Effects of Wearing Raised Heel Insoles (RHI) for a Long Term on Physical Functions: Focused on an Adult Male in Their Twenties

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Research

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Abstract

Background: The objective of this study was to evaluate the effects of the long-term wear of raised heel insoles (RHI) on the changes in overall body functions and mechanical adaption.

Methods: This study measured pelvic range of motion (ROM), balance, sensory, ankle joint ROM, lower back pain (LBP), muscle tone, and the muscle stiffness and decrement of male subjects in their 20s. The subjects wore RHI (5cm) for 8 hours per day for 8 weeks (60 days) and measurements were conducted three times (0th, 30th, and 60th days from the experiment start date).

Results: Pelvic ROM increased and static balance decreased when the duration of wearing the RHI increased. Moreover, when the duration of wearing the RHI increased, the sensory function of two-point discrimination (2PD) decreased, the state of tension of the medial gastrocnemius (MG) increased, and the dynamic stiffness worsened.

Conclusions: This study provides baseline data for presenting guidelines for preventing the musculoskeletal deformity and degeneration of the body by revealing changes in overall physical functions due to the extended wearing of RHI.

Background

In the 20th century, men have become increasingly interested in their appearance. Consequently, they have been pursuing the aesthetic beauty of personality and fashion by using high-heeled (HH) shoes and insoles. It is for men to settle dissatisfaction in their physical appearance and gain confidence using raised heel insoles (RHI), just as women wear high-heeled shoes [1]. As men use RHI more frequently for a cosmetic purpose rather than functional purposes in daily life, people, regardless of gender, are more exposed to the risk of musculoskeletal disorders [2].

Various RHI are sold in the market. Interestingly, it was reported that men (70%) purchased RHI more than women (30%) did. Particularly, men in their 20s accounted for 30% of the total sale [3], and men preferred 3 and 5cm the most [4]. Insoles were originally designed and developed for satisfying a functional objective to prevent muscle fatigue by distributing body weight and protect ankle and knee joints by absorbing impacts. However, as more people are interested in the appearance, young men often use high-heeled shoes and RHI to overcome dissatisfaction with height and gain confidence in their body [1, 5].

Wearing high-heeled shoes weakens the anterior tibial muscle, changes the dynamics of the feet, and decreases the muscle strength of lower extremities, resulting in imbalances in lower extremity alignment. Garn et al [6] reported that it could cause various changes to the musculoskeletal system (e.g., muscle weakness, ligament injury, ankylosis, and improper body alignment) and chronic ankle instability. Jung et al [1] analyzed the effects of RHI on the overall body functions and showed that it affected balance ability, sensation, and range of motion (ROM).

Ankle instability damages joint movements and positional sensation, changes the local sensation of the ankle joint, changes the feedback system between the ankle joint and the central nervous system, and affects the recognition of it. The impairment of the sensory feedback hinders the ability to coordinate movements and adapt properly [7]. It was also reported that the common habit of wearing high- or low-heeled shoes affected healthy women in their 20s to decrease the sensitivity of the somatosensory system and reduce the balance ability [8]. Wearing high-heeled shoes makes it hard for the lower extremities to make an ideal walking condition, changes the center of body's gravity by altering the positions of the spine and lower extremity joints [9], raises the medial arch [10], puts more weight in front of one's feet while walking [11], decreases stability, and generates compensation in the knee and hip joints [12].

Lee et al [13] showed that wearing 4cm-thick insoles increased pelvic ROM. The results indicated an increase in the forward bending of the lumbar spine and they concluded that wearing tall insole negatively affected the spine. The sacroiliac joint needs the stability of ligaments and muscles because it has high mobility anatomically [14]. Kim et al [15] reported that spinal curvature was changed according to pelvic ROM and caused a lower back pain by increasing shearing force and changing the structure to stress the posterior ligaments and the posterior joints. High-heel changes the center of gravity (COG), increases the center of body mass (CBM), and hinders ideal walking [16, 17].

Nashner [18] indicated that maintaining balance is a process generated by the coordination among senses, movement, the central nervous system, and dynamic aspects. Wearing high-heeled shoes continuously can cause problems to the somatosensory system around the feet and change the normal mechanism of the feet to alter balancing abilities. As a result, it can adversely affect walking and feet in various ways [18]. Although more young male adults tend to wear RHI and insoles made of various materials and heights have been developed and sold, most studies have been conducted on women frequently using high-heeled shoes. There are only a few studies analyzing the overall physical changes of men because of wearing RHI, which are popular, for a long term habitually.

The objective of this study was to evaluate the effects of wearing RHI on the overall physical functions and mechanical adaption (e.g., pelvic ROM, balance, sensory around the ankle, ankle joint ROM, lower back pain (LBP), muscle tone, and muscle stiffness and decrement using male subjects in their 20s. The subjects wore RHI (5cm) for 8 hours per day for 8 weeks (60 days).

Methods

Participants and Settings

This study selected 22 healthy male subjects, who were attending A University, were in their 20s, were between 170 and 175cm tall, and had normal BMI (18.5-24.9). The subjects did not have an injury in the musculoskeletal system of the lower extremities in the past one year; had no orthopedic impairment and pain in the lower extremities; had normal ranges of knee and hip joint range of motion (ROM); did not have a surgery related to knee or hip; did not wear RHI before; and had no morphological alteration in the

foot (including flat feet). All subjects filled out an experiment participation consent form after listening to the objective and methods of the study fully before participating in the experiment. Two subjects dropped out in the middle of the experiment and the final subjects were 20 men.

This study measured pelvic ROM, balance, sensory around the ankle, ankle joint ROM, LBP, muscle tone, and muscle stiffness and decrement using following instruments (Table 1, Figure 1) using healthy adult

Raised heel insole (RHI)

The RHI (K Company) used in this study was 5cm-thick insole with an air cushion and made of urethane material. It was inserted into the inside of the shoe. When the height of the insole exceeds 5cm, it is burdensome to walk at the right posture, make people feel fatigue easily, stresses the feet too much, and affects the functions of the feet [19]. In order to limit the shoe material and the width of the shoes, the subject had to wear the following shoes. When the RHI is inserted into the shoes, the ankle is exposed above the shoes. This product wraps the ankle sufficiently to wear the RHI more safely (Figure 2).

Experimental methods and procedures

This study measured variables on the 0th day, 30th day, and 60th day after the beginning of the experiment. They were measured three times per measurement and the mean of measurements was calculated. The RHI and shoes were delivered to each subject after completing the measurements on 0th day (first measurement) in person and received a signature. The subjects were asked to wear them at least 8 hours per day for 8 weeks (60 days).

Statistical Analysis

All statistical analyses were conducted using SPSS / PC 12.0 for Windows Program. All statistical significance was determined at $\alpha=0.05$. The study calculated the means and standard deviations of all general characteristics of the study subjects using descriptive statistics. This study conducted repeated measures one-way ANOVA to examine the effects of wearing duration (0, 30, and 60 days) on variables, followed by a post-hoc test (Dunnett T3) when there was a significant difference.

Results

The subjects were 20 males with a mean age of 23.15 years, a mean height of 171.40cm, and a mean weight of 70.75kg (Table 2).

Comparing before and after wearing the raised heel insole

BROM (Back Range of Motion) II is a tool for measuring pelvic ROM. It was significantly different between 0th, 30th, and 60th days and the magnitude was in the descending order of 60th, 30th, and 0th days ($p < .001$). GaitView is a tool for measuring static balance. It was significantly different between 0th, 30th, and 60th days and the magnitude was in the descending order of 60th, 30th, and 0th days ($p < .001$).

Two-point discrimination (2PD) is a tool for measuring two-point discrimination. It was significantly different between 0th, 30th, and 60th days and the magnitude was in the descending order of 60th, 30th, and 0th days ($p < .05$) (Table 3, Figure 3).

Myotonometer measures the state of muscle tension and the muscle tone of medial gastrocnemius (MG) was examined using this device in the unit of frequency (F). F was significantly different between 0th, 30th, and 60th days and the magnitude was in the descending order of 60th, 30th, and 0th days ($p < .05$). Moreover, D was significantly different between 0th, 30th, and 60th days and the magnitude was in the descending order of 60th, 30th, and 0th days ($p < .05$). However, the F, S, and D of the tibialis anterior (TA) were not significantly different (Table 4, Figure 4).

Discussion

The objective of this study was to evaluate the effects of wearing RHI (5 cm) on the overall physical functions and mechanical adaptation (e.g., pelvic ROM, balance, sensory, ankle joint ROM, LBP, muscle tone, and muscle stiffness and decrement of male subjects in their 20 s. The subjects wore RHI (5 cm) for 8 hours per day for 8 weeks (60 days).

The results of this study showed that BROM2, measuring pelvic ROM, was significantly different between 0th, 30th, and 60th days and the magnitude was in the descending order of 60th, 30th, and 0th days. The results indicated that pelvic ROM increased when wearing the RHI longer. Lee [13] reported that pelvic ROM increased with longer use of the RHI (4 cm thick), suggesting the increase of the forward bending of the waist. The results agreed with a previous study suggesting that wearing RHI would adversely affect the spine. When wearing high-heeled shoes for a long period of time, the positions of body segments and the center of gravity are changed, resulting in kinematic and dynamic changes to compensate for these changes [17]. This compensation occurs first in the lumbar spine before other segments and it was suggested that this increased pelvic ROM [20].

The results of this study revealed that GaitView, measuring static balance, was significantly different between 0th, 30th, and 60th days and the magnitude was in the descending order of 60th, 30th, and 0th days. The shorter displacement of a center of pressure (COP) means a better balance level. Therefore, the results suggested that static balance decreased when wearing the RHI longer. The results of this study revealed that wearing the insole longer decreased the static balance level, which agreed with the results of Kim et al [8] who examined the effects of high-heeled shoes on the changes and balance of the sensory system. The results of this study also concurred with previous studies, which showed that habitually wearing high- or low-heeled shoes influenced the sensory system and balance of healthy women in their 20 s resulting in the decreased sensitivity of the sensory system and balancing abilities [21, 22].

The results of this study revealed that 2PD, measuring two-point discrimination, was significantly different between 0th, 30th, and 60th days and the magnitude was in the descending order of 60th, 30th,

and 0th days. The shorter distance between 2PD indicates a more normal sensory function. Since the results of this study exposed that the distance between 2PD sensations significantly farther when subjects wore it longer, the results indicated that sensory functions decreased. The results of this study showed that wearing RHI longer decreased sensory function more. It has been suggested that high-heeled shoes make the function of the foot as a sensory receptor lost and the foot delivers distorted information to the brain to lose balance [23, 24]. Wearing RHI for a long term changes the local sensation of the ankle joint and affects the changes and recognition of the feedback system between the ankle joint and the central nervous system.

The results of this study showed that the F of MG, measured by Myotonometer to examine the state of muscle tension, was significantly different between 0th, 30th, and 60th days and the magnitude was in the descending order of 60th, 30th, and 0th days. The results indicated that muscle tone increased when wearing the RHI longer. The results of this study revealed that decrement (D), indicating dynamic stiffness, was significantly different between 0th, 30th, and 60th days and the magnitude was in the descending order of 60th, 30th, and 0th days. D is better when it is closer to 0 (or lower). The results showed that D was worsened over time. F, S, And D of TA were not significantly different. The results of this study revealed that the muscle tone of MG increased with longer RHI wearing. There are limitations in comparing studies evaluating the effects of insole because not many studies used MyotonPro. Son et al [25] based on EMG signals reported that the taller high-heeled shoes relaxed the tibialis anterior more by increasing the contraction of the calf muscle because the ankle joint adapted the body to the heel height using the plantar flexion. This can be explained that muscles were contracted continuously to maintain the stability of the ankle in a standing posture [26].

Limitations

The limitation of this study was a small sample size. Future studies are needed to evaluate the effects of the RHI by comparing a control group and a treatment group using various age groups after wearing it for a long term (> 8weeks) with follow-up evaluation. Furthermore, it will be necessary to link the kinematic analysis, Myotonometer results, and EMG analysis for various motion tasks.

Conclusions

The objective of this study was to evaluate the effects of wearing 5 cm-thick RHI on the overall physical functions and mechanical adaptation by measuring pelvic ROM, balance, sensory around the ankle, the range of ankle joint's motion, LBP, muscle tone, and muscle stiffness and D of male subjects in their 20 s. The subjects wore RHI (5 cm) for 8 hours per day for 8 weeks (60 days). The results of this study showed that when the RHI were worn longer, pelvic ROM increased and static balance decreased. The sensory function of two-point discrimination also decreased. At the same time, the state of tension of the MG increased and dynamic stiffness was worsened when wearing the RHI longer. This study provides a guideline for preventing the musculoskeletal deformation and degeneration of the foot and body due to long-term wearing of RHI by revealing the changes in the overall function of men caused by wearing RHI

for a long time. The results of this study are expected to reduce medical and socio-economic costs and contribute to improving the quality of men's life.

Abbreviations

2PD

Two-point discrimination

BROM

Back range of motion

CBM

Center of body mass

HH

High-heeled

LBP

Low back pain

MG

Medial gastrocnemius

RHI

Raised heel insoles

ROM

Range of motion

Declarations

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Availability of data and materials

The data availability data used to support the findings of this study are included within the article.

Authors' contributions

YJC has solely carried out the data analysis, wrote and approved the manuscript.

Ethics approval and consent to participate

The study was approved by the ethical committee of the Institutional Review Board at the Semyung University (SMU-2019-03-001).

Consent for publication

All individuals who participated in this research provided written consent for de-identified data to be disseminated in publications.

Competing interests

The author declares that he has no competing interests.

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Tables

Table 1 Measuring Instruments.

	Equipment Model	Company	Variables
Pelvic RoM	BROM II	PA Products, USA	Degree (°)
Balance	Gaitview	alFOOTs, Korea	Displacement of a center of pressure (COP)
Myotonometer	MyotonPRO	MYOTON Ltd, Estonia	Muscle tone (Hz)
			Muscle stiffness (N/m)
			Decrement

* Measurement of dominant leg

Table 2 General characteristics of subjects.

(n=20)

	Mean $\pm$ SD
Age (years)	23.15 $\pm$ 2.56
Height (cm)	171.40 $\pm$ 4.68
Body weight (kg)	70.75 $\pm$ 9.31
Shoe size (mm)	263.75 $\pm$ 8.87

Table 3 Comparing before and after wearing the raised heel insole.

Variables	<i>Wearing Schedule</i>	Mean $\pm$ SD	F	<i>p</i>	ES	Post Hoc
BROM2	A (0 day)	88.50 $\pm$ 8.68	5.299	0.008**	0.196	C>B>A
	B (30 days)	92.22 $\pm$ 6.73				
	C (60 days)	100.75 $\pm$ 14.81				
GaitView	A (0 day)	32.39 $\pm$ 12.30	7.833	0.001***	0.520	C>B>A
	B (30 days)	91.57 $\pm$ 28.72				
	C (60 days)	106.92 $\pm$ 45.06				
FRT	A (0 day)	37.66 $\pm$ 6.44	0.130	0.879	0.035	
	B (30 days)	39.26 $\pm$ 5.19				
	C (60 days)	40.57 $\pm$ 7.26				
2PD	A (0 day)	11.73 $\pm$ 2.16	3.258	0.046*	0.040	C>B>A
	B (30 days)	11.82 $\pm$ 1.92				
	C (60 days)	12.53 $\pm$ 1.24				
Ankle ROM	A (0 day)	13.49 $\pm$ 4.14	0.434	0.650	0.017	
	B (30 days)	12.52 $\pm$ 4.45				
	C (60 days)	12.32 $\pm$ 3.22				
VAS	A (0 day)	1.65 $\pm$ 1.57	0.221	0.802	0.025	
	B (30 days)	2.30 $\pm$ 1.84				
	C (60 days)	2.05 $\pm$ 1.73				

* $p < .05$, ** $p < .01$, *** $p < .001$, VAS: Visual Analog Scale, BROM: Back Range of Motion, FRT: functional reach test, 2PD: two-point discrimination, ROM: Range of Motion, ES: effect size

Table 4 Comparing the muscle tone frequency (F), muscle stiffness (S), and decrement (D) before and after wearing the RHI.

Variables			Mean $\pm$ SD	F	<i>p</i>	ES	Post Hoc
TA	F	A (0 day)	19.19 $\pm$ 3.43	0.656	0.523	0.095	
		[Hz] B (30 days)	18.79 $\pm$ 2.98				
		C (60 days)	16.95 $\pm$ 2.82				
	S	A (0 day)	368.45 $\pm$ 103.82	2.203	0.120	0.137	
		[N/m] B (30 days)	346.45 $\pm$ 98.82				
		C (60 days)	283.45 $\pm$ 73.11				
	D	A (0 day)	1.07 $\pm$ 0.34	2.463	0.094	0.028	
		B (30 days)	1.58 $\pm$ 2.20				
		C (60 days)	1.26 $\pm$ 0.27				
MG	F	A (0 day)	17.43 $\pm$ 1.70	3.956	0.025*	0.034	C>B>A
		[Hz] B (30 days)	17.65 $\pm$ 1.06				
		C (60 days)	26.94 $\pm$ 42.17				
	S	A (0 day)	307.00 $\pm$ 45.80	1.119	0.334	0.019	
		[N/m] B (30 days)	308.95 $\pm$ 31.56				
		C (60 days)	292.92 $\pm$ 73.83				
	D	A (0 day)	1.63 $\pm$ 2.14	3.431	0.039*	0.046	A>B>C
		B (30 days)	1.07 $\pm$ 0.14				
		C (60 days)	1.07 $\pm$ 0.13				

**p*<.05, F: frequency, S: stiffness, D: decrement, ES: effect size, TA: tibialis anterior, MG: medial gastrocnemius

Figures

a. Tibialis anterior (TA)

b. Medial gastrocnemius (MG)

Figure 1

Muscle tone, stiffness, and decrement were measured using MyotonPro device on muscle site.

Figure 2

The raised heel insoles (5cm) and shoe used for the study.

Figure 3

Comparing before and after wearing the raised heel insole.

Figure 4

Comparing the muscle tone frequency (F), muscle stiffness (S), and decrement (D) before and after wearing the RHI using Myotone.