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Original Research

Effects of wearing raised-heel insoles for 60 days on physical functions: focusing on adult males in their twenties

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Abstract

Background and objectives: As men frequently use raised-heel insoles (RHIs) for a cosmetic purpose rather than a functional purpose in daily life, they are exposed to the risk of musculoskeletal disorders. The objective of this study was to evaluate the effects of wearing RHIs for 60 days on overall body functions and mechanical adaption.

Materials and methods: This study measured pelvic range of motion (ROM), balance, two-point discrimination (2PD), ankle joint ROM, lower back pain (LBP), muscle tone, stiffness, and decrement in male subjects in their 20s. Subjects wore RHIs (5 cm) for 8 h per day for 8 weeks (60 days). Measurements were conducted at 0, 30, and 60 days after the experiment began. Repeated-measures one-way analysis of variance (ANOVA) was performed 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: Pelvic ROM decreased ($p < 0.01$), whereas static balance and 2PD increased ($p < 0.001$, $p < 0.01$, respectively) when the duration of wearing RHIs increased. The pelvic ROM on day 0 was significantly different from that on day 60 (p = 0.01). Static balance showed significant differences between day 0 and day 60 or day 30 (p = 0.000, p = 0.000, respectively). Dynamic balance, ankle joint ROM, and LBP did not differ significantly. The muscle tone of the plantar flexors (medial gastrocnemius) increased ($p < 0.05$), whereas decrement decreased ($p < 0.05$).

Conclusions: It was found that wearing RHIs for a long time would adversely affect the human body. Wearing RHIs for a long time decreased pelvic ROM, whereas static balance and 2PD increased. It might have affected the overall body functions by increasing the muscle tone of the plantar flexors and worsening dynamic stiffness at the same time. The clinical significance lies in the fact that wearing RHIs for long durations would adversely affect the human body.

Keywords

Balance; Habituation; Pelvic ROM; Raised-heel insole; Sensory function

1. Introduction

In the 21th century, men are increasingly interested in their appearance. Consequently, some men have been pursuing aesthetic beauty of personality and fashion using high-heeled shoes (HH shoes) or raised-heel insoles (RHIs) to address dissatisfaction with their physical appearance and gain confidence [1]. As men use RHIs frequently for a cosmetic purpose rather than a functional purpose in daily life, they are exposed to the risk of musculoskeletal disorders [2].

Various raised-heel insoles (RHIs) are sold on the market. Interestingly, it has been reported that more men (70%) purchase RHIs than women (30%) [3]. In particular, men in their 20s account for 30% of the total sale. They prefer 3-cm and 5-cm RHIs the most [3, 4]. Oh *et al.* [5] have argued that people have difficulty walking with the correct posture when the heel height of the shoe is over 5 cm, which fatigues the foot very easily. Insoles were originally designed and developed to achieve a functional objective to prevent muscle fatigue by distributing body weight and protecting the ankle and knee joints by absorbing impact [6]. However, as more people are becoming interested in appearance, young men often use HH shoes and RHIs to overcome dissatisfaction with their heights and gain confidence regarding their heights [1, 7].

Wearing HH shoes weakens the anterior tibial muscle, changes the dynamics of the feet, and decreases the muscle strength of the lower extremities, resulting in imbalances of lower extremity alignment. Jamali *et al.* [8] reported that wearing HH shoes could cause various changes in the musculoskeletal system (e.g., muscle weakness, ligament injury, ankylosis, and improper body alignment) and chronic functional ankle instability. Jung *et al.* [1] evaluated the effects of wearing RHIs (5 cm) for four weeks on whole-body functional changes and reported that it can decrease dynamic balance, worsen two-point discrimination (2PD) and sense of position, and significantly increase ankle range of motion (ROM).

Walking in high heels compromises gait and affects performance and balance [2]. It changes the body's center of gravity by altering the positions of the spine and lower extremity joints [9], raises the medial arch [10], puts more weight on the front of one's feet during walking [11], decreases stability, and generates compensation in the knee joints and lumbosacral junction [12]. De Oliveira Pezzan *et al.* [13] examined experienced wearers of HH shoes between ages of 13 and 20 after increasing pelvic alignment angles. Their results indicated an increase in the forward bending of the lumbar spine. Thus, they concluded that wearing HH shoes could negatively affect the spine. On the other hand, Russell *et al.* [14] reported that HH shoes do not affect lumbar lordosis in a static standing posture. Consequently, whether heel height can influence pelvic ROM remains controversial.

Alonso *et al.* [15] argued that balance maintenance is a process involving the coordination of senses, movement, the central nervous system, and dynamic aspects. Continuously wearing HH shoes can affect the somatosensory system around the feet, change the normal mechanism of the feet, and alter balancing ability, thus adversely affecting walking and foot morphology in various ways. Although more young male adults tend to wear RHIs made of various materials with different heights than female adults, most studies have been conducted on women who wear HH shoes frequently. Only a few studies have focused on the overall physical changes in men after wearing RHIs daily for a long duration.

Previous studies have been limited to body (e.g., the musculoskeletal system) adaptation problems while wearing RHIs. Diverse research studies using various approaches are needed. Therefore, the objective of this study was to evaluate the effects of wearing RHIs for 60 days on overall physical functions and mechanical adaptation (e.g., pelvic ROM, balance, sensory function around the ankle, ankle joint ROM, LBP, muscle tone, and stiffness and decrement) of male subjects in their 20s.

2. Methods

2.1 Participants

Participants were recruited through off-line bulletin boards at A University; 22 healthy male college students who were in their 20s were selected. The total number of subjects in this study is 22, considering a 10% dropout rate. They were 170 cm to 175 cm tall with normal BMI (18.5–24.9 kg/m^2). All subjects gave their informed consent for inclusion before they participated in the study, which was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the Institutional Review Board at Semyung University (SMU-2019-03-001). Exclusion criteria were the following: (i) those who had sustained an injury in the musculoskeletal system of the lower extremities in the past one year, (ii) those who had history of lower leg surgery or fracture of the foot and ankle, (iii) those who had undergone a surgery related to the knee or hip, (iv) those who had worn raised-heel insoles before, and (v) those who had received a previous diagnosis of morphological deformity of the foot (including flat feet).

2.2 Study design

A single-group repeated-measures design was used to evaluate the effects of wearing RHIs on the overall physical functions and mechanical adaption of male subjects in their 20s. These subjects wore RHIs (5 cm) for 8 h per day for 60 days. The RHIs (K Company) used in this study were 5-cm-thick insoles with an air cushion made of urethane material. They were inserted into the subjects' shoes. The raised-height insoles, which could absorb shock owing to the air cushion, were 5 cm high based on previous studies [1, 5, 16, 17]. When the RHIs were inserted into the subjects' shoes, the ankles were exposed above the shoes. These sneakers wrapped the ankles sufficiently to help the subjects wear RHIs more safely (Fig. 1). To control the shoe materials and the widths of the shoes, the subjects had to wear the same type of shoes as shown below.

All subjects filled out an experiment participation consent form after the objective and methods of this study were fully explained to them before they participated in the experiment. Informed consent was obtained from all subjects. Two subjects dropped out in the middle of the experiment. One could not wear RHIs due to severe knee pain. The other did not cooperate with the re-evaluation. Thus, the data of 20 subjects were analyzed (Fig. 2).

This study measured pelvic ROM, balance, static 2PD sensation, ankle joint ROM, LBP, muscle tone, stiffness, and decrement using the instruments shown in Table 1.

2.3 Data Collection

FIG. 1. Raised-height insoles (5 cm) with air cushions, which function as shock absorbers, and shoes that sufficiently wrap ankles.

TABLE 1. List of measuring instruments and variables.

		Equipment model	Company	Variables (Unit)
Pelvic ROM		BROM II	Sammons Preston, Inc., USA	Degree (°)
Balance	Static	Gaitview	alFOOTs, Korea	Displacement of COP (mm)
	Dynamic	Functional reach test		Comfort rating (score)
2PD sensation		Dellon Disk-Criminator	Fabrication Enterprises, USA	Threshold (cm)
Ankle joint ROM		Goniometer	Acme United, USA	Degree (°)
Lower back pain		Visual analog scale		Score
Mechanical properties of muscle	Tone	MyotonPRO	MYOTON Ltd, Estonia	Frequency (Hz)
	Stiffness			Stiffness (N/m)
	Decrement			Elasticity (Log)

* Measurement of dominant leg, Decrement is equal to the logarithmic decrement of the natural oscillation. 2PD, two-point discrimination; BROM, back range-of-motion; COP, center of pressure; LBP, lower back pain; ROM, range of motion.

2.3.1 Pelvic ROM

"Pelvic ROM" refers to the lumbar lordotic angle (LLA). It evaluates the degree of lumbar lordosis. This study used a back range-of-motion (BROM II) instrument proven to be highly reliable [18] to measure the angle of pelvic ROM by placing an L-shaped slide arm between the T12 and S1 spinous processes. Each subject took a relaxed and standing posture and placed his arms in a comfortable position while putting his feet 15 cm apart [19]. The gap between the feet was marked on the floor to exclude the effect of the distance between the feet on the lumbosacral angle in each condition (Fig. 3a). There was a 1-min break between measurements. The test-retest ICC of BROM II was 0.939, and the ICC of area 95% was 0.793 [20].

2.3.2 Balance

A Gaitview(®) AFA-50 system (alFOOTs, Seoul, Republic of Korea) was used to measure static balance. Each subject was asked to maintain an upright posture for 15 s with his eyes closed. The subject took a break of 10 s between measurements. Measurements were performed three times, and the mean value was calculated [21]. The path length of the center of pressure (COP) was measured using a Gaitview Pro 1.01 analysis program and expressed in mm (Fig. 3b). A shorter COP displacement indicated a better balance level with a better static balance. The intraclass correlation coefficient (ICC) ranged from 0.69 to 0.97. The coefficient of variation (CoV) ranged from 9.9% to 59.97% for all parameters [22].

A functional reach test (FRT) was conducted to measure the dynamic balance. The FRT is a validated test that measures the distance from the tip of the middle finger to the maximum extended position when the arm is raised to shoulder height in an upright position. The arm is extended forward as far as possible [23] (Fig. 3c). The FRT developed by Duncan *et al.* [24] has demonstrated a high test-retest reliability in various adult groups (r = 0.89–0.92).

2.3.3 2PD sensation

A Dellon Disk-Criminator was used to measure static 2PD sensation, which reflected the ability to perceive two different stimuli when two stimuli were simultaneously applied to the sole [25] (Fig. 3d). A shorter distance between 2PD indicated a more normal sensory function. Novak reported that the inter-examiner reliability of 2PD is high [26] (inter-rater ICC ranged from 0.66 to 0.85 with an overall intra-rater ICC of 0.77).

2.3.4 Ankle joint range of motion (ROM)

A goniometer was used to measure ankle joint ROM. While each subject was lying on his back on a table with ankle dorsiflexion, the active ROM, indicating the maximum dorsiflexion, was measured from the lateral side of the subject while the subject maintained the middle ankle joint (90°) at the starting point (Fig. 3e). Konor *et al.* [27] reported that the within-session intra-rater reliabilities of the goniometer for the right foot and left foot are 0.85 and 0.96, respectively, indicating good reliability and low measurement error.

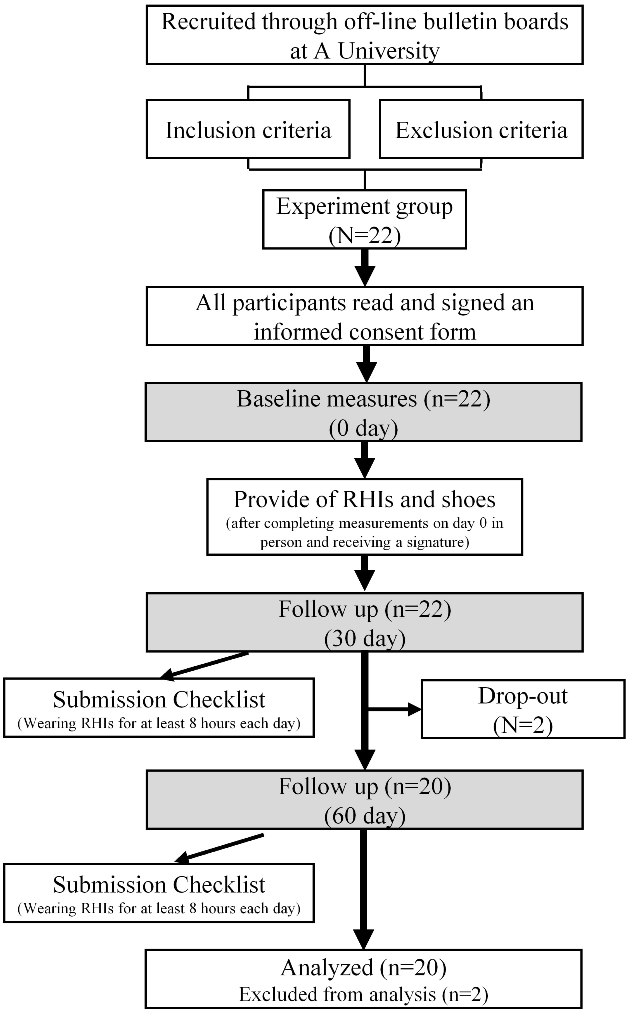

FIG. 2. Flow chart of research methodology.

2.3.5 Lower back pain (LBP)

Pain was measured on days 0, 30, and 60 (end-date) using a visual analog scale (VAS) to evaluate the degree of subjective lower back pain (LBP). The degree of LBP was expressed numerically, with 0 points indicating that a subject had no issue in conducting daily activities and felt no pain and 10 points meaning that a subject continuously experienced severe pain and that the subject could not maintain daily activities at all because the pain was unbearable [28]. VAS is a reliable (ICC = 0.99) and valid pain evaluation tool [29]. It has been widely used in clinical settings because it can efficiently evaluate the degree and change of pain [30].

2.3.6 Muscle tone, stiffness and decrement

The MyotonPRO device was used to measure muscle tone, stiffness, and decrement. MyotonPRO is very useful in the biomechanical analysis of muscles that control body movements [31]. Measurements were taken after the subject had maintained a stable state for at least 5 min. Each subject laid face down on his abdomen. Each muscle belly was marked with a harmless marker. The MyotonPRO device was supported with both hands to maintain a right angle to muscles (Fig. 3f). Measurements were taken and recorded

TABLE 2. Characteristics (age, height, body weight, and shoe size) of subjects (N = 20).

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

SD, standard deviation.

five times. Decrement is equal to the logarithmic decrement of the natural oscillation [32]. Decrement was better when it was closer to 0 (or lower) [33]. The medial gastrocnemius (MG) and tibialis anterior (TA) were selected and measured based on previous studies [33, 34]. The intra-rater reliability of the MyotonPRO for muscle tone ranged from 0.75 to 0.82. The confidence interval (CI) range was 0.37 to 0.93 [35]. The MyotonPro showed very high to excellent within-day reliability and good to high between-day reliability [36].

2.4 Data analyses

In this study, variables were measured at 0, 30, and 60 days after the experiment started. Baseline data were measured on day 0. The effects of RHI on overall physical functions and mechanical adaption were evaluated on days 0, 30, and 60 when the subjects were not wearing RHIs. Each subject was measured three times and evaluated by the same person. The mean values of the three measurements were then calculated. Data were collected by a researcher (YJC) and a trained research assistant (CHL). The order of evaluation was randomized at the beginning of each set by having the subject. The subject took a 5-min break between measurements. RHIs and shoes were delivered to subjects after the measurements had been completed on day 0 in person and their signatures had been obtained. Subjects were asked to check every day using a checklist after wearing RHIs for at least 8 h each day for 60 days. The checklist was submitted twice on evaluation days (day 30 and day 60). It was found that the performance rate was 97%.

All statistical analyses were conducted using the SPSS/PC 12.0 for Windows program. All statistical significance was determined at $\alpha = 0.05$. The means and standard deviations of all general characteristics of the subjects were calculated using descriptive statistics. Repeated-measures one-way analysis of variance (ANOVA) was performed 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.

3. Results

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

Pelvic ROMs differed significantly at 0, 30, and 60 days. The magnitude of pelvic ROM was in the descending order of 0, 30, and 60 days ($p < 0.01$). The pelvic ROM on day 0 was significantly different from that on day 60. Static balance

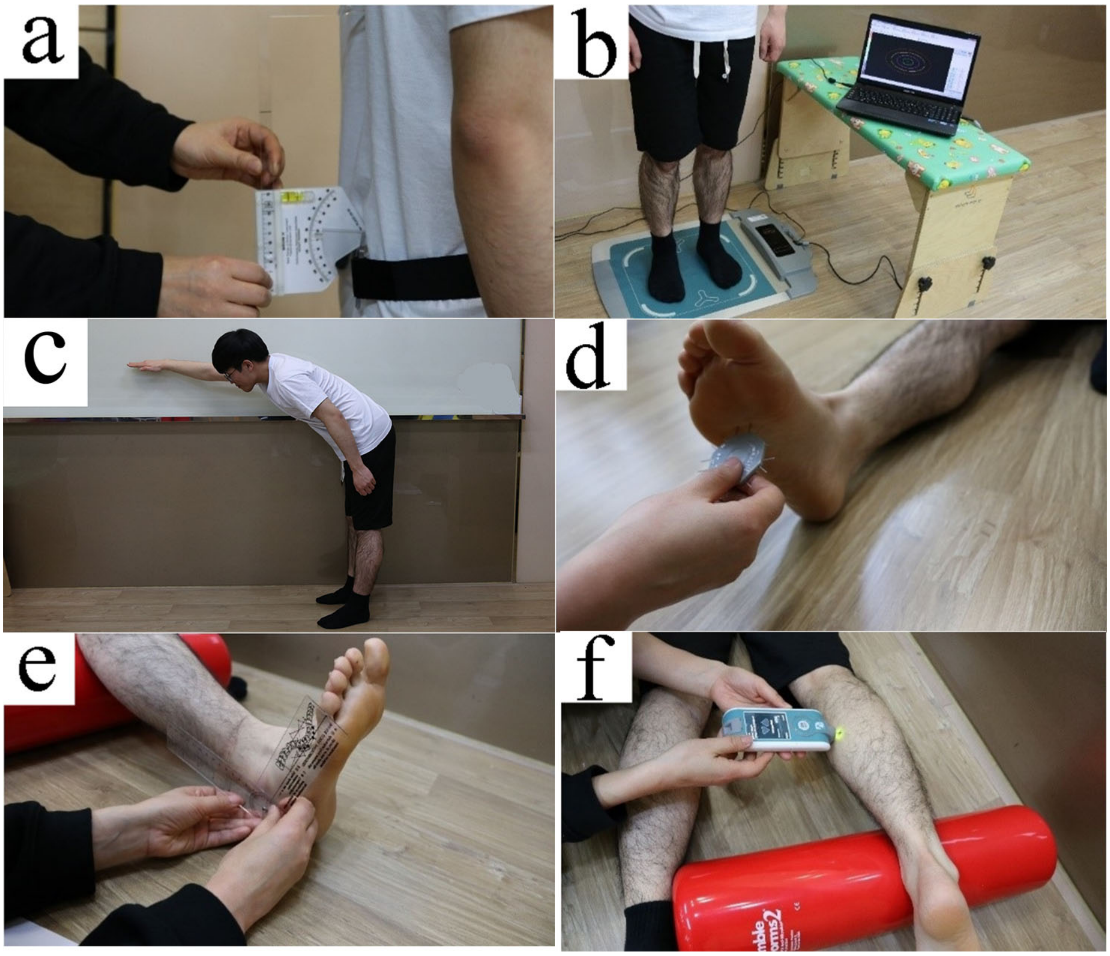

FIG. 3. Measuring instruments. (a) BROM II to measure pelvic ROM. (b) Gaitview system to measure static balance. (c) Functional reach test to measure dynamic balance. (d) Dellon Disk-Criminator to measure 2PD sensation. (e) Goniometer to measure ankle joint ROM. (f) MyotonPro to measure muscle tone, stiffness and decrement. BROM, back range-of-motion; 2PD, two-point discrimination; LBP, lower back pain.

differed significantly at 0, 30, and 60 days. The magnitude of static balance was in the descending order of 60, 30, and 0 days ($p < 0.001$). Static balance showed significant differences between day 0 and day 60 or day 30. The 2PD sensation differed significantly different at 0, 30, and 60 days. The magnitude of 2PD sensation was in the descending order of 60, 30, and 0 days ($p < 0.05$). A shorter distance between 2PD indicated a more normal sensory function; thus, the sensory function was reduced. Dynamic balance, ankle joint ROM, and LBP did not differ significantly at 0, 30, and 60 days (Fig. 4, Table 3).

Muscle tone of MG differed significantly at 0, 30, and 60 days. The magnitude of muscle tone was in the descending order of 0, 30, and 60 days ($p < 0.05$). Moreover, decrement of MG differed significantly at 0, 30, and 60 days. The magnitude was in the descending order of 60, 30, and 0 days ($p < 0.05$). However, the muscle tone, stiffness, and decrement values of the TA did not differ significantly at different time points (Fig. 5, Table 4).

4. Discussion

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

Results of this study showed that pelvic ROMs differed significantly at 0, 30, and 60 days. Pelvic ROM decreased more when RHIs were worn longer. These results were consistent with the results of the previous studies [37, 38]. Displacements of lines of gravity changed after RHIs were habitually worn for a long time due to compensations of various body segments. The decrease in pelvic ROM was one of them. The overuse of lumbar muscle due to wearing RHIs for a long time can make lumbar tissues more rigid and lead to pronounced back complaints with advancing age.

The results of this study revealed that static balance differed significantly at the three time points (0, 30, and 60 days), suggesting that static balance decreased when RHIs were worn longer. The results also revealed that wearing RHIs longer decreased the static balance function, which is consistent with previous studies that have shown that habitually wearing high- or low-heeled shoes could influence the sensory system and balance of healthy women in their 20s, leading to decreased sensitivity of the sensory system and balancing abilities [39].

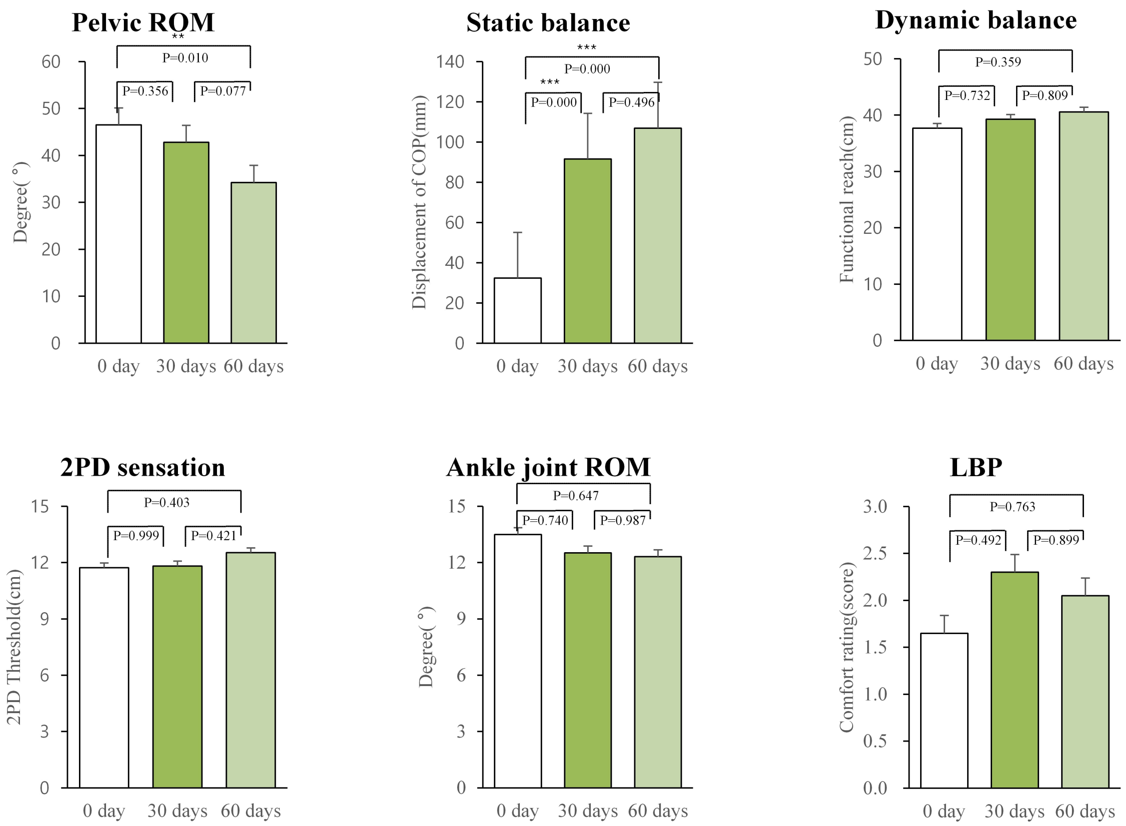

FIG. 4. Post-hoc analysis results by the duration of wearing RHIs (0, 30, and 60 days). $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. ROM, range of motion; 2PD, two-point discrimination; LBP, lower back pain.

TABLE 3. Comparison between the period (0, 30, and 60 days) of wearing RHIs.

Variables	Wearing schedule	Mean ± SD	F	*p* value	Post hoc
Pelvic ROM	A (0 day)	46.50 ± 8.68	5.299	0.008**	C > B > A
	B (30 days)	42.78 ± 6.73			
	C (60 days)	34.25 ± 14.81			
Static balance	A (0 day)	32.39 ± 12.30	7.833	0.001***	C > B > A
	B (30 days)	91.57 ± 28.72			
	C (60 days)	106.92 ± 45.06			
Dynamic balance	A (0 day)	37.66 ± 6.44	0.130	0.879	
	B (30 days)	39.26 ± 5.19			
	C (60 days)	40.57 ± 7.26			
2PD sensation	A (0 day)	11.73 ± 2.16	3.258	0.046*	C > B > A
	B (30 days)	11.82 ± 1.92			
	C (60 days)	12.53 ± 1.24			
Ankle joint ROM	A (0 day)	13.49 ± 4.14	0.434	0.650	
	B (30 days)	12.52 ± 4.45			
	C (60 days)	12.32 ± 3.22			
LBP	A (0 day)	1.65 ± 1.57	0.221	0.802	
	B (30 days)	2.30 ± 1.84			
	C (60 days)	2.05 ± 1.73			

$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. RHIs, raised heel insoles; LBP, lower back pain; ROM, Range of Motion; 2PD, two-point discrimination.

The results of this study revealed that 2PD values differed significantly at 0, 30, and 60 days. Moreover the distance between 2PD sensations was significantly farther when subjects wore RHIs longer, indicating that sensory functions decreased more if RHIs were worn longer. Wearing RHIs for a long time can change the sensory functions of the foot and affect recognition of the feedback system between the foot and the central nervous system (CNS), which is consistent with results obtained by Lee *et al.* [21] who examined the effects of HH shoes on changes and balance of the sensory

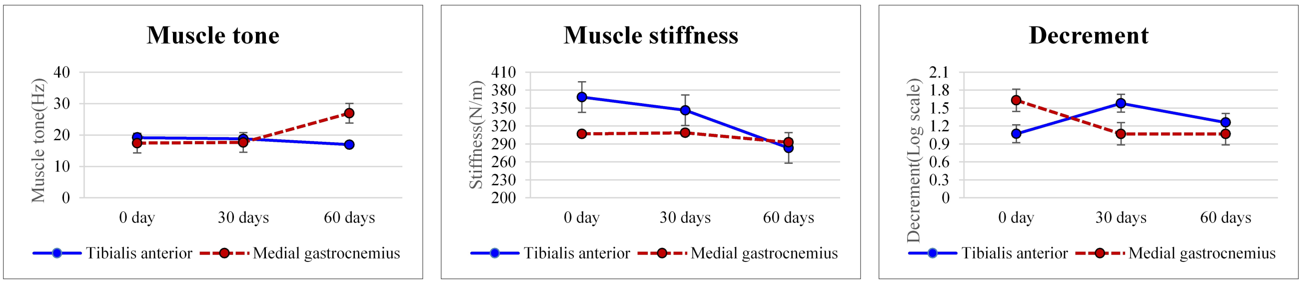

FIG. 5. Comparison of muscle tone, stiffness, and decrement of TA and MG according to the duration (0, 30, and 60 days) of wearing RHIs. MG, medial gastrocnemius; TA, tibialis anterior.

TABLE 4. Comparison of muscle tone, stiffness, and decrement of TA and MG according to the duration (0, 30, and 60 days) of wearing RHIs.

Variables			Mean ± SD	F	*p* value	Post hoc
TA	Tone (Hz)	A (0 day)	19.19 ± 3.43	0.656	0.523	
		B (30 days)	18.79 ± 2.98			
		C (60 days)	16.95 ± 2.82			
	Stiffness (N/m)	A (0 day)	368.45 ± 103.82	2.203	0.120	
		B (30 days)	346.45 ± 98.82			
		C (60 days)	283.45 ± 73.11			
	Decrement (Log scale)	A (0 day)	1.07 ± 0.34	2.463	0.094	
		B (30 days)	1.58 ± 2.20			
		C (60 days)	1.26 ± 0.27			
MG	Tone (Hz)	A (0 day)	17.43 ± 1.70	3.956	0.025*	C > B > A
		B (30 days)	17.65 ± 1.06			
		C (60 days)	26.94 ± 42.17			
	Stiffness (N/m)	A (0 day)	307.00 ± 45.80	1.119	0.334	
		B (30 days)	308.95 ± 31.56			
		C (60 days)	292.92 ± 73.83			
	Decrement (Log scale)	A (0 day)	1.63 ± 2.14	3.431	0.039*	A > B > C
		B (30 days)	1.07 ± 0.14			
		C (60 days)	1.07 ± 0.13			

*$p < 0.05$, RHIs, raised heel insoles; SD, standard deviation; TA, tibialis anterior; MG, medial gastrocnemius.

system. Chen *et al.* [40] also suggested that HH shoes could degrade the sensory receptor function of the foot and make the foot deliver distorted information to the brain, resulting in imbalance.

Alonso *et al.* [15] argued that maintaining static balance is highly dependent on the senses. The results of the present study showed a stronger correlation between the senses and static balancing ability because dependence on the visual system was eliminated by asking the subjects to close their eyes when static balance was evaluated. In other words, it was believed that damaged sensory function of the foot impaired the static balance ability.

Although results of this study showed that pelvic ROM decreased significantly, LBP di not change significantly, which is consistent with the findings of previous studies, which suggested that it was unclear whether changes in lumbar lordosis caused LBP [19]. When RHIs are worn longer, muscle tone and the sensory system in the ankle are changed, which limits the movement of the ankle joint and causes shortening. As a result, it is presumed to be the cause of the decrease in the pelvic ROM because it affects trunk stability.

These results indicated that MG muscle tone increased when RHIs were worn longer. In the present study, decrement indicating dynamic stiffness differed significantly at 0, 30, and 60 days. Its magnitude was in a descending order of 60, 30, and 0 days. These results showed that decrement worsened over time. The muscle tone, stiffness, and decrement values of TA did not significantly differ at the three time points. The results of this study revealed that the MG muscle tone increased when RHIs were worn longer, which is consistent with results obtained by Cha, who reported that females who wore high-heeled shoes showed high muscle tone of the rectus femoris (RF) and gastrocnemius medius (GM) because wearing RHIs for a long time continuously increased muscle activation of the plantar flexors and caused muscle imbalance of the lower limbs, which is likely to result in musculoskeletal disorders (MSD) [33].

This study had some limitations. First, the sample size was small. In addition, the participants were from a specific group, namely, college students. Therefore, it is difficult to generalize based on our results. By using the G-power version 3.1 (Kiel, Germany), the required minimum sample size was calculated to be 100 subjects [41]. Considering the proportion of eligible subjects (10%) and dropout due to incomplete data, it is recommended that future studies include 110 subjects as final samples. Moreover, pain was not measured in other pain indexes, such as the ankles and knees. Measures of pain and physical activity levels should be controlled in future research because they can influence outcomes. Further research is also necessary to examine the effects of physical activity level on the human body by monitoring the number of steps, calorie consumption, walking time, and activity distance from rising in the morning until going to bed in the evening.

5. Conclusions

Wearing RHIs for a long time negatively affected men's overall body functions and biomechanics in several ways. Analyzing male subjects in their 20s indicated that wearing RHIs for a long time decreased pelvic ROM, while static balance and 2PD increased. It might have affected the overall body functions by increasing the muscle tone of plantar flexors and worsening dynamic stiffness at the same time. There is clinical significance in that wearing RHIs for a long time would adversely affect the human body.

Author contributions

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

Ethics approval and consent to participate

All subjects gave their informed consent for inclusion before they participated in the study, which was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the Institutional Review Board at Semyung University (SMU-2019-03-001).

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Conflict of interest

The authors declare no conflict of interest.

Data availability

The data used to support the findings of this study are available from the author upon request.

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