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Plantar pressure distribution and postural balance in beauty pageant contestants before and after wearing high-heeled shoes

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Purpose: The aim of this study was to assess the biomechanics of the foot in beauty pageant contestants wearing shoes that increase calcaneal height. Plantar pressure distribution and postural balance were examined in women after one hour of wearing high-heeled shoes. *Methods*: Foot arch measurements were conducted using EPSR1. Based on these measurements, 18 of the 19 tested women were diagnosed with significant pes cavus. *Results*: The experiment revealed a significant reduction in the excessively high metatarsal arch of both feet. The mean load on the metatarsus measured at rest was 0.0% in both feet, and it increased by 0.6% in the left leg ($p \leq 0.022$; $Z = 2.293$) and by 2.7% in the right leg ($p \leq 0.023$; $Z = 2.271$). These results suggest that excessive stretching of the plantar fascia and impaired function of the short muscles of the foot lead to a temporary reduction in the arch of the foot. This phenomenon can be compared to stretching a bowstring and its return to the shortest length under static conditions. A statistical analysis of the results of stabilographic measurements revealed significant changes only in the left foot barycenter. An analysis of the ability to maintain postural balance revealed that the observed changes contributed to postural destabilization at $p \leq 0.011$ and $Z = 2.535$. *Conclusions*: Further research involving electromyography tests is needed to examine plantar muscle tension during isotonic contractions. The duration of the exercise-induced reduction in pes cavus should also be determined for therapeutic purposes.

Key words: *high heels, beauty contest, plantar pressure, stability*

1. Introduction

High-heeled shoes are increasingly popular among women and they are promoted by the fashion industry as the ultimate symbol of being a woman [21]. According to research, 59% of women wear high-heeled shoes for 1–8 hours a day [24]. Esthetic factors play a very important role in women's footwear choices, and high-heeled shoes are regarded as the epitome of beauty, self-confidence and elegance [15]. High-heeled shoes are particularly popular among younger women who participate in beauty pageants and fashion shows [17]. High heels force the foot into an unnatural position, which is why they have been raising serious concern among medical professionals and researchers for more than 50 years [26]. Feet play a key role in the biomechanics of human movement by ensuring the static and dynamic stability of the body. Feet are organs of locomotion that support the human body. Healthy feet are flexible and have an arch on the plantar aspect, which provides cushioning and support

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for the foot when walking or running and gives stability when standing [2]. The forces acting on feet can have positive or negative consequences and can lead to defects [1]. Repeated tension from wearing high heels leads to plantar fasciitis, a condition that causes heel and instep pain [27].

High-heeled shoes are highly popular among women despite their harmful effects on the physiology of the foot [6]. They affect the movement pattern and women who wear stilettoes find it more difficult to maintain correct body posture. High heels increase the load on the forefoot, which exerts a negative effect on postural stability during movement [7]. High heels also influence gait and plantar pressure distribution by raising the heel, increasing the load on the forefoot and the transverse arch of the foot. The severity of these adverse effects is determined by heel width, the age at which the subject began to wear high-heeled shoes, the number of years spent wearing high heels and experience [31]. It is believed that high-heeled shoes force the feet into an unnatural position. Abnormal posture affects the musculoskeletal system, including the lumbar and cervical spine [12], causes progressive musculoskeletal deformities and pain, and affects the body's mechanical functions and physical appearance [4]. Frequent and prolonged use of high-heeled footwear can damage foot architecture, leading to foot and back pain [17]. The appropriate heel height restriction for an individual wearer can be estimated by a physician, but it would be impractical to seek professional medical help when purchasing high-heeled shoes [13]. High-heeled shoes exert a much greater strain on the musculoskeletal system than flat sole shoes. Prolonged walking in high heels induces permanent changes in gait kinematics and leads to irreversible foot deformities over time [11]. Bone structures can become deformed when physical problems, including foot and talocrural joint overload, are ignored. High-heeled shoes with pointed toes can also contribute to hallux valgus [12]. Yin et al. [28] reported that long-term use of high-heeled shoes can induce changes in arch morphology: the longitudinal arch tends to rise within 2–5 years; it is flattened within 6–10 years, and collapses over a period of 20 years.

Research has shown that high-heeled shoes can negatively affect the spine, hips, knees, ankles and feet, and alter the wearer's posture and gait. High heels can cause foot pain if worn for a long period of time [10]. The aim of this study was to assess the biomechanics of the foot in women participating in beauty contests, who regularly wear high-heeled shoes that increase calcaneal height.

2. Materials and methods

Nineteen (n = 19) women were randomly selected for the study from the group of contestants participating in the Miss Mazovia 2021 beauty pageant (Fig. 1).

The candidates for the study were aged 18–25 years. All women who qualified for the study met the inclusion criteria had not been diagnosed with orthopedic disorders, foot dermatitis or other health problems. The inclusion criteria involved experience in wearing stilettoes with 9 to 10 cm heel in height.

The mean age of the studied population was 22.21 ± 2.39 years; the mean body height was 172.32 ± 4.24 cm; the mean body weight was 56.02 ± 3.91 kg and the mean body mass index was 18.87 ± 1.71.

The body composition analysis was conducted with the use of the InBody 270 device. Before the study, the participants' data (ID number, date of birth, height) were entered into the analyzer software by a qualified person. Body height was measured by the researcher with the Soehnle height rod (Soehnle, Gaildorfer Straße 6, 71522 Backnang, Germany). After the body composition analysis, the measured values were automatically uploaded into the Lookin'Body 120 program. The E.P.S./R1 pedobarographic mat with 2304 active surface sensors (Letsens Grupa Letsens S.R.L. Via Buozzi, CastelMaggiore, Bologna, Italy) was used to measure plantar pressure distribution and postural balance. The participants were registered anonymously in the Biomech Studio program (Biomech Studio 2.0, Letsens Group, Letsens SRL Via Buozzi, CastelMaggiore, Bologna, Italy) to collect data for the gait analysis. The measurements conducted on the pressure sensing mat lasted 20 s and the collected data were automatically sent to the Biomech Studio program.

Data were processed statistically in the Statistica 13.0 program (Statsoft, Kraków, Poland). The Shapiro–Wilk test was performed to check for the normal distribution of the random variable. The analyzed data were not normally distributed, therefore, they were subjected to the Mann–Whitney–Wilcoxon test (also known as the Mann–Whitney test, Wilcoxon rank sum test, or the unpaired two-samples Wilcoxon test).

The study was conducted on two dates (November 28, 2021 and December 12, 2021) during two meetings for Miss Mazovia 2021 contestants organized in the Mistral Hotel in Marki.

The participants' body height was measured with the Soehnle height rod, and their body composition was analyzed with the InBody 270 device. During the podological exam, the participants were asked to stand barefoot on a pedobarographic sensing mat, with feet

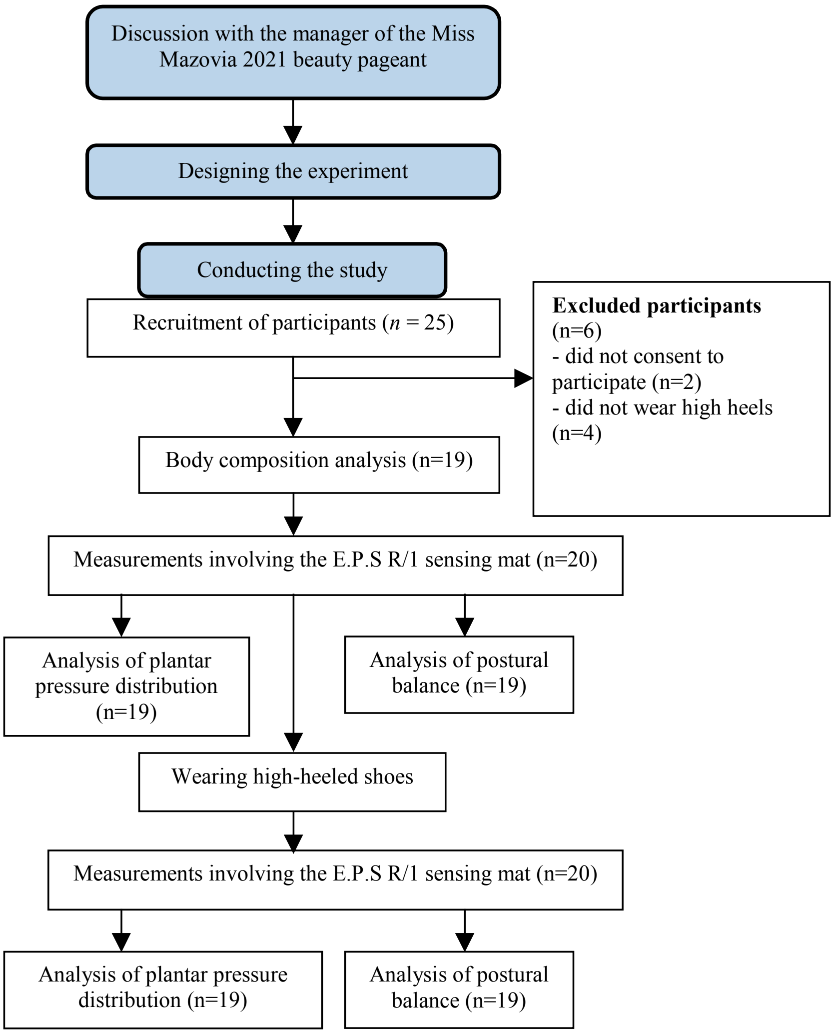

Fig. 1. Recruitment process and the number of study participants

shoulder width apart, while maintaining correct body posture. The resulting images were recorded. The area of the forefoot region, metatarsal region and calcaneal region was measured before and after wearing high-heeled shoes. The foot barycenter and the body barycenter were determined. The participants were then asked to walk in high-heeled shoes for one hour, after which plantar pressure distribution was measured once again. All measurements were conducted at room temperature (22 °C). The participants walked in high-heeled shoes on a flat floor without any cavities, protrusions or architectural barriers.

3. Results

The pedobarographic assessment revealed that the majority of the studied women were affected by pes cavus. In 14 out of the 19 analyzed subjects, forefoot load was determined at 0–7% (normal forefoot load is 21.1–28.0%). A minor and moderate increase in right and left foot arches was noted in four participants. Only one subject was characterized by normal foot arches.

Forefoot load was measured at rest and after 60 minutes of walking in high heels (10 cm). The average left forefoot load increased by 2.4% (from 34.1% at rest to 36.5% after walking on high heels) and the average right forefoot load decreased by 1.10% (from 54.0% to 52.9%). The average left heel load decreased by 4.6% (from 61.4% to 56.8%) and the average right heel load decreased by 2.1% (from 42.1% to 40.0%). The observed changes in forefoot and heel load did not differ significantly between the right and the left foot (Fig. 2).

The noted differences in metatarsal load distribution in both feet were statistically significant. The mean metatarsal load in both feet was 0.0% at rest, and it increased by 0.6% in the left foot ($p \leq 0.022$; $Z = 2.293$) and by 2.7% in the right foot ($p \leq 0.023$; $Z = 2.271$) after walking in high heels.

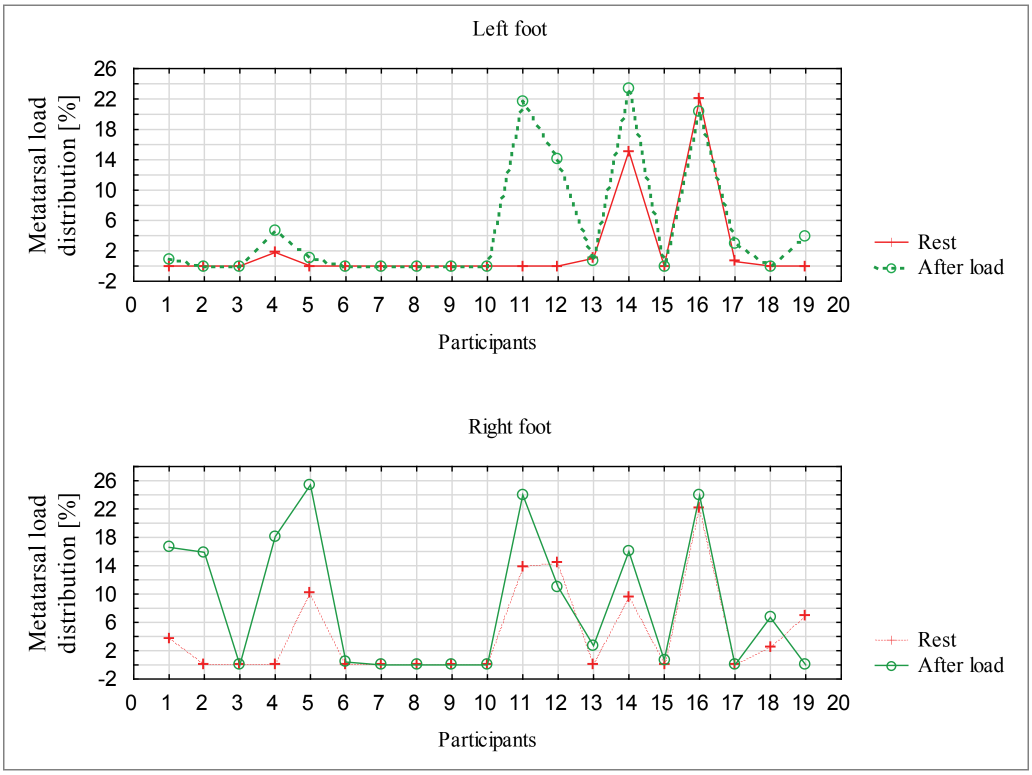

Fig. 2. Metatarsal load distribution before and after walking on high heels

In the metatarsal region, significant differences in all biomechanical parameters of the foot were noted at rest and after walking in high heels (Table 1).

Table 1. Significant differences in the metatarsal area revealed by the posturographic test at rest and after one hour of walking in high heels in the studied population

	Maximum plantar pressure [kPa(r)]	Mean plantar pressure [kPa(r)]	Plantar pressure [Kgf]	Plantar pressure [%]	Area [cm^2]
Left foot	0.004*	0.008*	0.012*	0.005*	0.004*
Right foot	0.015*	0.011*	0.011*	0.007*	0.015*

*$p \leq 0.05$.

A statistical analysis of stabilographic measurements revealed significant changes only in the left foot barycenter. An analysis of the ability to maintain postural balance revealed that the observed changes contributed to postural destabilization at $p \leq 0.011$ and $Z = 2.535$.

4. Discussion

The present study analyzed the effect of walking in high-heeled shoes on plantar pressure and postural balance in adult women participating in a beauty pageant. Similarly to the work of Melvin et al. [16], this study aimed to increase awareness and demonstrate the consequences of walking in high heels by registering forefoot load.

Similar results were reported by Wan et al. [25], who analyzed the influence of calcaneal pitch on foot stability in women wearing high heels. They demonstrated that high heels force the foot into an unnatural position and lead to excessive forefoot loading. Previous research on the impact of high-heeled shoes on forefoot loading produced similar findings. Moreover, considerable changes in the structure of the Achilles tendon, induced by high calcaneal pitch, were observed in women who regularly wear high heels.

Deng and Ning [5] analyzed the distribution of forces on the ground and found that wearing high heels for a long time can cause changes in the arch of the foot and contribute to a flat foot. In women who wore high heels, the length of the second metatarsal was significantly correlated with increased pressure. The length of the second metatarsal was determined at 5–7 cm in women who wore high heels and at 3–5 cm in women who wore low-heeled shoes. The above conclusions confirm the results of the present study.

Naseer et al. [19] reported significant differences in lateral talar-first metatarsal angle in women who wore high heels regularly. Their results suggest that wearing heels for even less than two years can cause changes in the longitudinal arch. However, a study of female college students who wore high heels for 7–8 hours a day did not reveal any changes in the longitudinal arch. These findings contradict the results of the present study.

The problem of high heels was also addressed by Chen et al. [3], who compared the impact of of heel height on postural stability and functional mobility in inexperienced and experienced high heel shoe wearers. They found that perceived stability and functional mobility decreased when wearing high heels. During dynamic perturbations, the percentage of ankle strategies and motor control strategies was higher in women who wore 3.9-cm-high heels than in flat shoe wearers. Experienced high heel wearers used a higher percentage of ankle strategies and COG directional control in postural control than novices. In addition, experienced wearers achieved greater postural stability and demonstrated better functional mobility. The influence of high heels on experienced and inexperienced high heel wearers was examined by Lee et al. [14]. They observed that novices altered lower limb joint angles and moments to achieve balance during gait while carrying an asymmetrical load.

The present study demonstrated that high heels affect body balance, and similar observations were made by Shang et al. [23], who found that young women developed different gait adjustments when climbing stairs in high-heeled and flat shoes. To stabilize body posture during stair ascent in high-heeled shoes with a small heel base area, compensatory changes were needed to drive an effective motor response, including an increase in the pelvic range of motion in the transverse and sagittal planes, and changes in the joint angles of the lower extremities.

Team sports such as soccer increase the risk of sole disorders and forefoot overload, which leads to discomfort and compromises performance. Excessive forefoot load causes high plantar pressure in both men and women [8]. Similar observations were made in this study, where a relationship was found between forefoot load and walking in high-heeled shoes, comparable with that noted in soccer players.

Jaszczur-Nowicki et al. [9] analyzed changes in postural balance and plantar pressure distribution under the influence of various factors. In a study of children wearing backpacks, significant differences ($p < 0.05$) in plantar pressure distribution were reported in forefoot and midfoot regions of the left foot. *P*-values were below 0.05 in forefoot and midfoot regions of the right foot. Jaszczur-Nowicki et al. [9] conducted a similar study on university students and compared forefoot load values at rest and after physical exertion. The results were similar to those noted in the study of children wearing backpacks, and physical exertion increased the load on the feet. Significant differences ($p < 0.05$) in plantar pressure distribution were also reported by Zawadka et al. [29], who analyzed the impact of an external load (backpack) on foot load. They observed that a backpack worn near the center of mass affected plantar pressure distribution in forefoot and rearfoot regions. In backpack wearers, the forefoot load was maximized when the arms were bent at an angle of 90°.

The negative impact of high heels was confirmed by Lin et al. [13] who studied the effects of high-heeled shoes on the sagittal- and frontal-plane knee kinetics/kinematics during gait. They demonstrated that a greater Cohen's *d*-effect (ES) at the moment of knee flexion was associated with increased heel height in high-heel wearers ($P = 0.02$) and greater body weight ($P = 0.012$).

The foot is the distal region of the lower limb which plays locomotive, supportive and load-bearing roles in the human body. Foot disorders are commonly diagnosed. Flat feet can contribute to postural deformities. High body mass increases the load on the feet and can cause the foot arch to collapse [22]. Zdunek et al. [30] confirmed the hypothesis that repeated foot overload in soccer players, fencers and wrestlers increases the risk of flat feet. The above sports disciplines act as external factors that lead to injuries and dysfunctions of the lower limbs, including feet. A literature review conducted by Mikołajczyk et al. [18] revealed a relationship between a high arch (pes cavus) and overweight and obesity.

High-heeled shoes exert similar effects. In the present study, permanent changes in gait kinematics were observed in women wearing high heels.

5. Conclusions

A considerable increase in the longitudinal arch of the foot was noted in 18 women at rest and after walking in high-heeled shoes. Normal foot biomechanics (foot arch) was observed only in one tested subject. These results indicate that prolonged wearing of high-heeled shoes induces changes in the position of foot bones, joints and muscles, thus, leading to an abnormally high plantar longitudinal arch.

The experiment revealed a significant reduction in the excessively high metatarsal arch of both feet. These observations were made based on the results of a podological test and measurements of foot surface area and the maximum and mean plantar pressure. Foot images captured before the loading test revealed high longitudinal (medial and lateral) arches of the foot in the sagittal plane. The longitudinal arches of the feet decreased directly after walking in high-heeled shoes. These results suggest that excessive stretching of the plantar facia and impaired function of the short muscles of the foot lead to a temporary decrease in the arch of the foot. This phenomenon can be compared to stretching a bowstring and its return to the shortest length under static conditions.

Further research involving electromyography tests is needed to examine plantar muscle tension during isotonic contractions. The duration of the exercise-induced reduction in pes cavus should be also determined for therapeutic purposes.

A significant difference in the ability to maintain postural balance was found with respect to the left foot barycenter, where greater instability was noted after load. High-heeled shoes force the feet into an unnatural position, and this biomechanical factor compromised postural stability, in particular, in the left leg which was the dominant (support) limb.

Limitation of the study

A limitation of this study was that regional and international beauty contests involve only a small percentage of the total female population. Therefore, in a greater study group, the results may differ. In future studies, we plan to expand our study group to include women walking in high-heeled shoes, but not participants in beauty contests.

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References

[1] BUKOWSKA J.M., JEKIEŁEK M., KRUCZKOWSKI D., AMBROŻY T., JASZCZUR-NOWICKI J., *Biomechanical aspects of the foot arch, body balance and body weight composition of boys training football*, Int. J. Environ. Res. Public Health, 2021, 18, 5017, DOI: 10.3390/ijerph18095017.

[2] BUKOWSKA J.M., JEKIEŁEK M., KRUCZKOWSKI D., AMBROŻY T., RYDZIK Ł., SPIESZNY M., JASZCZUR□NOWICKI J., *Podiatric and stabilographic examinations of the effects of school bag carrying in children aged 11 to 15 years*, Applied Sciences (Switzerland), 2021, 11, 9357, DOI: 10.3390/app11199357.

[3] CHEN Y., LI JX., WANG L., *Influences of heel height on human postural stability and functional mobility between inexperienced and experienced high heel shoe wearers*, Peer J., 2020, 8, DOI:10.7717/peerj.10239.

[4] DABOLINA I., FOMINA J., LAPKOVSKA E., SILINA L., *Selected dynamic anthropometrics and body characteristics for posture corrector fit*, Communications in Development and Assembling of Textile Products, 2020, 1, 96–103. DOI: 10.25367/cdatp.2020.1.p96-103.

[5] DENG J., NING L., *Effects of high heels on plantar stress in women*, Proceedings of International Conference on Artificial Life and Robotics, 2021, DOI: 10.5954/icarob.2021.os12-15.

[6] GAJDOS M., JANDOVA S., LENKOVA R., VADASOVA B., CUJ J., MIKULAKOVA W., NECHVATAL P., *Perceived changes in the university students' health behavior after participating in the study on wearing high-heeled shoes*, Physical Activity Review, 2020, 8, 104–112. DOI: 10.16926/par.2020.08.12.

[7] HAMANDI S.J., RUKEN DM., *Biomechanical study with kinematic and kinetic descriptions of the effect of high-heeled shoes in healthy adult females based on gait analysis*, IOP Conf. Ser. Mater. Sci. Eng., 2020, 671, DOI: 10.1088/1757-899X/671/1/012063.

[8] HUSAIN E., ANGIOI M., MEHTA R., BARNETT D.N., OKHOLM KRYGER K., *A systematic review of plantar pressure values obtained from male and female football and the test methodologies applied*, Footwear Sci., 2020, 12, 217–233. DOI: 10.1080/19424280.2020.1791977.

[9] JASZCZUR-NOWICKI J., BUKOWSKA J., KRUCZKOWSKI D., SPIESZNY M., PIENIĄŻEK M., MAŃKO G., *Analysis of students' foot pressure distribution on the ground, as well as their body balance before and after exercise*, Physical Education of Students, 2020, 24, DOI: 10.15561/20755279.2020.0402.

[10] KUMAR N., PANDA S.N., KAUSHAL RK., *High heel shoes with adjustable height of the heel*, IOP Conf. Ser. Mater. Sci. Eng., 2020, 993, DOI: 10.1088/1757-899X/993/1/012120.

[11] KUROS F., *Wysokie obcasy najczęstszą przyczyną nabytych deformacji i dolegliwości bólowych w obrębie stóp u kobiet*, Kosmetologia Estetyczna, 2020, 9, 177–182 (in Polish).

[12] LEE M.-W., JEONG Y.-W., *An Analysis of the Correlation between High Heels and Pain in the Low Back, Knee, Ankle and Toe, Length of Legs, and Plantar Pressure among Women in Their Twenties. 2)*, The Journal of Korean Orthopedic Manual Physical Therapy, 2020, 26, 11–18 (in Korean).

[13] LEE S.H., LIN B.S., LEE H.C., HUANG X.W., CHI Y.C., LIN B.S., ABE K., *Artificial intelligence-based assessment system for evaluating suitable range of heel height*, IEEE Access, 2021, 9, DOI: 10.1109/ACCESS.2021.3063912.

[14] LEE S., XU M., WANG L., LI JX., *Effect of high-heeled shoes on balance and lowerextremity biomechanics during walking in experienced and novice high-heeled shoe wearers*, J. Am. Podiatr. Med. Assoc., 2020, 110, DOI: 10.7547/17-185.

[15] MALICK W.H., KHALID H., MEHMOOD Z., HUSSAIN H., *Association of musculoskeletal discomfort with the use of high heeled shoes in females*, J. Pak. Med. Assoc., 2020, 70, DOI: 10.47391/JPMA.536.

[16] MELVIN J.M.A., PRICE C., PREECE S., NESTER C., HOWARD D., *An investigation into the effects of, and interaction between, heel height and shoe upper stiffness on plantar pres-*

sure and comfort, Footwear Sci., 2019, 11, DOI: 10.1080/19424280.2018.1555862.

[17] MESKÓ N., ŐRY F., CSÁNYI E., JUHÁSZ L., SZILÁGYI G., LUBICS O., PUTZ., LÁNG A., *Women walk in high heels: Lumbar curvature, dynamic motion stimuli and* Environ. Res. Public Health, 2021, 18, DOI: *attractiveness*, Int. J. 10.3390/ijerph18010299.

[18] MIKOŁAJCZYK E., JANKOWICZ-SZYMAŃSKA A., SMOŁA E., *Characteristics of foot arches and foot pressure distribution in 10–11--year-old male soccer players*, Journal of Kinesiology and Exercise Sciences, 2018, 28, DOI: 10.5604/01.3001.0013.6498.

[19] NASEER S., BABU R., PANJALA A., ARIFUDDIN M., MANFUSA H., RAO E., *Comparison of medial longitudinal arches of the foot by radiographic method in users and nonusers of high-heeled footwear among young women*, J. Anat. Soc. India, 2021, 70, DOI: 10.4103/jasi.jasi_202_20.

[20] NGUYEN L.Y., HARRIS K.D., MORELLI K.M., TSAI L.C., *Increased knee flexion and varus moments during gait with high-heeled shoes: A systematic review and meta-analysis*, Gait Posture, 2021, 85, DOI: 10.1016/j.gaitpost.2021.01.017.

[21] POLAT S., KABAKCI A.G., *The effects of wearing high heeled shoes on the muscles and joints of lower limb*, Biomed. Hum. Kinet., 2021, 13, 81–96. DOI: 10.2478/bhk-2021-0011.

[22] ROSENDE-BAUTISTA C., MUNUERA-MARTÍNEZ P.V., SEOANE--PILLADO T., REINA-BUENO M., ALONSO-TAJES F., PÉREZ-GARCÍA S., DOMÍNGUEZ-MALDONADO G., *Relationship of body mass index and footprint morphology to the actual height of the medial longitudinal arch of the foot*, Int. J. Environ. Res. Public Health, 2021, 18, DOI: 10.3390/ijerph18189815.

[23] SHANG J., CHEN L., ZHANG S., ZHANG C., HUANG J., WANG X., YAN A., MA X., *Influence of high-heeled shoe parameters on biomechanical performance of young female adults during stair ascent motion*, Gait Posture, 2020, 81, DOI: 10.1016/j.gaitpost.2020.07.065.

[24] DI SIPIO E., PICCININI G., PECCHIOLI C., GERMANOTTA M., IACOVELLI C., SIMBOLOTTI C., CRUCIANI A., PADUA L., *Walking variations in healthy women wearing high-heeled shoes: Shoe size and heel height effects*, Gait Posture, 2018, 63, 195–201, DOI: 10.1016/j.gaitpost.2018.04.048.

[25] WAN F.K.W., YICK K.L., YU W.W.M., *Effects of heel height and high-heel experience on foot stability during quiet standing*, Gait Posture, 2019, 68, DOI: 10.1016/j.gaitpost.2018.12.004.

[26] WANG M., JIANG C., FEKETE G., TEO EC., GU Y., *Health View to Decrease Negative Effect of High Heels Wearing: A Systemic Review*, Appl. Bionics Biomech., 2021, DOI: 10.1155/2021/6618581.

[27] WANG M., LI S., TEO EC., FEKETE G., GU Y., *The Influence of Heel Height on Strain Variation of Plantar Fascia During High Heel Shoes Walking-Combined Musculoskeletal Modeling and Finite Element Analysis*, Front. Bioeng. Biotechnol., 2021, 9, DOI: 10.3389/fbioe.2021.791238.

[28] YIN C.M., PAN X.H., SUN Y.X., CHEN Z BIN., *Effects of duration of wearing high-heeled shoes on plantar pressure*, Hum. Mov. Sci., 2016, 49, 196–205. DOI: 10.1016/j.humov.2016.06.005.

[29] ZAWADKA M., KOCHMAN M., SOBIECH M., GRUDZIEŃ O., *Wpływ zewnętrznego obciążenia na amplitudę przemieszczenia środka nacisku oraz rozkład nacisku stóp* (*Influence of external load on sway amplitude and foot pressure distribution*), [in:] M. Maciąg, K. Maciąg (Eds.), *Przegląd badań z zakresu fizjoterapii*, Wydawnictwo Naukowe TYGIEL sp. z o.o., ul. Głowackiego 35/341, 20-060 Lublin, www.wydawnictwo-tygiel.pl, 2019, 105–113.

[30] ZDUNEK M.K., MARSZAŁEK J., MOLIK B., *Influence of sport discipline on foot arching and load distribution: Pilot studies*, Journal of Physical Education and Sport, 2020, 20, DOI: 10.7752/jpes.2020.02104.

[31] ZEIDAN H., KAWAGOE M., KAJIWARA Y., HARADA K., NISHIDA Y., YAMADA K., KAWABE R., YOKOTA J., YAMASHIRO C., ODAKE Y., TAKEDA M., DOI N., NEGORO K., MATSUMURA N., MORINO T., YOSHIOKA CKB., CHEN CY., AOYAMA T., *The shape of the transverse arch in high heels while standing*, PLoS One, 2020, 15, DOI: 10.1371/journal.pone.0233958.