JESK J Ergon Soc Korea 2015; 34(4): 303-312
http://dx.doi.org/10.5143/JESK.2015.34.4.303
http://jesk.or.kr eISSN:2093-8462

The Effect of Insole Height on Lumbosacral Angle and Body Function in Male University Students

Young Sin Lee[1], Seong Hun Yu[2], Seong Su Kim[3]

[1]Musculoskeletal Disorder Prevention Center, Gwangju Samsung Electronics, Gwangju, 62217
[2]Department of Physical Therapy, Gwangju Trauma Center, Gwangju, 61964
[3]Department of Physical Therapy, Gwangju Health University, Gwangju, 62287

Corresponding Author
Seong Hun Yu
Department of Physical Therapy, Gwangju Trauma Center, Gwangju, 61964
Mobile : +82-10-8624-4750
Email : yshjj18@hanmail.net

Received : April 01, 2015
Revised : April 02, 2015
Accepted : June 11, 2015

Copyright@2015 by Ergonomics Society of Korea. All right reserved.

This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/3.0/), which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Objective: The aim of this study is to investigate the effect of insole height change in the lumbosacral angle and physical functions in healthy males.

Background: In order to release male's dissatisfaction with his height and to increase satisfaction with his body, using insole is generalized. There have been researches on female's body change in accordance with function of insole and heel height, whereas there are few researches on males.

Method: Participants were divided into three groups. A control group had 10 participants who wore 0cm insole. Experimental group I had 10 participants who wore 2cm insole. Experimental group II had 10 participants who wore 4cm insole. All participants wore insoles during their daily lives for a trial period of 8 weeks. The results were evaluated before and after comparison, and we measured lumbosacral angle, balance (dynamic balance, agility, quickness) and lumbar pain (LBP).

Results: This study showed that insole height affected lumbosacral angle and dynamic balance and pain. In particular, there were significant differences in the 4cm group among the three groups (p<.05). The 2cm group did show a significant difference in lumbosacral angle and pain (p<.05). Furthermore, no significant difference was observed within the control group.

Conclusion: The 4cm insole height suggests that the increase of lumbosacral angle contributes to some changes in LBP, balance, pain and physical functions, probably leading to negative effects on variety of activities of daily life.

Application: The results of wearing insoles with proper height will help to prevent musculoskeletal disorders.

Keywords: Balance, Insole height, Lumbosacral angle, Lumbar pain (LBP)

1. Introduction

Although, an insole is designed from the functional aspect to prevent muscle fatigue by distributing weight, and protect ankle and knee joints through shock absorption, young males solve dissatisfaction with their height, and ensure confidence on their bodies through the use of height increasing insoles for beauty purpose (Lee et al., 2009; Jung et al., 2009). However, the use of insoles having higher height disturbs ideal walking by changing body center of gravity (COG), and increasing the range of

fluctuation of the center of body mass (CBM). Such a use also increases pelvic inclination as the compensation of postural alignment control, according to the kinematic and kinetic changes of spinal and lower limb joints, induces muscle fatigue, reduces balance, and heightens fall risk (Berg et al., 1992; Snow and Williams, 1994; Kim and Lee, 2007; Paillard, 2012).

Kim and Lee (2007) said heels higher than 4cm affect balance and increase fall risk of young females and elderly women. Kim et al. (1997) asserted wearing shoes with about 3cm height of heels are ideal for walking with the most clear extending and bending exercise at the lower limb segments. The preceding studies reported the increase of muscle fatigue on the back and lower limbs, and balance reduction when one walks, according to an increase of heel height. Also, correlations between muscle activity and muscle fatigue, according to the height of a heel, were identified (Lee and Jung, 2004). A high heel has an impact on both pelvic slopes, spinal curvature and lumbosacral angle, and raises a risk to be exposed to musculoskeletal disorders including ankle disease and lumbar pain (Snow and Williams, 1994; Franklin et al., 1995; Jung, 2005; Cronin, 2014).

Although, many studies on shoes' heel height change and insole function targeting females were carried out, no study on the effect of insole height on human body targeting males has been conducted. This study was performed to grasp the effect of wearing 2cm and 4cm insoles in daily life on the change of lumbosacral angle, balance and lumbar pain (LBP), which are important to maintain the balance and posture of spinal curvature, targeting males in their 20s for 8 weeks.

2. Method

2.1 Subjects

The participants of this study were 30 healthy males attending G University in Gwangju. Those who had no orthopedic disorders on lower limbs and no pain, no limitation in hip joint ROM, no surgery on knees or hip joints in the past, no experience of wearing insoles and no morphologic transformation were selected. The purpose and method of this study were sufficiently explained to all the subjects, and they voluntarily participated in the study. The characteristics of the subjects are as follows (Table 1).

Table 1. Characteristic of the subject

Classification	Age (year)	Height (cm)	Weight (kg)
Control group (n=10)	24.50±2.27	175.00±1.70	77.00±6.45
2cm group (n=10)	23.15±1.50	174.74±1.21	72.36±2.72
4cm group (n=10)	24.12±0.34	172.27±0.64	72.76±4.38

2.2 Design

This study divided the 30 subjects into a control group (n=10), 2cm insole wearing group (n=10) and 4cm insole wearing group (n=10) using a simple random sampling. The subjects used mountable/dismountable and height adjustable insoles made of urethane mad by JH Co. Korea (Figure 1). The insoles did not give burden to a foot, and wearing sensation was not bad for even long time use of them. Before the experiment, the subjects' general characteristics were measured, and also the changes of lumbosacral angle, dynamic balance and lumbar pain (LBP) were measured twice, namely before wearing the insoles and after 8 weeks of wearing them.

Figure 1. Insole height types (insole, JH co., Korea)

2.3 Measurement tool and method

2.3.1 Measurement of lumbosacral angle

This study measured lumbosacral angle using a picture archiving communication system (PACS), after x-ray examination, in order to identify the change of lumbosacral angle. That is, the angle that a line connecting the lower surface of L5 and a line connecting the upper surface of S1 meet was measured (Figure 2). An angle increase means the increase of lordosis.

Figure 2. Lumbosacral angle

2.3.2 Measurement of dynamic balance

This study measured limited balance, quickness and agility to find out the change of dynamic balance ability. To measure limited balance, this study used Biodex balance system (BBS, Biodex Inc., USA) (Figure 3). A subject stood gathering both arms to chest on a circular plate embedded with a motion sensor, moved his body toward a target displayed on the monitor without taking off feet, while moving the cursor. The average of three times of measurements of front and back shaking and left and right shaking for 20 seconds was used. As the measured balance index is higher, the balance level means lower level, and the level is revealed with 0~9 points.

To find out the change of quickness, Sargent jump (Helmas II, O2run, Korea) (Figure 4) was used. A subject stood with a shoulder

width on a foot mat, jumped as high as possible in line with the signal coming from the equipment, and the time, when both feet contacted the mat surface was measured by converting the time into height (cm). After two times were carried out, the highest record was used: as the value is higher, it means quickness is excellent (Kwon, 2007).

To find out the change of agility, this study used reaction time (Helmas II, O2run, Korea) (Figure 4). The time (ms), when a subject's both feet were off instantly in response to sudden signal coming from the equipment, and contacted the surface, was measured. After two times were carried out, the highest record was used: as the value is smaller, it means that agility is excellent.

Figure 3. BBS, Biodex Inc, USA

Figure 4. Helmas II, O2run, Korea

2.3.3 Measurement of visual analog scale (VAS)

This study measured subjective pain, according to insole height, using visual analog scale (VAS). According to lumbar pain, the same examiner measured with 0 point for no disturbance to daily life and no awareness of pain, and 10 points for no leading daily life, and continuously severe lumbar pain that cannot be tolerated (Verbunt et al., 2003).

2.4 Data analysis

Concerning the data of this study, average and standard deviation were calculated using the SPSS 18.0 program. For comparison of differences in each group, according to insole height, this study conducted one-way ANOVA, and a paired *t*-test for differences between and after wearing insoles among the groups. For the post hoc test, a Scheffe test was conducted. All statistical significance level was set to be α=.05.

3. Results

3.1 Change of lumbosacral angle according to insole height

Significant differences of lumbosacral angle were revealed in each group, after wearing insoles for 8 weeks. As a result of the post hoc test, significant differences between 0cm and 4cm insole groups and between 2cm and 4cm insole groups were revealed, respectively (p<.001). In comparison of each group, before and after wearing insoles, significant changes were revealed in the 2cm and 4cm insole groups, respectively (p<.001) (Table 2).

Table 2. Change of lumbosacral angle between insole heights (°)

	Group	Mean ± SD	F	Post hoc
Pre	0cm (A)	16.88±3.10	1.510	
	2cm (B)	15.64±2.18		
	4cm (C)	14.67±3.17		
Post	0cm (A)	16.87±2.78	10.430***	BIC AIC
	2cm (B)	18.04±3.50†††		
	4cm (C)	22.67±2.64†††		

M ± SD, ***p<.001; significant difference compared with the One-way ANOVA, †††p<.001; significant difference compared with the paired t-test

3.2 Change of dynamic balance according to insole height

Significant differences of limited balance, quickness and agility were revealed among the groups, after the subjects wore insoles for 8 weeks, and significant difference was shown between the 0cm insole and 4cm insole groups as a result of the post hoc test (p<.001). In comparison of each group before and after wearing insoles, significant changes were revealed in limited balance (p<.001) and agility (p<.05) (Table 3).

Table 3. Change of dynamic balance between insole heights

		Group	Mean ± SD	F	Post hoc
BBS (score)	Pre	0cm (A)	4.18±0.74	0.924	
		2cm (B)	4.39±0.87		
		4cm (C)	3.97±0.35		
	Post	0cm (A)	4.04±0.56	8.075**	AIC
		2cm (B)	5.04±2.15		
		4cm (C)	6.80±1.52†††		
Quickness (cm)	Pre	0cm (A)	27.80±4.24	0.442	
		2cm (B)	26.10±3.70		
		4cm (C)	26.80±4.24		
	Post	0cm (A)	27.90±3.87	4.456*	AIC
		2cm (B)	22.70±8.43		
		4cm (C)	19.70±5.46		
Agility (ms)	Pre	0cm (A)	269.60±26.00	1.151	
		2cm (B)	305.80±78.28		
		4cm (C)	303.40±62.26		

Table 3. Change of dynamic balance between insole heights (Continued)

		Group	Mean ± SD	F	Post hoc
Agility (ms)	Post	0cm (A)	268.20±24.40	6.941**	AIC
		2cm (B)	335.70±77.77		
		4cm (C)	385.10±89.09†		

BBS; Biodex balance system, M ± SD, *p<.05, **p<.01; significant difference compared with the One-way ANOVA, †p<.05, †††p<.001; significant difference compared with the paired t-test

3.3 Subjective lumbar pain change according to insole height

Significant differences of subjective lumber pain were revealed, after the subjects wore insoles for 8 weeks, and significant differences were shown between the 0cm insole and 2cm insole groups and between 0cm insole and 4cm insole groups as a result of the post hoc test (p<.001). In comparison of each group before and after wearing insoles, significant changes were revealed in the 2cm insole and 4cm insole groups (Table 4).

Table 4. Change of VAS between insole heights (score)

	Group	Mean ± SD	F	Post hoc
Post	0cm (A)	0.00±0.00	55.95***	AIB AIC
	2cm (B)	3.40±0.97†††		
	4cm (C)	4.20±1.32†††		

M ± SD, ***p<.001; significant difference compared with the One-way ANOVA, †††p<.001; significant difference compared with the paired t-test

4. Conclusion and Discussion

According to Yoo et al. (1981) and Kim and Baek (2003), the change of lumbosacral angle increases spinal curvature and shearing force, adds structural change pressuring posterior ligament and facet joint, and thus becomes a factor causing lumber pain (Yoo et al., 1981; Kim and Baek, 2003). This study analyzed the effect of insole height on the structural lumbosacral angle change of males in their 20s through PACS, after x-ray examination. As a result of comparison before and after wearing insoles for 8 weeks, the differences of -0.01°, 2.40° and 8.00° in the 0cm group, 2cm group and 4cm group, were revealed, respectively. Especially, statistically significant difference was revealed in the 4cm group, as a result of the post hoc test.

Bendix et al. (1984) said a high heel reduces lumbosacral angle, and Song and Park (2001) reported a high heel does not influence the change of lumbosacral angle. Consequently, they reported conflicting results. However, the increase of lumbosacral angle was shown, when subjects wore 2cm and 4cm insoles as a result of this study. This means the increase of spinal curvature and wearing insoles with insoles having high height is considered to negatively affect spine.

Balance is an essential factor to maintain physical balance in daily life (Wade and Jones, 1997). However, high heels reduce balance

and elevate fall risk (Kim and Lee, 2007). Lord and Bashford (1996) insisted the group wearing high heels showed reduced static and dynamic balance performance as a result of evaluating balance, according to the height of a heel targeting elderly women. Kim and Park (1997) reported the reduction of static balance in the group wearing 7cm heels targeting females in their 20s, who wore shoes with 7cm and 3cm heels in terms of the comparison of static balance. Oh et al. (2009) reported instability in the case of wearing 5cm insole in the comparison of OSI average difference, according to bare foot and insole height. As a result of difference comparison before and after wearing insoles for 8 weeks, the scores of 0cm, 2cm and 4cm insole groups were -0.14, 0.69 and 2.83, respectively, and this study confirmed insole height affects dynamic balance. Also, as the insole height increases, balance sensation was known to decrease, as a result of the post hoc test. This result matches preceding studies' outcome reporting ankle's imbalance goes up, due to the increase of surrounding muscles activity and body shaking, as shoe's heel gets higher.

When one wears high heels for a long time, abnormality is caused on somatosensory system, foot normal mechanism change is caused, and resultant overload on joints occurs (Saunders et al., 1953) and also the location sensation of joint movement is damaged (Barrack et al., 1989). Unlike this study, the subjects of the preceding studies were mostly females, and slight differences existed in experimental method, because measurement was made in the status of wearing high heels not during daily life activity. Also, the difference of results is considered to be revealed, due to contact support surface was different by using high heels, not using insoles. However, insoles are conjectured to negatively affect human body, as insole height gest higher (Bullock-Saxton, 1994).

Although, static balance evaluation is meaningful, various dynamic balance measurements are needed for physical balance evaluation from a functional aspect (Redfern et al., 2001; Perrin et al., 2002). Agility and quickness are related with muscle, reaction time and speed, and how much effective harmony between nervous system functions and muscles can be made is able to be evaluated (Fabio, 1995). Quickness is defined as an ability to spurt maximum energy with explosive motion, or an ability to maximize muscular contraction with the fastest speed ratio, if possible (Kwon, 2007). Agility means an ability to precisely and quickly move part or whole of human body. Agility is closely related with muscle, reaction time, speed, quickness and flexibility, and is developed through the combination of all these. As a result of quickness difference comparison before and after wearing insoles, ocm, 2cm and 4cm insole groups were 0.10cm, -3.40cm and -8.90cm, respectively. It was confirmed that higher insole height affected the decline of quickness.

The post hoc test result confirmed quickness fell significantly in the 4cm insole group. As a result of agility difference comparison before and after wearing insoles, the 0cm, 2cm and 4cm groups showed -0.60ms, 29.90ms and 81.70ms, respectively. It was confirmed that higher insole height affected the reduction of agility in this study.

To quickly change human body into gentle whole body motions and partial body motions, the balance of such muscles as hips, stomach and back conveyed from lower limbs to upper limbs is needed. In consideration of the dynamic balance, quickness and ability results of this study, the 4cm insole is considered to reduce lower limbs' muscle balance and stability.

An insole contributes to the improvement of comfort and balance to reduce foot fatigue and pain by absorbing shock and distributing weight (Gu, 2011). Lumbar pain disturbs posture balancing, causes abnormal posture, and increases biomechanical stress of musculoskeletal system (Gill and Callaghan, 1998). Body center cannot be distributed, and surface repulsive power is not properly absorbed, when one walks, through strong pressure on central forefoot, due to destroyed balance on leg bones with twisting foot bones arrangement and the heel, when one wears insoles (Lee et al., 2009).

According to the comparison of subjective pain differences before and after wearing insoles for 8 weeks, the ocm group did not cause pain, the 2cm group scored 3.4 points, and the 4cm group scored 4.2 points. Therefore, it was confirmed that higher insole

height affected subjective pain. As a result of the post hoc test, pain was significantly caused in the 2cm and 4cm insole groups, respectively.

Wearing insoles for 8 weeks showed significant changes of lumbosacral angle. Due to this, significant difference of pain is considered to be caused, because of spinal structural change and imbalance. Repetitive wearing of insoles to increase one's height is conjectured to easily expose males to various musculoskeletal disorders, owing to causing asymmetric posture.

The limitations of this study are that there is a difficulty to generalize the study results to all age brackets, and that the number of subjects and the diversity of insoles were insufficient, and that specific physical conditions were not considered. A further study is considered to be necessary through the use of various types of insoles (different height) for a variety of age brackets.

Acknowledgements

This work was funded by grants from Korean Federation of Science and Technology Societies (Grant-#KFSTS0000000).

References

Barrack, R.L., Skinner, H.B. and Budkley, S.L., Proprioceptor in the anterior cruciate deficient knee. *Am J Sport Med*, 17, 1-6, 1989.

Bendix, T., Sorensen, S.S. and Klausen, K., Lumbar curve, Trunk muscles and line of gravity with different heel height. *North American Spine Society*, 1984.

Berg, K.O., Maki, B.E., Williams, J.L. et al., Clinical and laboratory measures of postural balance in an elderly population. *Arch Phys Med Rehabil*, 73(11), 1073-1080, 1992.

Bullock-Saxton, J.E., Local sensation changes and altered hip muscle function following sever ankle sprain. *Phys Ther*, 74(1), 17-31, 1994.

Cronin, N.J., The effects of high heeled shoes on female gait: a review. *J Electromyogr Kinesiol*, 24(2), 258-263, 2014.

Fabio, R.P.D., Sensitivity and specificity of platform posturography for identifying patients with vestiular dufuction. *Phys Ther*, 75(4), 290-305, 1995.

Franklin, M.E., Chenier, T.C., Brauninger, L. et al., Effect of positive heel inclination on posture. *J Orthop Sports Phys Ther*, 21(2), 94-99, 1995.

Gill, K.P. and Callaghan, M.J., The measurement of lumbar proprioception in individuals with and without low back pain. *Spine*, 23(3), 371-377, 1998.

Gu, B.O., The Effect of Height Increase Elevator Shoes Insole on Gait and Foot Pressure, *Journal of Physical therapy science*, 6(2), 199-205, 2011.

Jung, E.H., Study on the biomechanical effects of the heel types (height and area) of heel shoes, degree of Dong-eui university, 2005.

Jung, J.H., Kim, J.E., Moon, Y.E. et al., The effect of height increase elevator shoes insole on whole body functional changes - Focused on adult male in their twenties. *Journal of the Korean of sports science*, 18(2), 1403-1418, 2009.

Kim, K. and Lee, J.H., Effect of heel-heights of shoe on balance in older women. *Journal of korea sport research*, 18(2), 311-320, 2007.

Kim, S.J., Kim, D.H., Na, J.K. et al., The Effects of High Heeled Shoes on Plantar Pressure and Muscle Fatigue. *Annals of Rehabilitation Medicine*, 21(5), 1010-1016, 1997.

Kim, S.Y. and Baek, I.H., Effects of Transversus Abdominal Muscle Stabilization Exercise to Spinal Segment Motion on Trunk Flexion-Extension. *Korean Research Society of Physical Therapy*, 10(1), 63-76, 2003.

Kim, Y.H. and Park, E.Y., Effects of the High-Heeled Shoes on the Sensory System and Balance in Women, *Korean Research Society of Physical Therapy*, 4(2), 10-17, 1997.

Kwon, T.W., A Study on the reliability between the power tests of sargent jump, standing long jump and standing vertical jump used by Helmas Power Tester. *Journal of the Korean of sports science*, 16(4), 169-177, 2007.

Lee, C.M. and Jung, E.H., The Study on Musculoskeletal Effects of Heel Types, *Journal of the Ergonomic Society of Korea*, 23(1), 39-48, 2004.

Lee, C.M., Yoo, J.H. and Shin, G.H., The study on the biomechanical effects of the heel-up insole. Journal Proceeding of the 2009 Fall Conference of the Ergonomics Society of Korea.

Lord, S.R. and Bashford, G.M., Shoe characteristics and balance in older women. *J Am Geriatr Soc*, 44(4), 429-433, 1996.

Oh, M.H., Lee, J.H., Kwon, Y.J. et al., Effect of Heel-heights of Insole on Balance in Healthy Adults. *Journal of the korean society of physical medicine*, 4(2), 79-86, 2009.

Paillard, T., Effects of general and local fatigue on postural control: A review. *Neuro sci Biobehav Rev*, 36(1), 162-176, 2012.

Perrin, P., Deviterne, D., Hugel, F. et al., Judo, better than dance, develops sensorimotor adaptabilities involved inbalance control. *Gait and Posture*, 15(2), 187-194, 2002.

Redfern, M.S., Jennings, J.R., Martin, C. et al., Attention influences sensory integration for postural control in older adults. *Gait and Posture*, 14(3), 211-216, 2001.

Saunders, J.B.D.E.C., Inman, V.T. and Ebhart, H.D., The major determine in normal and pathological gait. *J Bone Joint Surg*, 35(3), 543-548, 1953.

Snow, R.E. and Williams, K.R., High heeled shoes: Their effect on center of mass position, posture, three dimensional kinematics, rearfoot motion and ground reaction forces. *Archives of Physical Medicine and Rehabilitation*, 75(5), 568-576, 1994.

Song, B.H. and Park, J.Y., The effect of heel-heights on lumbar lordosis for young ladies. *Journal of korean research society of physical therapy*, 13(3), 613-624, 2001.

Verbunt, J.A., Seelen, H.A., Vlaeyen, J.W. et al., Disuse and deconditioning in chronic low back pain: concepts and hypotheses on contributing mechanisms. *Eur J Pain*, 7(1), 9-21, 2003.

Wade, M.G. and Jones, G., The role of vision and spatial orientation in the maintenance of posture. *Physical Therapy*, 77(6), 619-628, 1997.

Yoo, D.M., Ko, B.Y., Mang, G.Y. et al., Statistical Study of the Lumosacral Angles in Lumbago. *Journal of musculoskeletal surgery*, 16(1), 52-58, 1981.

Author listings

Young Sin Lee: lys3231@naver.com
Highest degree: doctor completion, Department of Physical Therapy, Dong-shin University
Position title: Physical Therapist, Musculoskeletal Disorder Prevention Center, Gwangju Samsung Electronics Co., Ltd
Areas of interest: Musculoskeletal Disorder Prevention, Therapeutic exercise, Neuroscience

Seong Hun Yu: yshjj18@hanmail.net
Highest degree: PhD, Department of Physical Therapy, Dong-shin University
Position title: Physical Therapist, Department of Physical Therapy, Gwangju trauma center
Areas of interest: Trauma, Psychology, Orthopedic manual therapy

Seong Su Kim: suri1300@ghu.ac.kr, suri1300@daum.net
Highest degree: PhD, Department of Physical Education, Korea University
Position title: Professor, Department of Physical Therapy, Gwangju Health University
Areas of interest: Physiology of Exercise, Therapeutic Exercise