending on the shape of the heel with the heel height preferred by young female adults.

According to the analysis of domestic and foreign clinical research data so far, the infrared thermographic imaging diagnostic test usually has the diagnostic accuracy by clinical symptoms of more than 93% and shows a high concordance rate and correlation of 85% or more with computed tomography, magnetic resonance imaging, electromyography, and vertebral angiography (Korean Society of Thermology). The purpose of this study was to find out changes in muscle activity and body heat of tibialis anterior and gastrocnemius muscles according to the area touching the ground through the areas of different heel heights using electromyography and infrared thermography.

Ⅱ. Method

1. Subjects and period

This study was carried out for 15 healthy women from G University. They listened to the explanation of the experiment process, had no problems, and voluntarily participated in the experiment. Also, the average shoe size of the subjects was 235 mm, and those who did not have musculoskeletal history of the lower extremity for the last 3 years were selected as subjects. The experiment was conducted for a total of 3 groups of 5 persons.

2. Measuring tool

1) EMG (electromy gram) of Noraxon

It is a test method to check the electrical activity of muscles using Telermyo 2400T G2 and is to examine the muscle's response to nerve stimulation by detecting electrical changes in the muscle.

2) Infrared thermography

IBB-6000 visualizes the heat emitted from the surface of the body to the wavelength region of infrared rays by varying the contrast or color of high and low areas in the contour shape and is to diagnose the lesion by detecting the body temperature difference of the dominant region of the nerve being stimulated by the lesion region or lesion.

3. Research Method

The height of the shoe heel used in the experiment was the same as 7cm, the most preferred by women in their 20s (Sun-Hee Choi, and Jong-Sook Chun, 2000), and the areas of the heels were 3 kinds of narrow heel (3cm 2 heel), middle heel (9cm 2 heel) and wide heel. EMG was performed on the first day and the body temperature measurement was repeated three times on the second day for a total of 6 days.

The room temperature was set to 22ºC, and subjects wore short training pants and short sleeves. They undressed before the test and adapted to the room temperature sufficiently for 20 minutes and walked on the treadmill for 30 minutes at a speed of 1.3m/s, the average walking speed of ordinary people (Yoon-Won Che et al, 2011). And then, the measurement and analysis were performed by EMG and infrared thermography.

In order to find out the effect of each experimental condition on muscle activity, the instrument was attached to tibialis anterior and gastrocnemius muscles and 4-channel analysis was carried out. After walking for 30 minutes, it was measured for 1 minute. In order to find out the effects on the change of body temperature, tibialis anterior and gastrocnemius muscles were analyzed for the body temperature of meridian points (Young-Gon Choi et al, 2008). After walking for 30 minutes, the body temperature was measured in a standing state in front of the measuring instrument, and the distance between the treadmill and the thermography was about 50M, which may cause an error in measurement.

4. Data analysis

Data for this study were analyzed using PASW (Predictive Analytics SoftWare) version 18.0 for Window statistical program. The mean and standard deviation were calculated using descriptive statistics to find out the changes in muscle activity and body heat in each group and one-way ANOVA analysis was used to compare the difference in muscle activity and change in body heat of tibialis anterior, medial gastrocnemius muscle and lateral gastrocnemius muscle depending on the condition of each heel area. If there is a significant difference between the groups, the Duncan's multiple test was conducted with a post-test to check a group with a significant difference and all statistical significance levels a were set to 0.05.

Ⅲ. Results

1. General characteristics of subjects

The characteristics of age, weight, and height of the subjects participating in this study are as follows (Table 1).

2. Comparison of muscle activity of three muscles depending on heel areas

All of tibialis anterior, medial gastrocnemius muscle, and lateral gastrocnemius muscle showed significant differences in muscle activity by shoe heel area (Table 2).

1) EMG changes in tibialis anterior depending on heel area

According to EMG changes in tibialis anterior depending on heel area, the mean was 263.00 ± 13.83 μV in the narrow heel, 240.00 ± 22.42 μV in the middle heel, and 147.66 ± 10.35 μV in the wide heel. Since the significance probability is smaller than $p<0.05$, the results were statistically significant.

The results of the post-analysis showed that there were all significant differences between wide and middle heels, middle and narrow heels, narrow heel and wide heels (Figure 6).

2) EMG changes in medial gastrocnemius muscle depending on heel area

According to EMG changes in medial gastrocnemius muscle depending on heel area, the mean was 165.00 ± 16.21 μV in the narrow heel, 152.20 ± 13.38 μV in the middle heel, and 132.80 ± 7.66 μV in the wide heel. Since the significance probability is smaller than $p<0.05$, the results were statistically significant.

The results of the post-analysis showed that there were significant differences in middle and narrow heels and there were no significant differences in wide heel and middle heel, middle heel and narrow heel (Figure 6).

3) EMG changes in lateral gastrocnemius muscle depending on heel area

According to EMG changes in lateral gastrocnemius muscle depending on heel area, the mean was 157.40 ± 12.81 μV in the narrow heel, 135.80 ± 15.27 μV in the middle heel, and 128.40 ± 4.27 μV in the wide heel. Since the significance probability is smaller than $p<0.05$, the results were statistically significant.

The results of the post-analysis showed that there were significant differences in wide and narrow heels, middle and narrow heels and there were no significant differences in wide and middle heels.

3. The results of infrared body heat analysis depending on the heel area

All of tibialis anterior, medial gastrocnemius muscle and lateral gastrocnemius muscle showed statistically significant comparison in body heat change depending on the heel area ($p<.05$) (Table 3).

1) Changes in body heat of tibialis anterior depending on the heel area

According to body heat changes in tibialis anterior depending on heel area, the mean was 36.84 ± 0.12 ºC in the narrow heel, 36.47 ± 0.09 ºC in the middle heel, and 35.86 ± 0.23 ºC in the wide heel. Since the significance probability is smaller than $p<0.05$, the results were statistically significant.

The results of the post-analysis showed that there were significant differences in wide and middle heels, middle and narrow heels, narrow and wide heels.

2) Changes in body heat of medial gastrocnemius muscle depending on the heel area

According to body heat changes in medial gastrocnemius muscle depending on heel area, the mean was 36.14 ± 0.75 ^{o}C in the narrow heel, 35.49 ± 0.31 ^{o}C in the middle heel, and 35.28 ± 0.13 ^{o}C in the wide heel. Since the significance probability is smaller than $p<0.05$, the results were statistically significant.

The results of the post-analysis showed that there were significant differences in wide and narrow heels, and there were no significant differences in wide and middle heels, middle and narrow heels.

3) Changes in body heat of lateral gastrocnemius muscle depending on the heel area

According to body heat changes in lateral gastrocnemius muscle depending on heel area, the mean was 36.26 ± 0.26 °C in the narrow heel, 35.21 ± 0.45 °C in the middle heel, and 35.63 ± 0.18 °C in the wide heel. Since the significance probability is smaller than $p<0.05$, the results were statistically significant.

The results of the post-analysis showed that there were significant differences in wide and narrow heels, middle and narrow heels and there were no significant differences in wide and middle heels.

Ⅳ. Discussion

This study was carried out to find out the relationship between changes in body heat and muscle activity depending on the heel area. The results of the comparison of muscle activity and body temperature measurement by heel area and the result of changes in the heel area of 4 channels showed that tibialis anterior, medial gastrocnemius muscle and lateral gastrocnemius muscle were all significant in body heat and EMG. In a study on the effect of the heel area on the human body, Chang-Min Lee and Eun-Hui Jeong (2002) said that lower extremities showed a clear decrease in muscle load and statistically significant difference depending on the changes in width of the heel, matching with the significant results of body heat and EMG of this study. Cathleen (2012) asked the subjects to wear middle and wide heels and studied by comparing them to high heels and found that middle and wide heels reduce biomechanical tension and help reduce injuries and pain. As in the above study, this study compared and studied the heel area using narrow, middle and wide heels and did not perform a biomechanical study because the experiment was conducted within a short period of 6 days but the same results were obtained by measuring EMG and body heat changes before and after treadmill exercise. According to a study on lower extremity muscle activity when running in other shoes, the muscles used vary depending on the area of the shoe and the EMG values of muscle rectus femoris, biceps muscle of thigh, tibialis anterior, and gastrocnemius muscles are changed (James, 2002). This study obtained the same results when EMG values of tibialis anterior and gastrocnemius muscles were changed by varying the area of the shoes touching the ground.

Anna et al (2009) who studied the activity of lumbar extensor muscle depending on the height of the shoes found that the higher the shoe heel, the higher the muscle activity of the lumbar extensor muscle. Unlike previous studies, this study made the heights of the heels the same and varied the area touching the ground and the smaller the area touching the ground, the greater the activity of tibialis anterior and gastrocnemius muscle.

Amit et al (2012) studied the muscular strength of the gastrocnemius muscle and muscle soleus according to the walking cycle by varying the height of the heel and as a result, the higher the height of the heel, the greater the muscle activity of gastrocnemius muscle and muscle soleus. This study compared and studied the muscle activity of tibialis anterior and gastrocnemius muscle by making the height of the heel the same regardless of the walking cycle and allowing the subjects to walk on the treadmill and the experimental measurement was performed by varying the areas of heels and it was found that the larger the area of the shoe heel, the lower the muscle activity.

Soul Lee (2011), who studied changes in joint motion by gradually increasing the height of the heel and varying the weight and weight load of the subjects, said that the increase in the height of the heel and the asymmetrical weight load are related to the time and space when walking, resulting in the change of parameters and lower extremity kinematics. This study has a limitation in not seeing the joint kinematics according to the weight load, and the weights of the subjects are different, so there are differences according to the weight load, but the focus is on different heel areas, and it was found that the broader the area of the heel touching the ground, the lower the EMG and body heat changes of the tibialis anterior and gastrocnemius muscles.

Danielle Barkema (2010) said that as the heel height increases, the kinematics of the knee may change during walking, which may affect the load on the knee. This study has a limitation of not studying depending on the height of the heel and did not carry out the kinematic study of the knee depending on the heel and measured muscle activity and body heat with the experiment of walking on the treadmill by varying the area of the shoe touching the ground.

In a study of comparing the effects of walking speed and stride length depending on heel height, Il-Yeo Chae (2012) assumed that the height of the heel affects the walking speed and stride length of people and said that the lower heel shows much longer stride length and faster walking speed than the higher heel. In this study, we studied muscle activity and body heat depending on the heel shape, and although there are differences in the stride length according to the subjects, the muscle activity and the body temperature were measured after the treadmill exercise by making the heel height and the walking speed the same.

Seon-Mi Kim (1995), who measured body heat through isokinetic exercise on the femur, compared and measured the body heat of muscle quadratus femoris of one femur and that of muscle quadratus femoris of femur that did not exercise that did isokinetic exercise after performing isokinetic exercise only for one leg and as a result, there were insignificant differences. In the body heat measurement, this study measured the body heat after exercise of narrow, middle and wide heels and higher body heat was found in the narrow heel than in the middle heel and higher body heat in the middle heel than in the wide heel.

Ⅴ. Conclusion

This study was conducted to find out changes in muscle activity and body heat of tibialis anterior and gastrocnemius muscle depending on the area touching the ground through different heel areas. The subjects are 15 healthy adult women in their 20s and the following results obtained by measuring the changes in muscle activity and body heat after five people in each group walked on the treadmill for 30 minutes.

1. The results of the comparison of changes in muscle activity and body heat showed significant differences all in tibialis anterior, medial gastrocnemius muscle an lateral gastrocnemius muscle
2. The muscle activity according to the shape of the heel was lower as the area of the heel touching the ground was larger.
3. The changes in body heat of tibialis anterior and medial gastrocnemius muscles according to the shape of the heel were lower as the area of the heel touching the ground was wider.
4. The body heat changes of lateral gastrocnemius muscle were highest in the narrow heel and lowest in the middle heel.

Except for changes in the body heat of the lateral gastrocnemius muscle, the greater the area of the heel touching the ground, the lower the muscle activity and body heat changes, so it is considered that the fatigue is less in the wide heel than in the middle and narrow heels.

Based on this paper, we hope to generalize the research on the height and shape of shoes and apply it to everyday life to improve the public health.

References

Cathleen, M. (2012). The effects of wearing high heel shoes on your feet. Phoenix Magazine.

Chae, Y. (2011). Kinesiology of the Musculoskeletal System: Foundations for Rehabilitation. Bummun Education, 403-404.

Choi, S.-H., & Chun, J.-S. (2000). A Study on Purchase and Use of Women's Dress Shoes. Journal of the Korean Society of Clothing and Textiles, 24(2), 185-191.

Choi, S.-H., & Chun, J.-S. (2007). Relationship between discomfort area and foot type in the case of wearing shoes with 20s woman Journal of the Ergonomics Society of Korea, 28(3), 477-480.

Choi, Y.-G., Yim, C.-S., & Kwon, G.-R. (2008). Standardization Study of Thermal Imaging using the Acupoints in Human Body. Journal of pharmacopuncture, 11(3), 113-122.

Danielle. (2010). The effects of heel height on frontal plane joint moments, impact accelertion, and shock attenuation during walking. Iowa State University.

Kang, H. K., Seo, H. D., Lee, K. W., & Chung, Y. J. (2012). The Effects of elliptical training, treadmill walking and overground walking on Muscle Activation of Lower Extremity. Special Education Rehabilitation Science, 51(1), 253-266.

Kim, S.-M., Oh, Y.-S., Lee, J.-E., & Kwon, H.-C. (1995). Bilateral Skin Temperature Change of the Anterior Thigh Following Unilateral Isokinetic Exercise. Physical Therapy Korea, 2(1), 14-20.

Ko, E. H., Choi, H. S., Kim, T. H., Cynn, H. S., Kwon, O. Y., & Choi, K. H. (2008). The Effect of High-Heeled Shoes With Total Contact Inserts in the Gait Characteristics of Young Female Adults During Lower Extremity Muscle Fatigue. Journal of Korean Research Society of Physical Therapy, 15(1), 38-45.

Lee, C.-M., & Jeong, E.-H. (2004). The Study on Musculoskeletal Effects of Heel Types. Journal of the Ergonomics Society of Korea, 23(1), 39-48.

Lee, S. (2011). Combined effects of high-heeled shoes and load carriage on gait and posture in young healthy women: University of Ottawa (Canada).

Mika, A., Oleksy, Ł., Mikolajczyk, E., & Marchewka, A. (2009). Evaluation of the influence of low and high heel shoes on erector spine muscle bioelectrical activity assessed at baseline and during movement. Med Rehabil, 13(3), 9-18.

Oh, D. W., Chon, S. C., & Shim, J. H. (2010). Effect of Shoe Heel Height on Standing Balance and Muscle Activation of Ankle Joint. Journal of the Ergonomics Society of Korea, 29(5), 789-795.

Song, J.-W., Kim, S.-J., Lee, G.-H., Song, K.-B., & Kong, Y.-K. (2009). Evaluation of foot pressures and subjective discomfort ratings associated with sneakers, high heels, and kill heels. Journal of the Ergonomics Society of Korea, 28(3), 95-102.

Srivastava, A., & Tewari, R. (2012). Electromyography Analysis of High Heel Walking. International Journal of Electronics & Communication Technology, 166-169.

Wakeling, J. M., Pascual, S. A., & Nigg, B. M. (2002). Altering muscle activity in the lower extremities by running with different shoes. Medicine & Science in Sports & Exercise, 34(9), 1529-1532.

This study was received Oct. 27, 2017, was reviewed Nov. 22, 2017, and was accepted Nov. 30, 2017.

Appendix 1. Table

Table 1. General Characteristics of Subjects

	n	age (years)	Height (cm)	Weight (kg)	p
Narrow Heel	5	22 ± 0.71	162.2 ± 1.92	52.2 ± 3.77	.115
Middle Heel	5	22.8 ± 0.45	160.8 ±1.92	52.0 ± 2.92	.116
Wide Heel	5	22.6 ± 0.64	164.0 ± 2.73	50.4 ± 1.82	.585

Table 2. Comparison of Muscle Activity by Shoe Heel Area

	Shoe Heel Area	SS	df	MS	F	p
	Narrow Heel					
Tibialis Anterior	Middle Heel	37264.985	2	18632.493	69.721	.001*
	Wide Heel					
	Narrow Heel					
Medial Gastrocnemius	Middle Heel	2628.400	2	1314.200	7.871	.007*
	Wide Heel					
	Narrow Heel					
Lateral Gastrocnemius	Middle Heel	2270.533	2	1135.267	8.191	.006*
	Wide Heel					

*p<.05

Table 3. Comparison of Thermography by Shoe Heel Area

	Shoe Heel Area	SS	df	MS	F	p
Tibialis Anterior	Narrow Heel Middle Heel Wide Heel	2.463	2	1.231	44.217	.000*
Medial Gastrocnemius	Narrow Heel Middle Heel Wide Heel	1.984	2	.992	4.324	.007*
Lateral Gastrocnemius	Narrow Heel Middle Heel Wide Heel	2.750	2	1.375	13.067	.039*

*$p<.05$