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Influence of different safety shoes on gait and plantar pressure: a standardized examination of workers in the automotive industry

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Abstract:

Objective: Working conditions, such as walking and standing on hard surfaces, can increase the development of musculoskeletal complaints. At the interface between flooring and musculoskeletal system, safety shoes may play an important role in the well-being of employees. The aim of this study was to evaluate the effects of different safety shoes on gait and plantar pressure distributions on industrial flooring.

Methods: Twenty automotive workers were individually fitted out with three different pairs of safety shoes (“normal” shoes, cushioned shoes, and midfoot bearing shoes). They walked at a given speed of 1.5 m/s. The CUELA measuring system and shoe insoles were used for gait analysis and plantar pressure measurements, respectively. Statistical analysis was conducted by ANOVA analysis for repeated measures.

Results: Walking with cushioned safety shoes or a midfoot bearing safety shoe led to a significant decrease of the average trunk inclination ($p < 0.005$). Furthermore, the average hip flexion angle decreased for cushioned shoes as well as midfoot bearing shoes ($p < 0.002$). The range of motion of the knee joint increased for cushioned shoes. As expected, plantar pressure distributions varied significantly between cushioned or midfoot bearing shoes and shoes without ergonomic components.

Conclusion: The overall function of safety shoes is the avoidance of injury in case of an industrial accident, but in addition, safety shoes could be a long-term preventive instrument for maintaining health of the employees’ musculoskeletal system, as they are able to affect gait parameters. Further research needs to focus on safety shoes in working situations.

Key words: body posture, gait analysis, plantar pressure, safety shoes

1. Introduction

To prevent occupational injuries, many workers have to wear safety shoes for approximately 8 hours per day, 5 days a week. In a review on occupational footwear, Johnson[1)] stated that the main causes of foot problems while wearing safety shoes were prolonged standing and walking on hard floors, shoes that do not fit correctly, and a habitual wearing of the wrong shoes. However, footwear in general and safety footwear in particular can also have an effect on gait, as it can affect joint movements and plantar pressures and hence moments and forces.[2-5)] Although gait, and particularly gait abnormalities, are of scientific concern in occupational medicine, the influence of different safety shoes on gait and plantar pressures has not yet been extensively examined.

During a gait cycle, the heel lands on the floor with a force up to two times that of the body weight. The shock transmission from heel impact increases with the hardness of the floor; it can cause microscopic damage in bone and cartilage tissue and can, in the worst case, accumulate and result in injury.[1,6)] To diminish the transmission of unnecessary high forces from the floor to the musculoskeletal system, it is important to choose the right footwear at the interface between floor and body, as well as the right footwear for safety.

Unfortunately, most studies regarding safety shoes only refer to questionnaires to assess acceptance and foot problems.[7-10)] An investigation of 321 Australian workers by Marr and Quine[8)], for example, revealed that safety footwear caused new foot problems or negatively affected existing ones in 91% of the workers. The problems mentioned among others were painful feet (49%) and callouses (33%). Other concerns regarding the safety shoes were mainly associated with excessive heat (65%), inflexible soles (52%), weight (48%), and pressure from the steel toe cap (47%). Although the acceptance of safety shoes and self-reported foot problems are important issues, more far-reaching aspects, such as the effect of safety footwear on the musculoskeletal system, and hence the question if choosing the “right” safety shoe can affect musculoskeletal problems, have not yet been extensively examined in the occupational setting.

Therefore, the aim of this study was to investigate the influence of different safety shoes on body angles, joint movements, and plantar pressure distribution with an instrument that can be used directly at the workplace.

2. Methods

2.1 Subjects

Twenty male workers [age: 33.2 ± 10.5 years, height: 177.9 ± 3.9 cm, weight: 80.1 ± 7.8 kg, median foot size: 27.8 cm (min: 26 cm, max: 28.7 cm)] from the automotive industry (plant operators, plumbers, and quality control inspectors) volunteered for this study and provided informed written consent. All participants had no history of foot pain, were free of injuries, and did not complain about pain or disorders of the lower extremities and back for at least 6 months prior to the begin of the study. Employees at these workplaces are mainly exposed to standing and walking. All employees provided informed consent.

2.2 Safety shoes

Three different types of safety shoes were examined in this study (Figure 1). The first safety shoe (shoe 1, “normal” shoe) was a low priced shoe with a flat rubber sole and without any special ergonomic features. The second safety shoe (shoe 2, “cushioned shoe”) was characterized by forefoot cushioning as well as a bodyweight-adjustable cushioning element in the heel area. Furthermore, shoe 2 was available in four different widths from small to extra wide. The third safety shoe (shoe 3, rocker-bottom shoe) had a curved sole in the anterior-posterior direction.

-- Figure 1--

2.3 Measuring instrument (CUELA system supplemented by plantar pressure soles)

Body postures, joint angles, and body movements were measured with the CUELA system ("Computer-unterstützte Erfassung und Langzeitanalyse des Muskel-Skelett-Systems," a computer-assisted recording system, which allows the long-term analysis of musculoskeletal loads at the workplace).[11-14] This person-centered measuring system consists of motion sensors (3D accelerometers Analog Devices ADXL 103/203, gyroscopes muRata ENC-03R, and goniometers), which are attached to the body by Velcro®-fasteners over clothing or workwear (Figure 2). A small data logger (using a flash memory card) enables the synchronous recording of all measured data of gait and plantar pressure distribution at a sampling rate of 50 Hz.

Simultaneously to the kinetic assessment of the lower extremities, plantar pressure was measured using the in-shoe pressure measurement system paroTec® (Paromed, Germany), which consists of reusable insoles with a height of 3 mm in different sizes (European 31–48). The insoles hold 24 piezoresistive pressure sensors on each sole at biomechanically relevant measuring points (Figure 3) and are fit into the respective shoe.

The CUELA software is able to display data (in this case kinetic and plantar pressure data) simultaneously to the measurements with a 3D animated figure and a digitalized video of the measurements.[15)] These features were used for the analysis of the measurements, where one examiner analyzed the recorded measurements.

-- Figure 2 --

-- Figure 3 --

2.4 Experimental design

After an individual fitting, all participants received one pair of each study shoe and were obliged to wear each type of shoe for at least two weeks at their workplaces prior to the respective measurements (habituation phase).

After fitting the CUELA motion sensors and the associated shoe insoles, the insoles were calibrated in compliance with the manufacturer’s guidelines, and the CUELA system was initialized. Standing upright (relaxed) was used as the reference posture and all angles in this position were defined as 0°. Insole calibrations and initializations of the CUELA system were made before each measurement.

Motion and plantar pressure measurements were conducted on participants, who were equipped with the CUELA system and instructed to walk at a defined speed of 1.5 m/s (controlled by a metronome) along a 10 m level walkway (according to the protocol of Perry and Burnfield16)). Each participant performed one trial per pair of shoes and hence was measured altogether three times (in-between time intervals: approximately four weeks, because of the prior habituation phase (as described above)). The level walkway was typical industrial concrete and made of magnesite screed.

The study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2000.17)

2.5. Outcome parameters

Gait: The following joint angles were assessed by CUELA measurements to describe motion during gait (Figure 2):

- Trunk inclination angle: the sagittal inclination angle of the thoracic (T3) and lumbar spine (L5)
- Hip flexion angles: the angle between pelvis axis and thigh axis in sagittal plane (left and right hip)
- Knee flexion angles: the angle between thigh axis and lower leg axis in sagittal plane (left and right knee)

Fiftieth percentiles (50th), and the Range of Motion (RoM; i.e., the difference between the 5th and the 95th percentile) were calculated.

Plantar pressure: To localize areas of maximum pressure, the insoles were divided in eight zones (zone 1: heel–zone 8: toes) with two to four measure points. The mean value and standard deviation (SD) of the two most loaded measuring points per zone were calculated and used for further analysis. In addition, the course of the center of pressure (CoP) in posterior-anterior and medial-lateral direction was analyzed to describe the rolling characteristics of the participants' feet in the respective shoes (fiftieth percentiles (50th), and Range of Motion (RoM; i.e., the difference between the 5th and the 95th percentile) (Figure 2).

2.5 Data processing and statistics

After aligning the measurements and the video-documentation of the walk, five steps of both feet from the middle of the walking distance were selected and averaged for each subject. These data were processed by the CUELA software to calculate motion variables and plantar pressure values during the gait cycle. Initial descriptive statistical evaluation was also conducted with the CUELA software.11) The SPSS® software (IBM, Version 23.0) was used for further statistical analyses. ANOVA analyses for repeated measures (General Linear Model, GLM) were applied to motion data and plantar pressure values to determine the changes in gait and pressure with regard to different safety shoes and different zones of the insole (zones 1–8). Post-hoc multiple comparisons were performed using the LSD (Least Significance Difference) technique with the level of significance being set at $p < 0.05$.

3. Results

3.1 Motion analysis - gait

Walking in the three different safety shoes resulted in statistically significant differences in gait measurements (Table 1).

The 50th percentile of trunk inclination and hip flexion differed significantly between shoes, particularly between “normal” shoe 1 and the other two shoes. With regard to knee flexion, there were no statistically significant differences in the 50th percentile between the three different shoes.

The three different shoes showed approximately the same RoM of trunk inclination (~19°) and approximately the same RoM of hip flexion (~30°), but the RoM of knee flexion differed significantly between the three shoes. Particularly shoe 2 seemed to cause a slightly larger RoM when compared to shoes 1 and 3. This might be associated with an increased step length.

-- Table 1 --

3.2 Plantar pressure distribution and CoP

Maximum plantar pressure values differed with regard to shoe and with regard to the zone of measurement. From heel to toe, shoe 1 (“normal” shoe) caused the highest pressures in zones 1 and 2 (heel area) as well as in zone 7 (forefoot), whereas it showed the lowest pressures in the middle area of the foot (zones 3–5). The pressure in the middle area of the foot was relatively low for all three shoes, which is in accordance with the natural course of walking. With regard to the forefoot (zones 6–8), all shoes showed their respective maximum pressure in zone 7. Nevertheless, the pressure maximum values differed significantly between the shoes ($p < 0.001$). Furthermore, the pressure maximum in zone 6 was found for shoe 2 (cushioned shoe), in zone 7 for shoe 1 (“normal” shoe), and in zone 8 for shoe 3 (rocker bottom shoe; Table 2), implying differences in the rolling motion.

The RoM of the CoP showed different lengths in posterior-anterior direction with regard to the different shoes. The longest course of the CoP was found for shoe 1 (159.5 mm), followed by shoe 2 (149.1 mm) and then shoe 3 (143.7 mm) ($p < 0.001$). The RoM of the CoP also differed significantly in medial-lateral direction between the different shoes ($p = 0.003$), particularly with regard to shoe 3 (Table 2). Overall, post-hoc tests suggest that the pressure distribution over the pre-defined foot zones was more heterogeneous in “normal” shoe 1 compared to shoes 2 and 3 (Table 2).

-- Table 2 --

4. Discussion

The purpose of the present study was to analyse the effects of three different safety shoes on motion and plantar pressure during gait at a predefined velocity of 1.5 m/s on a 10 m level walkway with a smooth surface made of industrial concrete. It should be mentioned that the measuring system we used allows for the simultaneous measurement of kinetics and plantar pressure at workplaces. We found that wearing different safety shoes led to differences in gait, namely trunk inclination, hip angle, and knee range of motion as well as anticipated differences in plantar pressure distribution.

Motion analysis - gait

Winter et al.[18)] measured RoMs during a completed stride cycle while walking with a natural cadence and reported a RoM of 32.79° for the hip joint and a RoM of 64.86° for the knee joint. This study found a slightly lower RoM of the hip joint and knee joint when wearing “normal” shoe 1, which could be associated with the fact that the participants were supposed to adapt their cadence to a predefined speed of 1.5 m/s. Surprisingly, the RoM of trunk inclination of the male participants in “normal” shoe 1 (19°) was more than twice as high as the RoM of female participants walking at approximately the same speed in normal sports shoes (9°) in a study of Li and Hong.[19)] This suggests that the movement of the upper body was more pronounced in our cohort of male workers. This difference might be due to the shoes, due to a gender difference or, eventually, due to a selection bias. Unfortunately, our cohort did not include women, while the cohort of Li and Hong did not include men. Therefore, the question of gender differences needs to be addressed in future examinations.

In comparison to “normal” shoe 1, “cushioned” shoes 2 and rocker-bottom shoe 3 led to a relative backward tilt of the upper body (when regarding the mean value of the 50th percentile of trunk inclination). Li and Hong[19)] also reported a backward shift of trunk orientation when wearing negative-heeled shoes, a finding that is reflected in our results, as shoe 3 can be roughly described as having a negative heel. Similarly, other authors[20)] have found a backward shift of the trunk when participants wore rocker-bottom shoes. Surprisingly though, the cushioned shoe (shoe 2) showed approximately the same backwards shift of trunk inclination. In ergonomic workplace evaluation, trunk inclination is often used to characterize back loading.[21, 22)] While a forward lean of the trunk is believed to lead to postural strain and to be associated with back problems[23, 24)], the backward shift while wearing shoes 2 or 3 might be beneficial for preventing back problems at the workplace.

The alterations in trunk inclination were accompanied by a decreased median hip flexion for shoes 2 and 3. The findings with regard to shoe 3 are in accordance with findings of Romkes et al.[25)] and Nigg et al.[26)], who examined rocker-bottom shoes in general and found a reduction of peak hip flexion and peak hip extension when compared with walking in shoes with a normal sole geometry. In contrast to the present study, subjects in the study of Romkes et al. were free to choose their own walking speed and therefore walked significantly slower due to a smaller stride length as well as a slight reduction in cadence. Again, the cushioned shoe 2 showed a similar influence on the gait pattern to shoe 3. Measurements have shown that lumbar vertebral posture is largely secondary to the postural relationship between the trunk and the hips[27)]; therefore, a reclined trunk combined with decreased median hip flexion might also be able to prevent the occurrence of back complaints, as the angle between hip and trunk might be more stable.

Participants wearing “normal” shoe 1 showed a smaller RoM of the knee joint (62.3°) than the participants in the study of Winter (64.9°),[18] but also compared to the participants in the study of Li and Hong[19], who wore sports shoes (66.0°). Though the cushioned shoe 2 led to a significantly larger RoM of knee flexion (RoM shoe 2 = 64.0°), it was still slightly lower than the RoM found by Li and Hong. Larger RoMs of the knee joint are believed to be associated with an increased stride length,[28, 29] and increased stride lengths increase ground reaction forces.[30] Nigg und Denoth (1980) showed for running subjects that these forces that function along the leg-axis are, in part, dependent on body mass and knee angle at contact,[31] which might be why persons with lower back problems avoid increased stride lengths.[32, 33] Apart from ground reaction forces, stride length was also found to be associated with larger spinal rotations, a larger thorax-pelvis relative phase, and a lower pelvis-leg relative phase, while the thorax continues to counter-rotate with respect to the leg.[33] As cushioned shoes allow for increased stride length in healthy subjects, one could argue that cushioned shoes might also be beneficial for employees with episodes of back pain because they seem to reduce ground reaction forces and spinal rotation at normal stride length. However to the knowledge of the authors, this assumption has not yet been proven right. Furthermore, recent studies contradict the association between RoM of the knee and stride length and claim that stride length is rather associated with shoe weight, hip RoM, and rotational movements of the pelvis.[35]

Plantar pressure distribution

Different shoes led to differences in the distribution of peak plantar pressures. The highest peak pressures in the rear and forefoot area were measured when wearing shoe 1, which lacks additional cushioning elements; alternatively, these differences are associated with the differences in gait. Nevertheless, comparative studies have demonstrated that cushioning materials in safety shoes are advantageous when trying to reduce plantar pressure.(2, 9, 36) Due to a forefoot and rear foot cushioning element, shoe 2 showed lower pressure values with the exception of zone 6. In this area there was a transition area of the insole where a low shaped pad and a graphite point for electric static discharge were placed. This construction of the insole might have caused the high pressure values at a critical point, where the metatarsophalangeal joint is positioned. As higher pressure in the metatarsal region was found to be associated with foot/ankle disorders,37) this finding is dissatisfying and the shoe construction should be altered. Additionally shoe 2 was associated with an increase in the RoM of the knee, which might in turn lead to longer steps. An increase in stride length was found to be associated with an increase in plantar pressure;38) therefore, the cushioning effect of shoe 2 might have been even more pronounced when controlling for the step length. Plantar pressure distributions in shoe 3 were more equally distributed to the three foot regions (rear, middle, and forefoot), with the exception of zone 8 (toes), where maximum pressure values were significantly higher in shoe 3 (rocker-bottom shoe) than in the other shoes. These results are explained by the findings of Stewart et al.39) that the sloping design of the shoe base displaces the weight away from the heel. The lower pressure values under the midfoot and heel were a result of the shift in weight towards the front end of the foot. Accordingly, the CoP in posterior-anterior direction was clearly shorter when walking in shoe 3 (rocker-bottom shoe), and the first heel contact was closer to midfoot. This suggests that the rear foot is only briefly in contact with the surface.[26, 39] Shoe 3 also showed the shortest distance with regard to the medial-lateral CoP. As patients with knee osteoarthritis were found to have more lateral loading when compared with the CoP patterns of healthy subjects,[40] it would be expected that longer medial-lateral CoPs might not be beneficial for employees suffering from knee problems. In this context, Nigg et al.[41] reported pain reduction in patients with moderate knee osteoarthritis when wearing MTB shoes, which showed the shortest medial-lateral CoP in this study. The effects of an increase in medial-lateral direction are unclear from a preventive point of view though.

A limitation of the present study is the small pool of participants, whose results have to be interpreted carefully and do not yet allow for generalization. Another issue which needs to be discussed is the weight of the measuring system, as it might influence gait and plantar pressures. The CUELA system weighs three kilograms, which is a small weight compared to the body weight of the participants (approx. 3%–5% of the body weight). Furthermore, the weight of the system is distributed around extremities, with the main weight gathered around the waist (data logger). Therefore, the center of mass of the system is close to the center of mass of the body and therefore is not prone to influence body movements and particularly gait, as well as the distribution of plantar pressures, though the maximum plantar pressure might be slightly higher than in experiments with optical measurement systems. Future comparisons might be beneficial to prove this opinion.

All our measurements were carried out at the workplace, where the gold standard of gait analysis (three-dimensional infrared measuring systems) was not available, and we had to fall back to the mobile, robust CUELA system. The calibration of the insoles was conducted according to the manufacturer's instructions and the initialization of the CUELA system was carried out in a neutral body posture with no further means to control for the different shoes (e.g., stabilometers). Although this approach was similar to that of other authors,42) some doubt remains about the absoluteness of this initial "calibration," particularly with regard to the rocker-bottom shoe. Nevertheless, we assume that our initialization is sufficient for the comparisons conducted in this study, as our results are in accordance with the results of other researchers42) and in accordance with a recent systematic review.43)

Yet another aspect should be discussed, namely that this study about safety shoes bases on a "standardized" movement, i.e., walking on a plane surface at a given speed. Safety shoes should be examined at the workplace, where differences between the shoes might be more noticeable compared to measurements in standardized situations. Here lies the advantage of "field systems," e.g., the CUELA systems, which can be used in standardized situations as well as in laboratory settings. Note though that future examinations at the workplace should be adjusted for age, weight, foot size, and step length.

5. Conclusions

The key findings of this study are that different safety shoes can alter gait and plantar pressure distribution. Walking in a simple safety shoe without any special ergonomic features led to an increase of the trunk inclination angle and hip flexion angle and to higher plantar pressure loadings compared to safety shoes with cushioning elements and ergonomic designed outsoles. Hence, “normal” safety shoes might theoretically be associated with adverse health effects for healthy employees (e.g., an increased prevalence of back problems) and might have adverse effects for employees with existing medical conditions of the back and/or the lower extremities. The influence of these alterations in posture and their effect on the occurrence of work-related musculoskeletal disorders needs to be addressed and examined in more detail, preferably in longitudinal studies. Nevertheless, the current results point at the possibility that the choice of safety shoes might be a means to prevent negative health effects in workers, particularly with regard to the musculoskeletal system and in work environments when prolonged standing and walking on hard surfaces occurs frequently. Therefore, safety shoes are not only a part of the personal protective equipment to avoid injury in case of an industrial accident, but can possibly be a long-term preventive instrument for maintaining the health of the employees.

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7. Competing interests

The authors declare that they have no competing interests.

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characteristics	shoe 1	shoe 2	shoe 3
safety class	S1	S1	S2
safety cap	steel	aluminium	steel
weight (per shoe, size 43)	530 g	630 g	720 g
different widths	no	yes	no
cushioning	little	foretfoot, heel	heel
insole	no	yes	yes
treadsole	PUR (polyurethane)	TPU (thermoplastic polyurethane)	PUR/TPU
ergonomic specifics	none	weight-dependent vario® heel absorption, exchangeable	rocker-bottom sole construction
price	15 EUR	60 EUR	230 EUR

Figure 1: Pictures and characteristics of the three different safety shoes 1 – 3 (from left to right)

Figure 2: Front and back view of the CUELA measuring system and stick figure to demonstrate the outcome parameters for gait (Note: the direction of the arrows shows the positive direction of the outcome parameter)

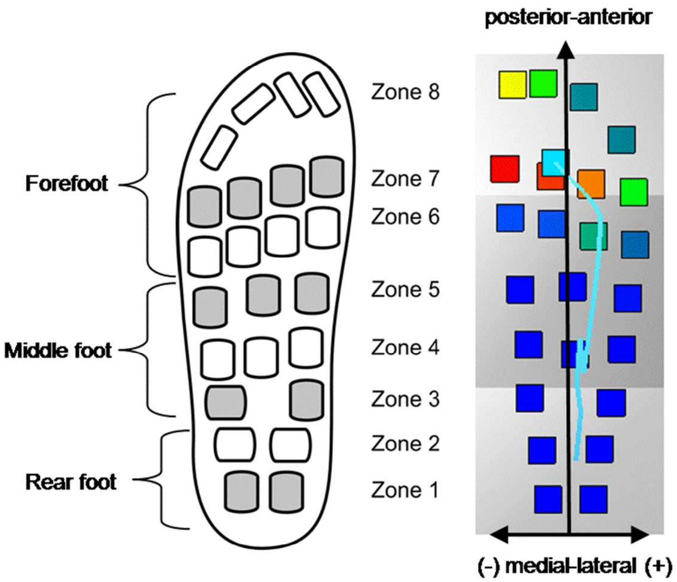

Figure 3: Classification of the pressure measurements in eight insole zones (left) and the corresponding plantar pressure distribution with the course of the center of pressure (CoP) (right)

Table 1: Mean values ± standard deviation and p values of different percentiles for trunk inclination, hip flexion angles and knee flexion angles during walking (speed 1.5 m/s) in three different safety shoes

Parameter and percentile values	**Shoes**			**p values**			
	1	**2**	**3**	**all shoes (GLM)**	**posthoc 1 vs. 2**	**posthoc 1 vs. 3**	**posthoc 2 vs. 3**
Trunk inclination [°]							
50th	8.9 ± 2.2	6.7 ± 3.5	5.9 ± 2.4	<0.001	0.005	<0.001	0.146
95th-5th (RoM)	19.2 ± 2.0	19.0 ± 2.4	18.9 ± 2.1	0.438	0.323	0.254	0.942
Hip flexion [°]							
50th	14.0 ± 3.6	11.5 ± 3.9	10.2 ± 2.8	<0.001	0.015	0.001	0.046
95th-5th (RoM)	30.6 ± 4.0	30.4 ± 4.1	30.1 ± 3.8	0.443	0.590	0.273	0.374
Knee flexion [°]							
50th	15.6 ± 3.2	15.3 ± 4.0	14.9 ± 3.5	0.525	0.628	0.316	0.455
95th-5th (RoM)	62.3 ± 3.4	64.0 ± 3.6	62.0 ± 4.3	0.003	0.008	0.695	<0.001

Table 2: Mean values ± standard deviation and p values of the maximum pressure and the Center of Pressure (CoP) during walking (speed: 1.5 m/s) in three different safety shoes

Parameter and percentile values	**Shoes**			**p values**			
	1	**2**	**3**	**all shoes (GLM)**	**posthoc 1 vs. 2**	**posthoc 1 vs. 3**	**posthoc 2 vs. 3**
Maximum pressure [mean ± SD; N/cm²]							
Zone 1	27.9 ± 3.1 *$^{1-2}$	24.2 ± 2.0 *$^{1-2}$	24.2 ± 2.9 *$^{1-2}$	<0.001	<0.001	<0.001	0.507
Zone 2	19.7 ± 3.1 *$^{2-3}$	14.4 ± 2.6 *$^{2-3}$	18.1 ± 2.7 *$^{2-3}$	<0.001	<0.001	0.083	<0.001
Zone 3	4.7 ± 1.3 *$^{3-4}$	5.5 ± 1.0 *$^{3-4}$	5.6 ± 1.1 $^{\text{ns } 3-4}$	0.002	0.002	0.005	0.555
Zone 4	2.8 ± 0.7 $^{\text{ns } 4-5}$	4.5 ± 1.2 $^{\text{ns } 4-5}$	5.2 ± 1.5 *$^{4-5}$	<0.001	<0.001	<0.001	0.002
Zone 5	2.9 ± 0.9 *$^{5-6}$	4.7 ± 1.5 *$^{5-6}$	4.0 ± 1.1 *$^{5-6}$	<0.001	<0.001	<0.001	0.002
Zone 6	12.0 ± 5.7 *$^{6-7}$	17.9 ± 5.9 $^{\text{ns } 6-7}$	14.0 ± 5.3 *$^{6-7}$	<0.001	<0.001	0.057	<0.001
Zone 7	25.0 ± 4.0 *$^{7-8}$	22.9 ± 3.4 $^{\text{ns } 7-8}$	20.9 ± 3.4 $^{\text{ns } 7-8}$	<0.001	0.003	<0.001	<0.001
Zone 8	17.7 ± 6.8	17.1 ± 6.4	19.8 ± 4.9	0.035	0.439	0.091	0.025
CoP: posterior-anterior [mean ± SD; mm]							
50th	144.3 ± 16.8	143.3 ± 15.1	140.9 ± 13.0	0.487	0.759	0.252	0.388
95th-5th	159.5 ± 10.8	149.1 ± 10.3	143.7 ± 10.5	<0.001	<0.001	<0.001	0.003
CoP: medial-lateral [mean ± SD; mm]							
50th	2.0 ± 1.7	3.5 ± 2.0	2.0 ± 2.0	<0.001	<0.001	0.926	0.002
95th-5th	22.1 ± 5.1	22.2 ± 4.7	20.2 ± 4.7	0.003	0.836	0.022	0.001

SD: standard deviation; * $^{1-2}$: signifies significant post-hoc tests between maximum pressures of zone 1 and zone 2, * $^{2-3}$ signifies a statistically significant post hoc test between zone 2 and zone 3, etc. ; $^{\text{ns } 4-5}$ signifies a non-significant post-hoc test between maximum pressures of zones 4 and 5, etc.; Note: non-significant changes stand for a more homogeneous passage between different zones of the foot during gait