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ORIGINAL ARTICLE

Ergonomic Evaluation of Barefoot Shoes during Prolonged Standing: A Combined Objective and Subjective Approach

FATEMEH SHEIKH[1], SOHEIL HASHEMI[2], MOHAMMAD HOSSEIN FAKHERI[2], MOHAMAD SADEGH GHASEMI[1], ALI ASGHAR FARSHAD[3], FERESHTEH TAHERI[3], EHSAN GAROSI[1,3*]

[1] *Department of Ergonomics, School of Public Health, Iran University of Medical Sciences, Tehran, Iran*

[2] *Liberto Research Center, Tehran, Iran*

[3] *Occupational Health Research Center, Iran University of Medical Sciences, Tehran, Iran*

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ABSTRACT

Background: This study aimed to evaluate the ergonomic suitability of barefoot shoes by assessing key usability indicators, including comfort, perceived pain, user satisfaction, and plantar contact pressure during simulated office tasks.

Methods: In this ergonomics field study, eight ergonomists selected their appropriate barefoot shoe size using a sizing scale and wore the shoes for eight hours. Their daily office routine included two hours of movement around the work environment at the start of the workday, followed by six hours of sedentary office and administrative tasks. At the end of each evaluation phase, participants completed questionnaires assessing foot pain, perceived discomfort in the lower limbs, satisfaction, and overall usability. Additionally, plantar contact pressure was measured in one participant (50th percentile) using the Ergo FS16 device across five anatomical regions of the foot.

Results: All participants (100%) reported that the shoe size selected via the sizing scale accurately matched their foot dimensions. Subjective discomfort levels remained minimal, with average scores of ≤1 in the calf and ankle regions at both 2-hour and 8-hour intervals. The heel region showed a slight increase in pain scores, from 1.25 at 2 hours to 2.1 at 8 hours, while all other foot regions reported no pain or discomfort. User satisfaction scores were consistently high, exceeding 7 out of 10 at both evaluation points. Usability assessments indicated that 75% of participants rated the shoes as acceptable, while 25% provided borderline acceptable ratings. Objective contact pressure measurements confirmed that all recorded values across the plantar surface remained below the established pain threshold.

Conclusion: The findings demonstrate that the barefoot shoes evaluated in this study are suitable and highly comfortable for prolonged standing and daily office tasks. The minimal reported discomfort and high user satisfaction scores support their ergonomic efficacy. However, further longitudinal studies are recommended to assess the long-term effects of barefoot shoe use, particularly in relation to musculoskeletal health and occupational performance.

KEYWORDS: *Barefoot, Ergonomic, foot insole,FSR*

Corresponding author: *Ehsan Garosi*
E-mail: *garosi.e@iums.ac.ir*

INTRODUCTION

Prolonged standing is a common occupational demand in professions such as healthcare, education, inspection, and assembly work. Although often overlooked, this posture has been consistently linked to a range of adverse health outcomes, including lower back pain, fatigue, discomfort in the lower limbs, and venous pooling in the legs [1, 2]. Such physical strains, when paired with inadequate ergonomic support—particularly poorly designed footwear—can lead to musculoskeletal disorders (MSDs), which remain one of the leading causes of work-related injuries and absenteeism worldwide [3–5]. The impact of MSDs is far-reaching, contributing not only to physical disability but also to increased healthcare costs, lost productivity, and reduced quality of life for affected workers [6].

Epidemiological data further emphasize the gravity of this issue. Studies report that nearly half of workers are at risk of MSDs due to prolonged standing at work [7, 8]. In the European Union, around 20% of employees identify prolonged standing as a direct source of musculoskeletal discomfort [9], while in the United States, approximately 83% of industrial laborers experience foot or leg pain associated with prolonged standing [10]. These findings highlight the urgent need for effective, practical, and evidence-based ergonomic interventions.

A variety of solutions have been developed to address standing-related discomfort, including anti-fatigue mats, supportive shoe inserts, footrests, and specialized footwear [11, 12]. However, these interventions often come with trade-offs. Anti-fatigue mats, for instance, may create slip hazards if not securely placed or if the floor is wet [13]. Shoe inserts can cause adjustment-related discomfort and have a short lifespan, particularly if not tailored to individual foot shapes [14]. Improperly adjusted footrests may lead to postural misalignment, increasing strain on the knees and lower back [15].

These limitations point to a gap in current ergonomic practices—particularly in the area of footwear design. In response, there has been growing interest in barefoot shoes as a potential ergonomic alternative. These shoes aim to mimic the natural mechanics of the foot by incorporating a flat, zero-drop sole and a wide toe box. Unlike traditional footwear—which often includes elevated heels and rigid cushioning that may interfere with natural gait—barefoot shoes encourage forefoot or midfoot striking patterns and allow for natural toe splay, potentially reducing impact forces and foot-related disorders over time [16–18]. Research suggests that this design promotes foot strength and functionality while minimizing the risk of deformities linked to narrow or restrictive shoes [19].

Despite these promising claims, scientific evidence evaluating the effectiveness of barefoot shoes in occupational settings—particularly those involving prolonged standing or low-mobility tasks—is still emerging. To address this gap, the present study investigates the ergonomic suitability of barefoot footwear during typical office tasks that include both movement and extended periods of sitting or standing. Key usability indicators such as comfort, perceived pain, user satisfaction, and plantar contact pressure are evaluated to determine the practical value of barefoot shoes in real-world work environments.

By exploring both subjective and objective measures of usability, this study aims to contribute meaningful insights into the role of barefoot shoes in occupational ergonomics. Ultimately, this research seeks to bridge theoretical ergonomic principles with practical applications, advocating for improved workplace well-being through evidence-based footwear solutions.

MATERIALS AND METHODS

Participants

A total of eight healthy adult volunteers participated in this experiment, consisting of five males and three females. Participants were recruited through local advertisements and selected based on their physical health status and ability to perform the required tasks. The mean age of the participants was 40.25 years (standard deviation [SD] = 9.4 years), indicating a middle-aged sample with moderate variability. The average height was 169.8 cm (SD = 9.9 cm), and the average body weight was 79.8 kg (SD = 11.9 kg), resulting in a mean body mass index (BMI) of 27.7 kg/m² (SD = 2.5), placing the group in the overweight range but within acceptable limits for the tasks performed.

Barefoot description

This study used a barefoot shoe from the Liberto brand (Figure 1), which is a relatively new type of footwear that has gained popularity over the past five years. No comparable barefoot shoe models with the same structural characteristics and ergonomic focus were found in the current domestic market. The most notable feature of barefoot shoes is their toe box design, which matches the natural shape of the human foot. Historically, the mismatch between shoe toe boxes and

Figure 1. Chosen Footwear used in this study
It is designed based on the anatomy of the human foot and have three main characteristics: first, open toes; second, a heel-less sole that helps strengthen the Achilles tendon and support the skeletal structure; and third, a flat toe sole to ensure proper distribution of foot pressure. These three components help prevent strain on the knees and back.

Figure 2. Participant while performing the test

the natural shape of the foot has led to various bone deformities. For example, pointed shoes can cause the big toe to deviate or even overlap with other toes over time [20]. Barefoot shoes, with their curvature resembling the human foot, provide enough space for the toes to move naturally, preventing and even treating toe deformities [18, 21].

Fig. 1. shows the barefoot used in this study.

Procedure

In this field ergonomic evaluation, eight ergonomists were asked to select their appropriate barefoot shoe size based on a sizing scale and wore the shoes for eight hours. They engaged in daily office work that included two hours of movement around the work environment at the beginning of the workday, followed by six hours of sedentary office and administrative tasks. At the end of each evaluation phase, participants completed questionnaires assessing foot pain, perceived discomfort in the lower limbs, satisfaction, and overall usability. Additionally, plantar contact pressure was measured in one participant (50th percentile) using the Ergo FS16 device across five anatomical regions of the foot. During the test, the participant was asked to remain standing (Figure 2).

Subjective measurements

The Visual Analog Scale (VAS) is a ruler graded from 0 to 10, specifically designed to indicate the level of pain in the foot area, where 0 represents no pain and 10 represents unbearable pain. Participants were asked to mark their perceived pain levels on this scale [22]. In addition, the Local Perceived Discomfort (LPD) questionnaire serves as a valuable tool for assessing musculoskeletal disorders. According to Hellander and Zhang, discomfort correlates with sensations such as pain, lethargy, and fatigue, with the LPD summarizing the body into 26 distinct parts for evaluation. This questionnaire focuses on specific areas including the lower back, hips, and knees, quantifying discomfort on a scale from 0 to 10, with defined benchmarks for each score [23, 24].

Moreover, the Satisfaction Questionnaire employs a VAS scale ranging from 0 (indicating very low satisfaction) to 10 (indicating complete satisfaction), with scores above 5 interpreted as satisfactory; scores closer to 10 indicate higher levels of satisfaction [25]. Lastly, product usability was assessed through the System Usability Scale (SUS), which consists of ten questions allowing responses on a scale from 1 (strongly disagree) to 5 (strongly agree). A score exceeding 70 is deemed acceptable. In this study, a tailored Persian version of the SUS was utilized, the validity and reliability of which have been confirmed [26].

Instrument

The ERGOFS16 device is designed for measuring contact pressure. Equipped with 16 electrodes, it is capable of recording compressive force signals on the surface of its sensors, with extensive applications in ergonomic and biomechanical measurements and evaluations. The device records raw force signals and stores them in its internal memory. Researchers can convert these raw data into force units (Newtons) using the provided MATLAB add-on software package and incorporate them into their analyses. The device transmits raw force signals via Bluetooth to a mobile phone, enabling real-time data monitoring.

During the data analysis phase, average pressure changes were used to compare between groups. The device operates at a recording frequency of 10 Hz, and its sensors can measure compressive forces ranging from 0.1 to 100 Newtons, with a resolution of 1 Newton. To ensure accurate placement and protect the sensors, a soft pad was used on both sides of each electrode to distribute pressure evenly and prevent damage.

At the end of the contact pressure recording, the applied pressure was converted to millimeters of mercury (mmHg) based on the sensor area and reported. In this study, 10 channels of the device were used to record contact pressure at various points on the sole of the foot. These locations were selected based on responses from a perceived pain questionnaire. According to standards for soft body tissues, contact pressure exceeding 80 mmHg is considered the threshold at which oxygen supply to the tissue may be reduced, potentially leading to pain [27, 28].

RESULTS

Perceived Discomfort

As shown in Table 1, perceived discomfort at both 2 and 8 hours after wearing the shoes was zero in the lower back, thigh, and knee regions, indicating no discomfort in these areas. In the calf and ankle regions, discomfort levels remained around 1 at both time points, signifying very minimal pain or discomfort, which is considered negligible.

Pain Assessment in the Soles of the Feet

Table 2 presents pain and discomfort levels across five anatomical regions of both the right and left soles of the feet. After two hours of wearing the barefoot shoes, the average pain reported at all four pressure points on both feet was less than or equal to one, indicating minimal discomfort. At both the 2-hour and 8-hour intervals, pain levels remained ≤1 in all regions except for area 5 (the heel), where the pain level increased to 2.1 after 8 hours, signifying slight discomfort. As the pain levels in the right and left feet were consistent and showed no statistically significant difference, a single average pain score was reported for both feet. Diagrams 3 and 4 illustrate the perceived pain levels across all participants.

Satisfaction

The results of the shoe satisfaction assessment after 2 and 8 hours of using the product are shown in the image below. As indicated, the average satisfaction scores at both evaluation points were acceptable and high.

Contact Pressure

Contact pressure was measured by resistive sensors at 10 points (five areas corresponding to pressure points for each foot), and the results, converted to average pressure in millimeters of mercury, are shown in Figure 5. In this chart, the contact pressure for the right foot corresponds to sensors 1–5, and for the left foot to sensors 6–10. The threshold for feeling pain and the point at which tissue experiences reduced blood flow due to pressure are highlighted at 80 mmHg. These results indicate that, in none of the recorded areas, did the contact pressure exceed 50 percent of the pain threshold. It should be noted that these results were recorded for the 50th percentile of the population—an individual weighing 75 kg with a shoe size of 42—and it is recommended to evaluate other population percentiles with different shoe sizes.

Table 1. Mean ± Standard Deviation of Perceived Discomfort in Different Body Regions after 2 and 8 Hours of Wearing Barefoot

Body Region	After 2 Hours	After 8 Hours
Lower Back	0	0
Thigh	0	0
Knee	0	0
Calf	0.1 ± 0.3	1.02 ± 1
Ankle	0.1 ± 0.3	1.25 ± 1

Table 2. Average Pain Levels Felt in Different Areas of the Soles of the Feet

Area	After 2 Hours	After 8 Hours
 Region 1	0.25	1.25 ± 1
 Region 2	0	0.25 ± 0.4
 Region 3	0	0.6 ± 0.5
 Region 4	0.25 ± 0.5	0.75 ± 1
 Region 5	0.7 ± 1.25	2.1 ± 1.8

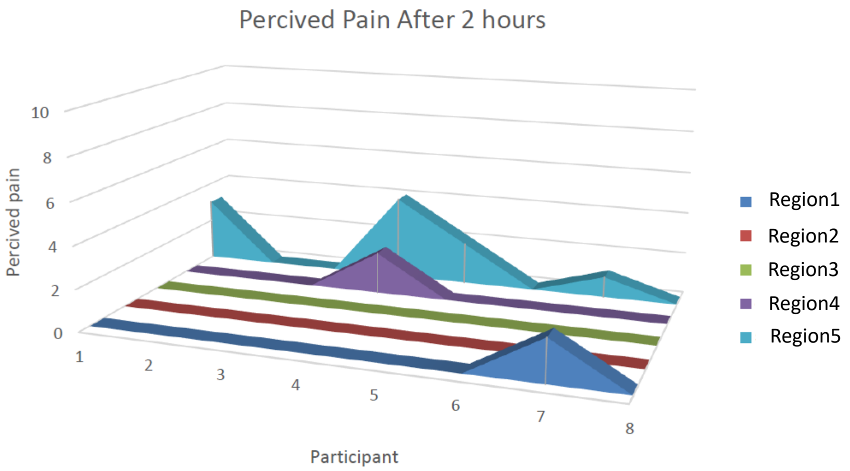

Figure 3. Graph of Pain Felt in the Soles of the Feet among the 8 Specialists Participating in the Study, Evaluated After 2 Hours

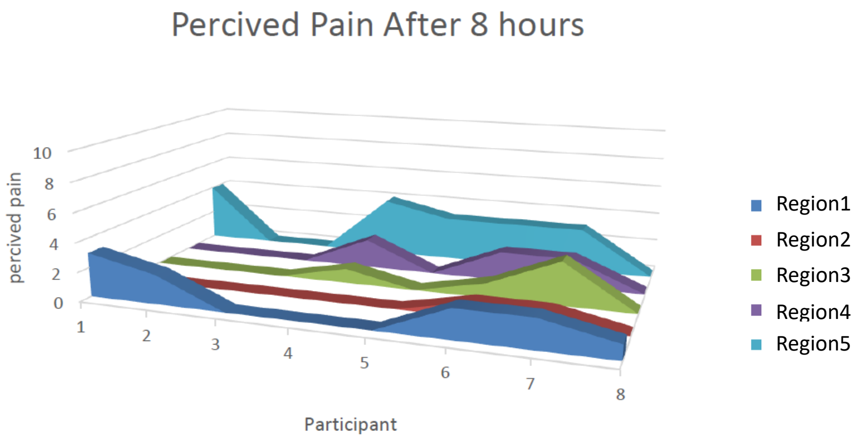

Figure 4. Graph of Pain Felt in the Soles of the Feet among the 8 Specialists Participating in the Study, After 8 Hours

Figure 5. Results of the Average Satisfaction with barefoot After 2 and 8 Hours of Wearing

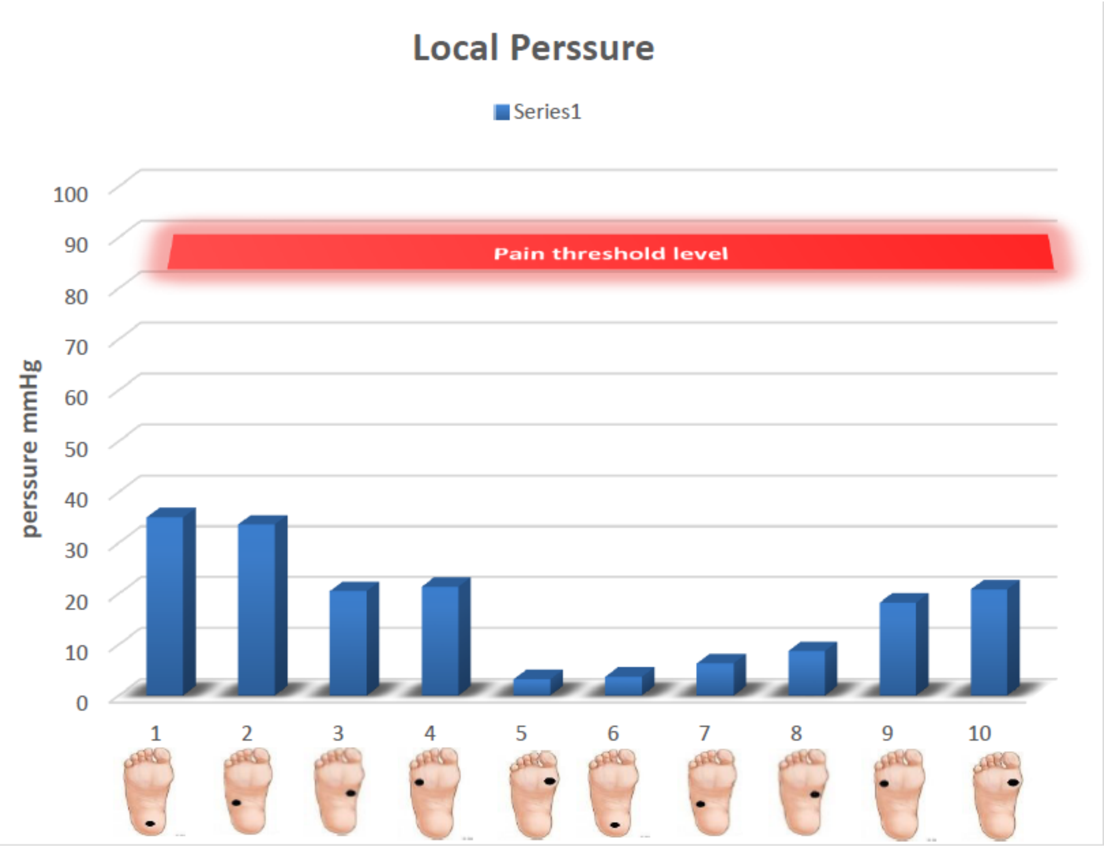

Figure 6. Results of the Average Contact Pressure Between the Soles of the Feet and the Shoes in 5 Points of Each Foot: 1-5 for the Right Foot and 6-10 for the Areas Corresponding to the Left Foot

Usability

The usability results showed that 75% of the participants, including 6 out of the 8 specialists in the study, rated the usability of the Liberto shoes as acceptable for performing daily and office tasks. Twenty-five percent of the participants, equivalent to 2 specialists, rated the usability as marginally acceptable. In the usability evaluation, a score above 70 is considered acceptable.

DISCUSSION

The primary aim of this study was to evaluate the ergonomic suitability of a barefoot shoe by assessing

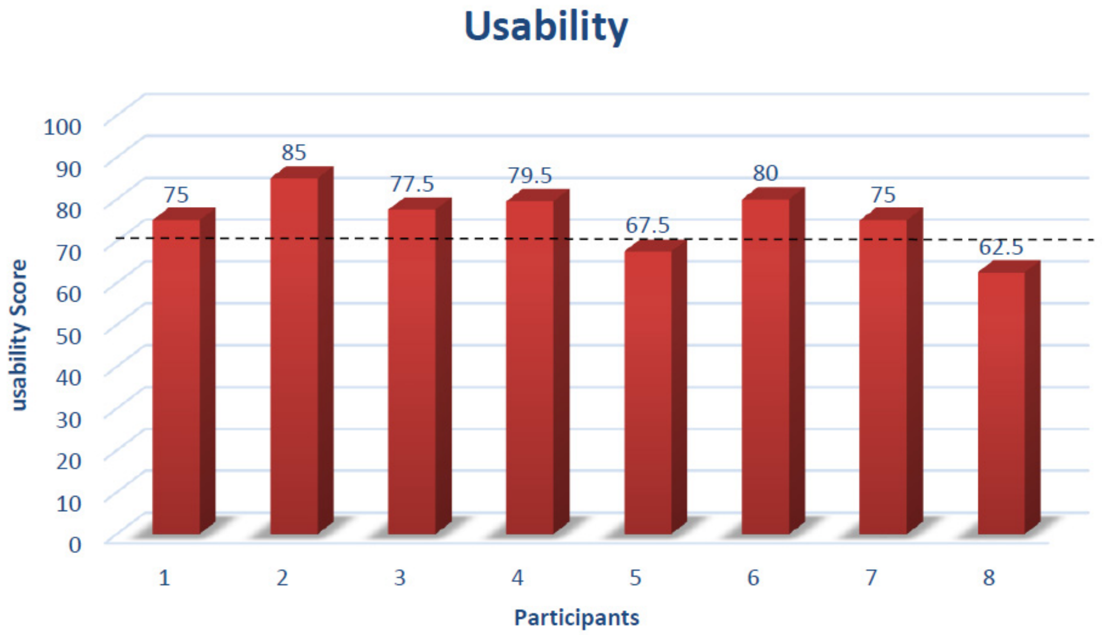

Figure 7.

usability indicators such as comfort, perceived pain, user satisfaction, and plantar contact pressure during simulated office tasks. The results indicated that the barefoot shoe could effectively meet the ergonomic needs of individuals engaged in prolonged standing and sedentary work within an office environment. An essential outcome of this evaluation was the subjective comfort reported by all participants, with an impressive 100% satisfaction in shoe size matching their foot dimensions. This finding aligns with existing literature, which suggests that well-fitted footwear enhances comfort, subsequently reducing the likelihood of foot pain and discomfort during daily activities. The minimal discomfort levels reported—averaging less than one on the pain scale for the calf and ankle regions—underscore the effectiveness of the shoe's design in supporting natural foot mechanics.

Interestingly, while most anatomical regions demonstrated consistently low discomfort, the heel region exhibited a modest increase in pain—from 1.25 after two hours to 2.1 at the end of the eight-hour workday. This slight escalation in discomfort could be attributed to factors such as localized pressure accumulation or the inherent design characteristics of barefoot shoes, which prioritize natural foot movement and flexibility over traditional cushioning methods. Future studies should consider exploring the specific design elements of barefoot shoes that may enhance heel support, particularly for users in roles requiring prolonged standing.

User satisfaction was another crucial metric in this study. Participants rated their overall satisfaction with the shoes highly, with scores exceeding 7 out of 10 at both evaluation points. This consistent satisfaction reflects the shoes' alignment with users' ergonomic needs and fulfills the expectation of comfort and utility in an office setting. The finding that 75% of participants rated the shoes as acceptable, while the remaining 25% rated them as borderline acceptable, suggests a preliminary endorsement of these shoes for regular office use, while also indicating room for improvement in user experience—particularly regarding shoe stability and potential for customizability.

Further, objective plantar contact pressure measurements revealed that all recorded values remained below established pain thresholds throughout the evaluation period, reinforcing the shoes' ergonomic design and suitability. The relationship between contact pressure and perceived discomfort lends significant credence to the effectiveness of barefoot shoes in minimizing footwear-related pain, which is critical in occupational health contexts. This outcome emphasizes the importance of evaluating not just subjective responses but also objective measurements to ascertain the comprehensive ergonomic efficacy of footwear.

Despite these promising findings, the study highlights the need for longitudinal evaluations to determine the long-term effects of barefoot shoe use. Musculoskeletal health may be influenced by prolonged periods spent in such footwear, and concerns regarding potential adaptations or injuries should be addressed through future research. Specifically, it is vital to examine any changes in foot strength, arch support, and overall physical health among regular users.

In summary, this study adds to the growing body of evidence advocating for the use of barefoot shoes in office environments, illustrating their potential to improve user comfort, satisfaction, and foot health. Nevertheless, ongoing research is necessary to deepen our understanding of their long-term implications on occupational performance and musculoskeletal health, ensuring that recommendations for workplace footwear fully support a productive and healthy workforce.

In many professions, tasks must be performed in standing or sitting postures. Numerous studies have shown that wearing inappropriate footwear can lead to various health issues, such as lower limb fatigue, pain, swelling and discomfort, venous blood pooling, and back pain. Foot muscle fatigue and blood pooling in the legs are two suspected mechanisms for creating discomfort in the lower limbs while standing. Venous pooling, resulting from the lack of muscle activity in the constricted and relaxed foot, leads to foot and calf swelling and increased hydrostatic venous pressure, which might explain the increase in discomfort and pain reports. Previous studies have reported that increased volume in the lower limbs (especially the calves and feet) is an indicator of insufficient blood return. Additionally, decreased blood supply in muscles subjected to gravitational load accelerates muscle fatigue and pain due to the accumulation of metabolites in the muscles. Recent research has indicated that the main cause of lower limb discomfort from standing has a more vascular origin.

The impact of standing-related discomfort on health insurance, absenteeism, productivity, and well-being is significant. Therefore, many countries prioritize preventing musculoskeletal problems associated with prolonged standing at work. Various ergonomic solutions have been proposed to mitigate these issues, including anti-fatigue mats, barefoot shoe insoles, footrests, sit/stand stools, and shoes. Physical changes are generally recommended as an effective intervention against musculoskeletal disorders in low, long-term load, or repetitive operation jobs [29]. However, using only appropriate shoe insoles may not yield optimal results for foot and body health. In this regard, Phyllis M. King demonstrated that there was no significant difference in fatigue or discomfort when comparing the overall effects of using shoe covers with wearing shoe insoles or combined conditions [30].

Future research should explore the effects of barefoot shoes during prolonged standing, dynamic tasks, and real-world workplace conditions, particularly in sectors where workers are on their feet for extended periods. Including participants with varying foot morphologies, gait patterns, and pre-existing musculoskeletal conditions will help determine population-specific suitability. Incorporating tools like electromyography (EMG), motion capture, and long-term plantar pressure monitoring could further enhance biomechanical and physiological understanding of barefoot shoe performance in occupational settings.

LIMITATION

While this study provides valuable insights into the ergonomic suitability of barefoot shoes in an office setting, several limitations should be acknowledged. First, the sample size was small (n = 8), consisting exclusively of ergonomists, which may limit the generalizability of the findings to a broader population. Additionally, the study duration was limited to a single 8-hour workday, preventing an assessment of long-term comfort or potential musculoskeletal adaptations. Plantar pressure measurements were collected from only one participant (representing the 50th percentile), which restricts the ability to generalize pressure distribution patterns across different foot types. Furthermore, the simulated office tasks may not fully replicate real-world occupational demands, such as prolonged standing or dynamic movements. Future studies should incorporate larger, more diverse participant groups, extended wear periods, and comprehensive biomechanical assessments to validate these preliminary findings.

CONCLUSION

The results from this study indicated that the barefoot shoe studied is highly suitable and very comfortable for performing daily and office tasks. Additionally, participants reported very low and minimal pain scores in the foot pain assessment. The results related to the contact pressure on the soles showed that the pressure exerted was 50% below the threshold for the onset of tissue hypoxia and pain. However, for prolonged walking, future studies are recommended.

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