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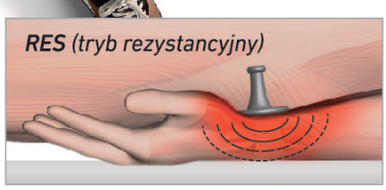

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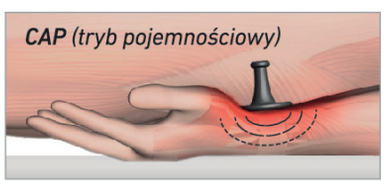

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Changes in body balance due to exposure to trauma – multi-center studies

Zmiany w równowadze ciała spowodowane narażeniem na urazy – badania wieloośrodkowe

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Abstract

Aim. The purpose of the study was to assess the impact of a traumatic event experienced by the subject on postural balance and biomechanical parameters of gait.

Research methodology. The study involved 31 people (n = 100%), including 22 women (nk% = 70.97%), 9 men (nm% = 29.03), aged 29-60. People with diseases and dysfunctions affecting body balance and gait pattern were excluded from the study.

Balance and gait tests were performed using pedobarography (pedobarograph mod. EPS R2, Biomech Studio v2 software). The balance test was performed while standing, for 20 seconds, with sampling every 1 ms (millisecond) – the number of samples during one test is 20,000. The balance and gait assessment tests were performed twice. Test I included testing in neutral conditions, Test II included testing in conditions in which the subject was exposed to a traumatic event he or she had experienced in the past (so-called exposure to "experienced trauma").

Results. The obtained results of studies on the impact of exposure to experienced trauma on body balance while standing showed significant differences in body fluctuations in the most important parameters of stabilometric assessment.

The obtained results of research on the impact of exposure to trauma on the subject's gait showed no significant differences between the test in neutral conditions and the test during exposure.

Conclusions. (1) Exposure to the trauma experienced by the subject significantly affects the body's balance in a standing position. (2) The research showed no influence of exposure to the experienced trauma on the subject's gait in the area of the time of contact of the feet with the ground and on the values of maximum and average pressure; The area of the plane where the feet are placed on the ground changes significantly before and after exposure to the trauma experienced by the subject. (3) In research on the impact of trauma on body posture, detailed results of studies on the range of COP fluctuations in each plane should be taken into account – the study showed that the analysis of only average results may significantly indicate an incorrect result in the assessment of body balance.

Keywords

stress, trauma, PTSD, body balance, gait, stabilometry, pedobarography

Streszczenie

Cel. Celem badania było ocenienie wpływu doświadczonego przez osobę zdarzenia traumatycznego na równowagę posturalną i biomechaniczne parametry chodu.

Metodologia badania. Badanie objęło 31 osób (n = 100%), w tym 22 kobiety (nk% = 70.97%) i 9 mężczyzn (nm% = 29.03), w wieku 29-60 lat. Z badania wykluczono osoby z chorobami i dysfunkcjami wpływającymi na równowagę ciała i wzorzec chodu.

Testy równowagi i chodu przeprowadzono przy użyciu pedobarografii (pedobarograf mod. EPS R2, oprogramowanie Biomech Studio v2). Test równowagi przeprowadzano w pozycji stojącej, przez 20 sekund, z próbkowaniem co 1 ms (milisekundę) – liczba próbek podczas jednego testu wynosi 20,000. Testy oceny równowagi i chodu przeprowadzono dwukrotnie. Test I obejmował testowanie w neutralnych warunkach, Test II obejmował testowanie w warunkach, w których osoba była narażona na doświadczone w przeszłości przez siebie zdarzenie traumatyczne (tzw. ekspozycja na "doświadczone traumy").

Wyniki. Uzyskane wyniki badań wpływu ekspozycji na doświadczone traumy na równowagę ciała podczas stania wykazały istotne różnice w wahaniach ciała w najważniejszych parametrach oceny stabilometrycznej.

Uzyskane wyniki badań wpływu ekspozycji na traumę na chód osoby nie wykazały istotnych różnic między testem w neutralnych warunkach a testem podczas ekspozycji.

Wnioski. (1) Ekspozycja na doświadczone przez osobę traumy znacząco wpływa na równowagę ciała w pozycji stojącej. (2) Badania nie wykazały wpływu ekspozycji na doświadczone traumy na chód osoby w zakresie czasu kontaktu stóp z podłożem oraz na wartości maksymalnego i średniego ciśnienia; Obszar płaszczyzny, na której stopy są umieszczone na podłożu, zmienia się znacząco przed i po ekspozycji na doświadczone traumy. (3) W badaniach wpływu traumy na postawę ciała należy uwzględnić szczegółowe wyniki badań zakresu fluktuacji COP w każdej płaszczyźnie – badanie wykazało, że analiza tylko średnich wyników może znacząco wskazywać błędny wynik w ocenie równowagi ciała.

Słowa kluczowe

stres, trauma, PTSD, równowaga ciała, chód, stabilometria, pedobarografia

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Introduction

The response to a threatening situation is quick emotional reactions and the activation of the fight and flight response mechanism. This reflex is a reflex mechanism that serves survival purposes [1]. It is a physiological and homeostatic response of the body, as described by W.B. Cannon in 1915 [2]. The development of knowledge in this area has proven that this phenomenon is the first stage of a general adaptation syndrome regulating stress responses in vertebrates and other organisms [3]. Although most organisms tend to avoid potential dangers, humans however experience a response that inclines them to approach potentinal dangers [4].

Animal studies have also shown that in situations of significant threat there is a freezing reaction, which occurs when there is no escape route [5], although this area has been much less frequently researched and, according to the authors, its occurrence in humans is somehow ignored in the human population [6]. D.C. Blanchard et al. (2011) distinguished between typical Freezing Responses and the cessation of activities that occur during the orientation and possible risk assessment phase [5]. Acccording to P.J. Lang et al. (1997), freezing is a reaction also used for survival, optimizing the processes of attention and preparing the body for action [7]. In the freezing reaction (similarly to the "fight and flight" mechanism), physiological symptoms occur, including: bradycardia (low heart rate) [8, 9]. Tonic immobility (TI) is also accompanied by muscle stiffness [10]. Many psychopathologies may arise as a consequence of freezing [6]. Research by the team M.J. Bovin et al. (2008) [11] showed a significant relationship between freezing and post-traumatic stress disorder (PTSD). This was also confirmed by other researchers [12–15].

Psychologically, people who repeatedly experienced single or chronic trauma showed higher levels of dissociation, flashbacks, shame, mood changes, and increased interpersonal dependency [16–19]. These people also show reduced resistance to current threats [20] as well as increased autonomic activity [21].

A study of literature showed that there are reports that stress affects motor reactions, and an increased number of traumas may result in more serious motor dysfunctions [22]. From a postural perspective, it is a limitation of body oscillations in the balancing process (while standing) and an increase in heart rate [23]. Research indicates that chronic stress, which includes PTSD, triggers a chain of neuroendocrine reactions [24]. According to the authors, it also affects the development of dysfunctions in the musculoskeletal system, including posture and locomotion dysfunctions [25]. This is caused by the susceptibility of glucocorticoid receptors to stress [26], as well as activation of the hypothalamic-pituitary-adrenal axis by stress. This axis has a direct impact on the dopaminergic system, which plays an extremely important role in regulating body motility [27]. According to the authors, this may have a significant relationship with the development of dopamine-related diseases, e.g. Parkinson's disease [25]. In response to stress, in addition to dopamine, the level of catecholamines and norepinephrine also increases. Norepinephrine acts as a regulator of interneuronal networks in the spine and is responsible for the excitation and activity of the locomotor system [28–30]. Glucocorticoids also play an important role in modulating neuronal plasticity [31–33], which influences the degree of structural and functional compensation in the course of pathologies and dysfunctions of the musculoskeletal system [25]. Persistently high levels of glucorticoids result in lack of adaptation, causing exacerbation of neurological disorders. It also impairs and degrades the cell's ability to survive injury in situations involving severe oxidative stress [34]. Chronic and aggravating neuroendocrine response to stress is the cause of many diseases, both of neurological, neuro-degenerative and cerebrovascular origin [35]. Research into PTSD has shown a pattern of lower white matter integrity in the brain [36]. It has also been shown that neurohormonal changes resulting from traumas that occur (most often in childhood) in the brain stem (in the locus coeruleus) are caused by increased secretion of norepinephrine [37]. According to researchers, the aspect and overlap of traumas causes sensitivity to stressors in adult life and, consequently, causes greater susceptibility to the development of PTSD [38, 39]. Studies have also shown that long-term and overlapping stressful stimuli can cause neuroanatomical changes, i.e. shrinkage of the hippocampus, decreased activity of Broca's area, increased activity of the amygdala and decreased activity of the prefrontal cortex. These changes may be accompanied by consolidation and strengthening of memories related to the traumatic event, which directly affects the development of PTSD symptoms [16, 40, 41].

Common knowledge indicates that stress affects increased excitability and increased vertical exploration (studies on rats) [25, 42, 43]. Chronic stress has the opposite effect [25]. However, no studies have been found that have assessed gait patterns in the human population, and this conclusion is empirical, based on knowledge about rat behavior. Research by A. Charlett et al. (1998) showed a significant relationship between walking performance and increased cortisol levels in healthy people. The authors showed that longer steps, which result in better postural control, are significantly associated with lower cortisol levels [45]. Studies on rats have also shown that oral administration of corticosterone significantly reduces limb functions [46]. These and other studies are aimed at proving the impact of the so-called stress hormones on the musculoskeletal system and motor functions, including their impact on the functioning of those areas of the brain responsible for movement and balancing of the body (such as the cerebellum) [46, 47].

However, it has been shown that people with a history of chronic stress perform motor tasks with increased reaction times and increased speed of action when experiencing a stressful or anxious state [48]. It has also been shown that people exposed to stress increase their body tilt forward, which was confirmed by electromyography [49]. It has also been shown that people experiencing panic disorder exhibit body balance disorders [50, 51].

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Most studies that assessed the impact of post-traumatic symptoms were tests conducted with subjects with closed eyes and exposure to aversive images. Those that were only exposed to images simulating trauma showed a reduction in body fluctuations [23]. Others included, for example, a comparative analysis of body oscillations in a test with closed and open eyes. The conclusions were drawn about an increase in body oscillations in the test with eyes closed compared to open ones. However, the authors agreed that unpleasant images cause the freezing reaction, while pleasant and neutral images do not [6]. Research conducted by M.A. Hagenaars et al. (2008 and 2010) suggested a correlation between freezing and the development of intrusive images [13, 52]. Freezing reversal and increased fear-induced freezing was also observed [20, 53, 54]. Most researchers therefore agree that traumatic life events influence the development of automatic freezing reactions and may indicate a cumulative post-traumatic effect [6, 23].

However, there are interesting reports on the impact of closed eyes on postural reactions in healthy people, which are important from the point of view of the sensitivity and reliability of this type of tests:
1. These numerous tests conducted on subjects with eyes closed may cause additional vigilance, which leads to excessive reaction to neutral and threatening stimuli (especially in people who demonstrate the need for constant observation of the environment as a result of post-traumatic disorders [55, 56].
2. Closing the eyes while standing upright in order to maintain balance requires shifting attention to vestibular and proprioceptive stimuli, which in healthy people results in increased body oscillations or no changes in this area [57, 58, 59].
3. According to the authors, passive viewing of aversive images, also used in research on the phenomenon of freezing and the resulting changes in postural control, also leads to a reduction in oscillations in healthy people [6, 60, 61]. In this case, the standing position and the observation of aversive images are a double cognitive factor that distracts conscious attention from balance control and causes a shift to more automated postural control [59]. In people with post-traumatic symptoms, dual tasking can distract attention from postural control, but also from anxiety and hypervigilance.

Considering the above (Ad. 1–3), closing the eyes while standing is excluded to observe changes in body oscillations, because reducing body oscillations is also a normal postural reaction [23, 61].
Automatic defense responses can be triggered by exposure to a past stressful situation. For example, affective viewing of images or other provocation causing concentration on the threat automatically prepares one to act. This is one of the methods of observing defensive reactions and the strong physiological reactions that occur with them [7, 61–64]. This test has been used many times to study standing balance [22, 60, 65–69], no studies were found that assessed gait.

Essence of the question

Aim

The purpose of the study was to assess the impact of a traumatic event experienced by the subject on postural balance and biomechanical parameters of gait.

Study group

The study involved 31 people (n = 100%), including 22 women (nk% = 70.97%), 9 men (nm% = 29.03), aged 29-60. Due to the nature of the study, orthopodology specialists took part in the study. However, the main author of the study asked to perform a pedobarographic examination while standing and walking, indicating the conditions of the examination (test I and test II), without informing the researchers about the purpose of the examination and the parameters that will be assessed. The study was carried out in a multicenter, 26 orthopedological offices, without the participation of the people who designed the study.
These conditions were similar to those of a double-blind study.
Consent of the bioethics committee KB-006/46/2022.

Inclusion criteria for the study

People who indicated that they had experienced an experience consistent with the definition of trauma in the past, adults who gave informed consent to participate in the study.

Exclusion criteria from the study

People with diagnosed neurological diseases and other diseases and dysfunctions that may affect body balance and gait pattern.

Research methods and tools

To examine body balance and gait parameters, EPS R2 pedobarographs with BIOMECH Studio 2.0 software were used in two tests:

FIRST TEST:

− Balance test (while standing) was carried out in a neutral standing position (i.e. in a natural position for the subject), within 20 seconds, with eyes open, without additional instructions to be performed by the subject. The results of the distribution of anterior-posterior and lateral loads (Fig.1) and stabilograms (Fig.2) were selected for statistical analysis.
− Gait test included a minimum of 12 traces for one limb (left and right), each subject walked in neutral conditions, without additional instructions. For statistical analysis, a result characterizing the spatiotemporal parameters of gait (average: time, speed, maximum and average speed) was selected, as shown in Fig. 3.

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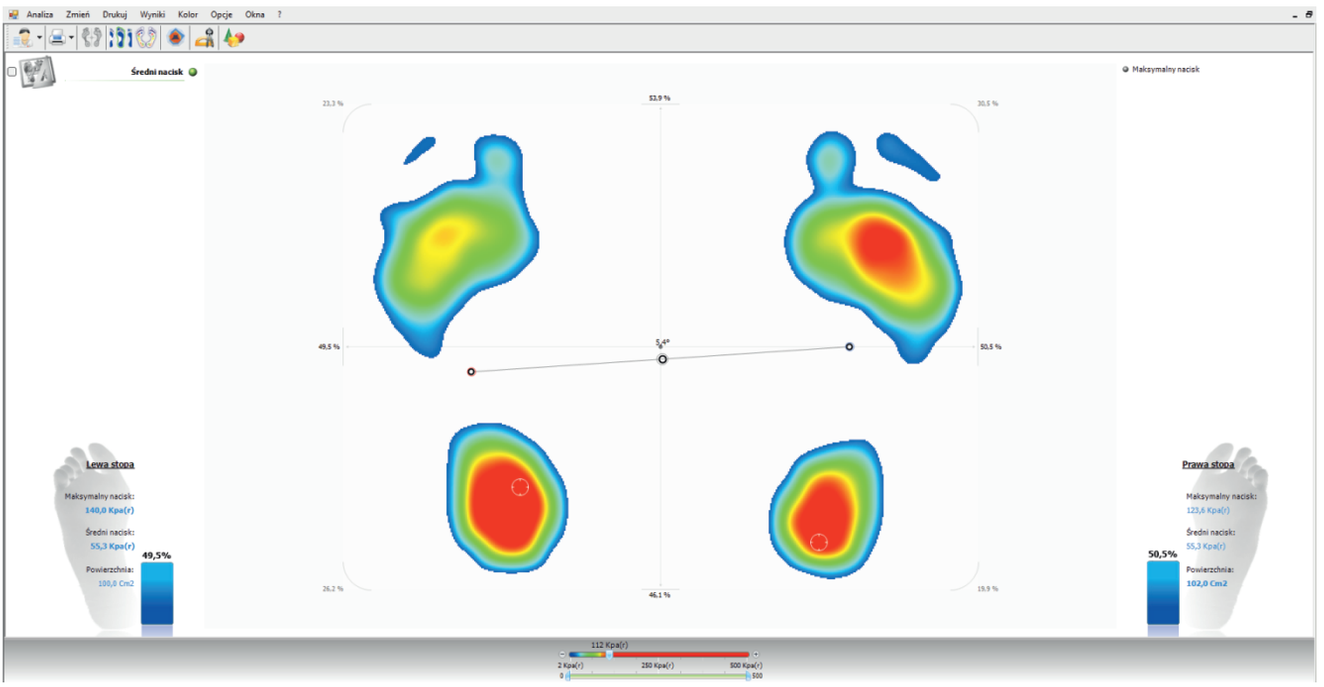

Fig. 1. An example result of a pedobarographic examination in terms of the anterior-posterior (Pr-T) and lateral distribution (reference values for the standing position are, respectively:
• for the anterior-posterior distribution: T = 60%, Pr = 40%, (marked in the figure in orange boxes),
• lateral (R-right and L-left side of the body) P = 52%, L = 48% (marked in the figure in green frames) [70, 71, 72].

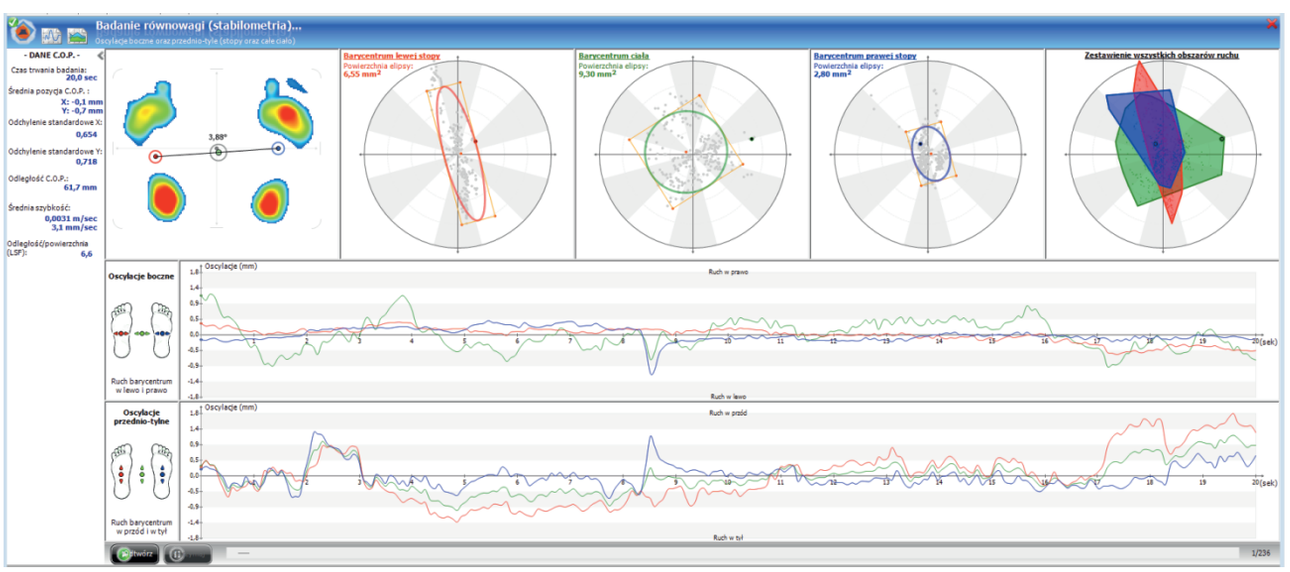

Fig. 2. Stabilogram - sample result of the stabilogram – reference values:
– front-posterior fluctuations: up to 19 mm (in people up to 30 years of age),
– lateral fluctuations – 7-9 mm (in people up to 30 years of age),
– over 60 years of age 50% increase in oscillation [73, 74, 75, 76].
The above result of the stabilometric test allows, among others, to observe the ranges of body fluctuations using the center of gravity of the body, imaged on the ground as the center of pressure, i.e. the reaction vector of the ground force on the plane of application of the feet (COP - center of pressure), and in particular:
− average COP position [X, Y] - means the average result of COP fluctuations (X-lateral, Y-anterior-posterior, respectively) from the zero point, i.e. the results obtained may have both negative and positive values, which significantly affects the result average (results marked in the green box),
− standard deviations – indicates a classic measure of variability of the COP distribution around the mean (results marked in the green box),
− COP distance – the length of the COP movement path (results marked in the green frame),
− barycenter – is the area of the ellipse determined by the COP movement, for the COP and COP movements of the left and right foot, respectively (results marked in the orange frame).

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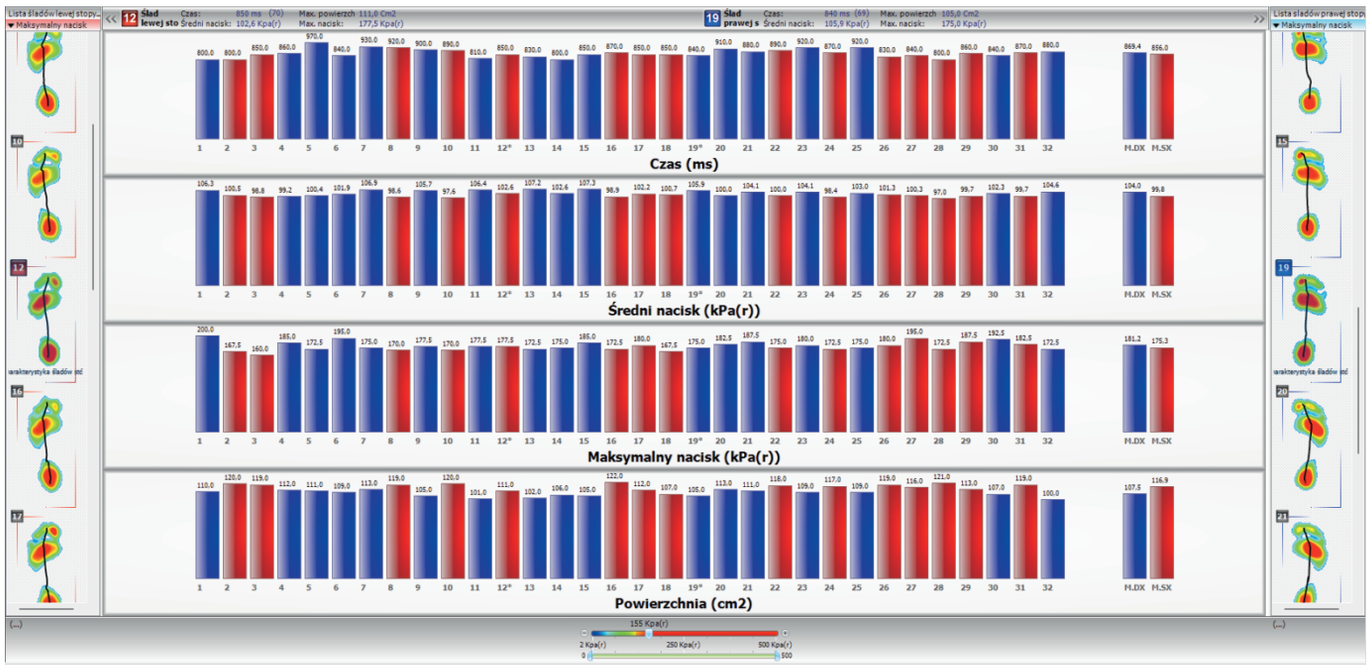

Fig. 3. Example result of a pedobarographic examination – statistical analysis of gait

TEST II

The second study was carried out in conditions of exposure to a traumatic event, in a neutral position, with open eyes and a provocation in which, before performing the test, the subject was asked to recall the traumatic event. Then, symbolic information was conveyed that this trauma was symbolized by the card presented to the subject. Then the sheet of paper was placed on the pedobarograph (this is a method of exposure that does not require further cognitive involvement of the examined person, i.e. there is no need to imagine images, recall the event, etc.). This is a type of a provocation "that the subject stands and walks after the trauma, i.e. as if at the time and circumstances that accompanied the traumatic event." This method of exposure eliminates the inclusion of any cognitive factor of the examined person. The study was focused on the experience of the subject and did not require any reactions from the person during the study (e.g. reminiscing, talking, recalling images, etc.). Nevertheless, the traumatic event was the actual experience of the examined person, thus eliminating fictitious conditions that were subject to a number of discussions in research works in a similar field.

Statistical analysis

In order to examine the significance of differences in characteristics in two samples, the t-test was used. Taking into account the relatively small sample, the results were considered significant at $p < 0.10$. Calculations were performed using the R program (The R Foundation for Statistical Computing, c/o Institute for Statistics and Mathematics, Wirtschaftsuniversität Wien), ver. 4.3.0.

Test results

Tab.1. Descriptive statistics of test results performed during trials I and II

	Study area	TEST I (in neutral conditions and position/free walking)							TEST II (in exposure to past trauma)						
		Min	Q1	Median	Q3	Max	Mean	SD	Min	Q1	Median	Q3	Max	Mean	SD
AREA I	Pressure share – left foot [%]	41.9	47.95	49.8	51.4	57.4	49.71	3.525	36.9	48.1	50.7	51.8	60	49.94	4.377
	Pressure share – right foot [%]	42.6	48.6	50.2	52.05	58.1	50.29	3.525	40	48.2	49.3	51.9	63.1	50.06	4.377
	Pressure share – forefoot [%]	27.2	46.15	50.5	54.85	67.5	50.73	8.153	38.5	46.2	49.2	54	67	50.23	6.924
	Pressure share – hindfoot [%]	32.5	45.15	49.5	53.85	72.8	49.27	8.153	33	46	50.8	53.8	61.5	49.77	6.924
AREA II	Average COP-X position [mm]	−2.2	−0.45	−0.1	0.4	1.2	−0.129	0.7708	−2.4	−0.6	0	0.45	1.6	−0.0645	0.8487
	Average COP-Y position [mm]	−4	−1.9	−1.1	−0.65	1.3	−1.194	1.101	−3.2	−1.75	−1.2	−0.7	1.1	−1.284	0.992
	Standard deviation – X [mm]	0.264	0.64	0.904	1.684	3.239	1.243	0.7959	0.288	0.709	1.601	2.258	6.805	1.835	1.491
	Standard deviation – Y [mm]	0.477	0.9095	1.133	1.653	5.739	1.699	1.441	0.328	1.113	1.76	3.299	6.79	2.443	1.752
	COP distance [mm]	19	41.45	54.9	80.7	147.9	63.47	30.93	17.8	50	73.7	97.05	174.5	76.71	38.6
	COP speed [mm/sec]	1.4	2.15	2.9	4.5	7.4	3.342	1.542	1.2	2.5	3.8	4.85	10.9	4.029	2.11
	Barycenter – left foot [mm^2]	0.77	2.755	3.98	9.96	56.1	10.08	13.21	0.64	3.87	10.58	20.77	107.7	17.09	23.88
	Barycenter – right foot [mm^2]	0.79	2.39	4.86	8.345	38.05	7.481	8.099	0.89	3.535	6.01	27.35	113.5	19.35	26.71
	Barycenter COP [mm^2]	3.48	12.11	18.8	41.06	211.4	38.7	50.92	2.4	16.37	33.96	102.9	300.4	74.98	83.68

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	Study area	TEST I (in neutral conditions and position/free walking)							TEST II (in exposure to past trauma)						
		Min	Q1	Median	Q3	Max	Mean	SD	Min	Q1	Median	Q3	Max	Mean	SD
AREA III	Rolling time – left foot [ms]	499.6	644.2	676	745.1	935.3	690.1	88.26	460.4	635.9	705	762.7	918.7	695.5	99.95
	Rolling time – right foot [ms]	533	650.6	698.5	741.5	913.6	695.9	83.19	606.8	658.9	695.3	750.9	904.6	707.9	72.18
	Average pressure – left foot [kPa(r)]	54.8	89.95	102.5	121.7	165.6	104.9	24.57	55	89.85	102.4	121	168.7	104.5	24.4
	Average medium pressure – right foot [kPa(r)]	55.8	89.45	103.7	118.9	158.6	105.3	23.86	55.2	90.55	102.5	117.9	160.9	104.7	23.28
	Average maximum pressure – left foot [kPa(r)]	83.3	169.1	211.7	238.7	431	216.6	88.02	83.5	169.1	210.9	237.6	410.6	216	86.59
	Average maximum pressure – right foot [kPa(r)]	83.3	166.6	211.7	252.5	474.4	227	103.8	83.4	169.1	211.3	262.4	462.7	227.2	101.5
	Average plane – left foot [cm^2]	84.1	110.8	120.1	132.1	175.1	121.7	20.71	89.8	109.2	123.2	136.6	170.7	122.9	20.44
	Average plane – right foot [cm^2]	85.1	111.9	124.5	139.4	169.1	124.4	20.22	86.8	111.5	125.7	139.2	181.4	125.3	20.83
	Average plane – both feet [cm^2]	84.1	110.7	122.2	137	175.1	123.1	20.34	86.8	110.7	123.8	137.8	181.4	124.1	20.5

Tab.1. Descriptive statistics of test results performed during trials I and II

	Study area	Min	Q1	Median	Q3	Max	Mean	SD	p
AREA I	Pressure share – left foot [%]	−11.8	−2.65	0.3	3.6	9.1	0.229	4.879	0.796
	Pressure share – right foot [%]	−9.1	−3.6	−0.3	2.65	11.8	−0.229	4.879	0.796
	Pressure share – forefoot [%]	−16.9	−2.3	−0.7	2.85	14.6	−0.4968	6.381	0.668
	Pressure share – hindfoot [%]	−14.6	−2.85	0.7	2.3	16.9	0.4968	6.381	0.668
AREA II	Average COP-X position [mm]	−1.9	−0.65	0.1	0.6	2.2	0.06452	1.038	0.732
	Average COP-Y position [mm]	−2.9	−0.55	0	0.6	1.9	−0.0903	1.18	0.673
	Standard deviation – X [mm]	−1.06	−0.282	0.374	0.957	4.307	0.5921	1.278	**0.015**
	Standard deviation – Y [mm]	−2.282	−0.647	0.229	1.414	6.148	0.7442	2.007	**0.048**
	COP distance [mm]	−70	−2.9	5.2	24.5	92.2	13.24	30.08	**0.020**
	COP speed [mm/sec]	−3.5	−0.25	0.3	1.25	6.1	0.6871	1.671	**0.029**
	Barycenter – left foot [mm^2]	−37.61	−1.485	2.15	12.46	90.51	7.009	21.41	**0.078**
	Barycenter – right foot [mm^2]	−5.96	−2.155	2.06	15.64	89.07	11.87	24.37	**0.011**
	Barycenter COP [mm^2]	−71.4	−4.935	3.81	60.98	253.8	36.28	76.81	**0.013**
AREA III	Rolling time – left foot [ms]	−222.9	−15.95	6.3	27.75	210.4	5.316	74.66	0.695
	Rolling time – right foot [ms]	−110.3	−13.95	8.3	16.05	158.6	11.95	57.58	0.257
	Average pressure – left foot [kPa(r)]	−5.5	−2	0.2	1	7	−0.3774	2.681	0.439
	Average medium pressure – right foot [kPa(r)]	−7.3	−1.85	−0.4	0.75	4.1	−0.6677	2.477	0.144
	Average maximum pressure – left foot [kPa(r)]	−28.9	−1.6	−0.1	0.75	18.3	−0.6258	9.749	0.723
	Average maximum pressure – right foot [kPa(r)]	−28.6	−2.2	0	0.95	61.7	0.2226	16.19	0.939
	Average plane – left foot [cm^2]	−9.4	0.25	0.7	3.35	6.3	1.181	3.182	**0.048**
	Average plane – right foot [cm^2]	−7.8	−1.25	0.9	2.9	12.3	0.8677	4.025	0.239
	Average plane – both feet [cm^2]	−9.4	−0.175	0.8	3.05	12.3	1.024	3.602	**0.029**

Descriptive statistics indicated in Table 1. showed a significant impact of trauma exposure on body balance while standing (marked in red). Most of the statistical analyzes of the results relating to the comparative analysis of samples I and II in area II (i.e. the balance results) indicated statistically significant results.

The exception is the result of the average COP positions (both in the X and Y axis), where the average values of trial I and trial II differ non-significantly (p = 0.732; 0.673 for the X and Y axes, respectively). It should be emphasized, however, that the average COP position is determined from the negative and positive values of all COP fluctuations measured during the twenty-second test, every one millisecond (i.e. 20,000 samples were determined during one test lasting 20 seconds). This means that it is the average of the positive and negative values around the average COP position, i.e. the front COP fluctuations are marked as a positive value ("+"), the rear ones as negative ("−"). As an average result, the results of the average COP position do not in any way reflect the range of mobility of the COP. Side oscillations should be understood in a similar way, i.e. one side was marked as positive, the other as negative.

However, the analysis of this area was not omitted in this study due to the fact that the software supporting the EPS R2 pedobarograph (i.e. BIOMECH STUDIO) allowed for the determination of the standard deviation of the average COP position (X and Y), which allowed for the assessment of the spread of individual samples. The standard deviations of the mean position differ significantly (p = 0.015; 0.048 for the X and Y axes, respectively), which indicates an increased range of fluctuations around the mean position in sample II.

Changes in the distribution of the mean COP item and its standard deviations are shown in Fig. 4a-d).

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Explanations for Figures 4-10: The left side of the graph shows the results of the tests ("Test") conducted in Tests I and II ("Test I", "Test II"). The sloping red lines on the left part of the graphs connect the values of the characteristics in the subjects (e.g. in Fig. 1a. each red line refers to the result of the average COP-X item in one subject, where the beginning of the line indicates the result obtained during test I, and the end of the line indicates the result obtained during test II). The right part of the graph indicates the change, which was determined by the difference in characteristics between tests I and II (i.e. the result obtained in test II was subtracted from the result obtained in test I).
Black points and vertical lines are the mean (±) standard deviation. This is how the results of statistical analyzes are presented throughout the publication.

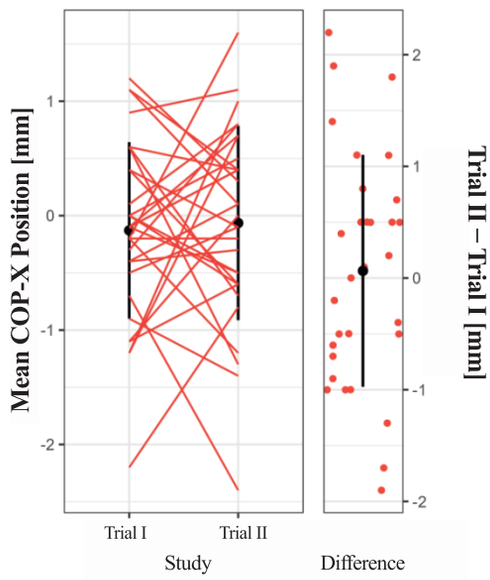

Fig. 4a. Comparative analysis of the average COP-X position

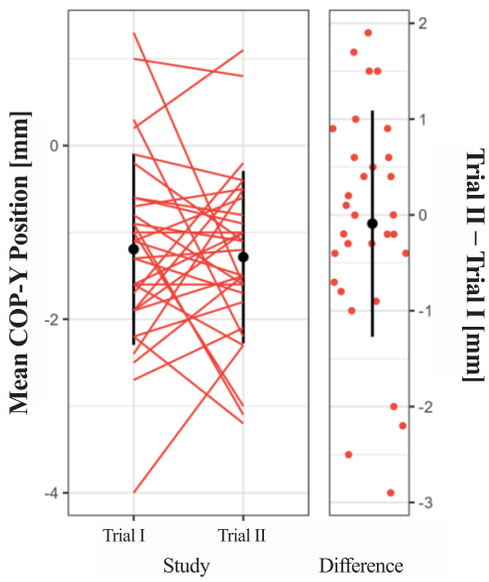

Fig. 4b. Comparative analysis of the average COP-Y

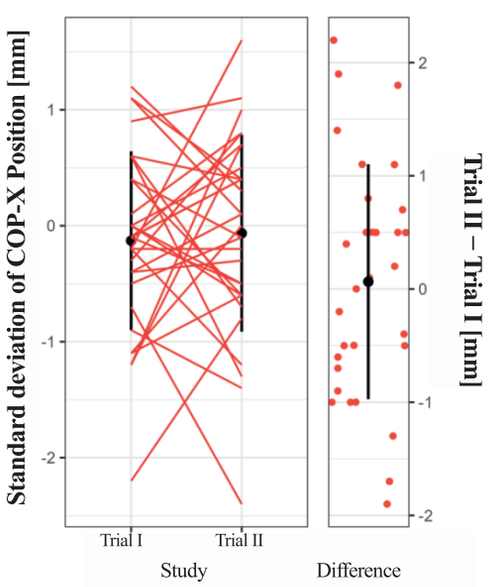

Fig. 4c. Comparative analysis of COP-X standard deviation

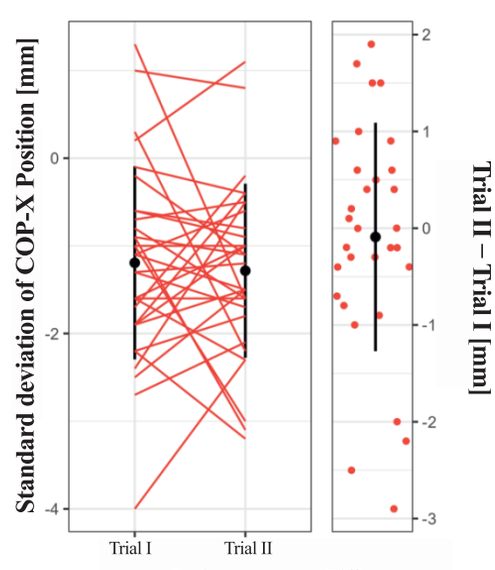

Fig. 4d. Comparative analysis of COP-Y standard deviation

The test results also indicate significantly higher values shown in trial II, both in terms of COP distance (p = 0.020) and COP fluctuation speed (p = 0.029). It should be understood that exposure to trauma causes increased fluctuations in the body's center of gravity, and therefore significantly affects maintaining balance while standing. The results of this are illustrated in Fig. 5a. and 5b.

Detailed balance test results also showed significant differences in test results in the barycenter area: left foot (p = 0.078), right foot (0.011) and body COP (p = 0.013). The result shows a clear increase in the ellipses defining the movement surfaces of the barycenters, which means a significant increase in the fluctuations of the entire body in each direction of movement. The results of balance tests in terms of foot barycenters and COP are shown in Fig. 6a-c.

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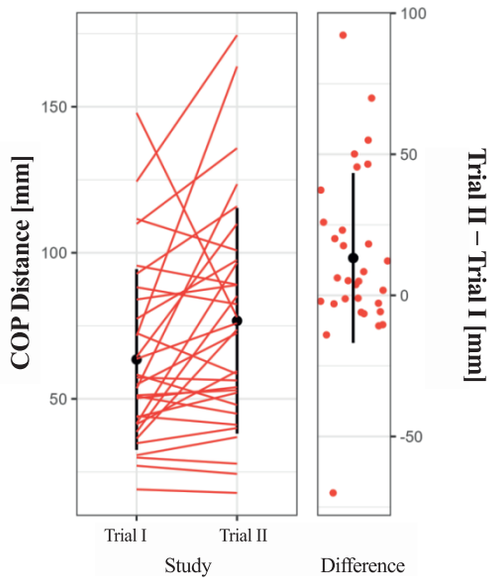

Fig. 5a. Comparative analysis of COP distances

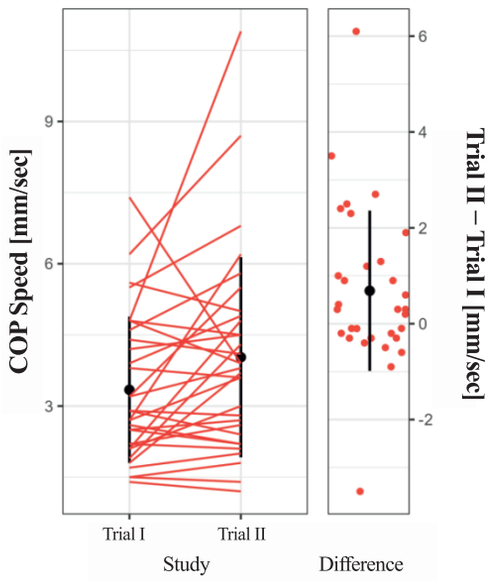

Fig. 5b. COP speed comparative analysis

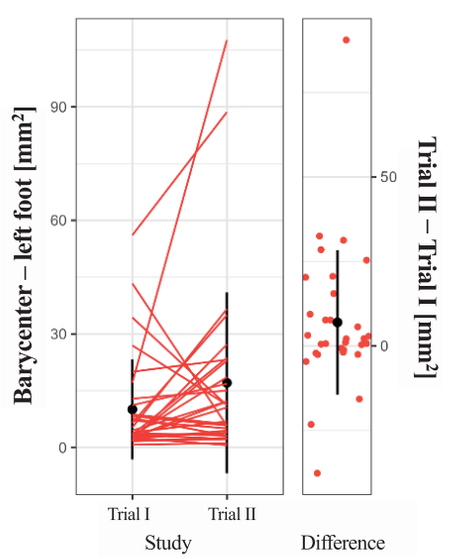

Fig. 6a. Comparative analysis of the barycenter of the left foot

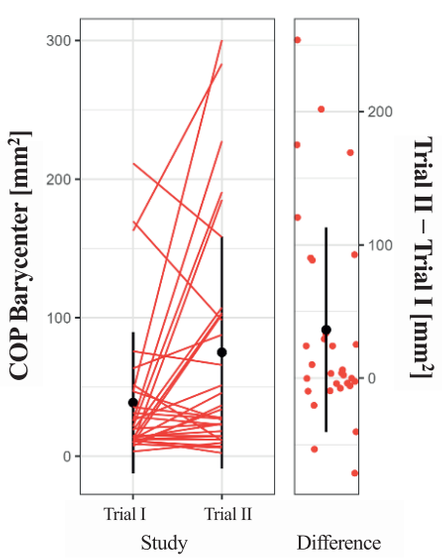

Fig. 6b. Comparative analysis of the COP barycenter

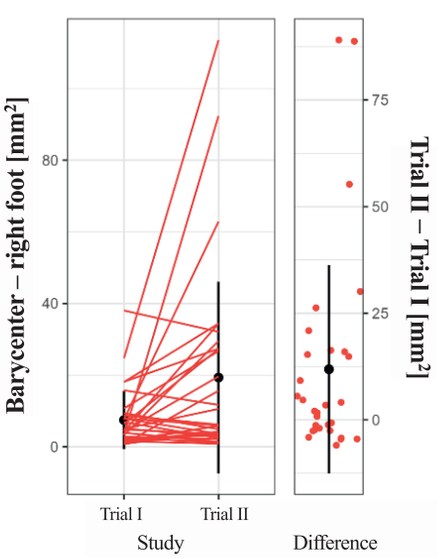

Fig. 6c. Comparative analysis of the barycenter of the right foot

The results of the overall distribution of pressure on the feet were analyzed, anterior-posterior and lateral (results summarized in Table 1 and Table 2 – "Area I"). This was due to the obtained results of significant changes in balance that occur during exposure to trauma. The analysis showed no significant difference between test I and II, both in terms of pressure on the forefoot and hindfoot (p = 0.668) and lateral pressure (p = 0796). However, this result should be treated in the same way as indicated in the analysis of the "average COP X and Y position", i.e. the obtained lack of statistical significance in the average values does not indicate the lack of significant differences in body fluctuations. Therefore, it does not indicate changes in the range of body oscillations. The results of differences in the share of pressure on the forefoot are shown in Fig. 7a, and on the left foot in Fig. 7b.

Postural balance tests also included gait assessment. The biomechanical parameters of the pressure on the feet were analyzed (average - Fig. 8a and b. and maximum – Fig. 8c and d.) and time-spatial parameters, i.e. the duration of rolling each foot (Fig. 9a and b) and the application plane. analyzed jointly for both feet (Fig. 10).

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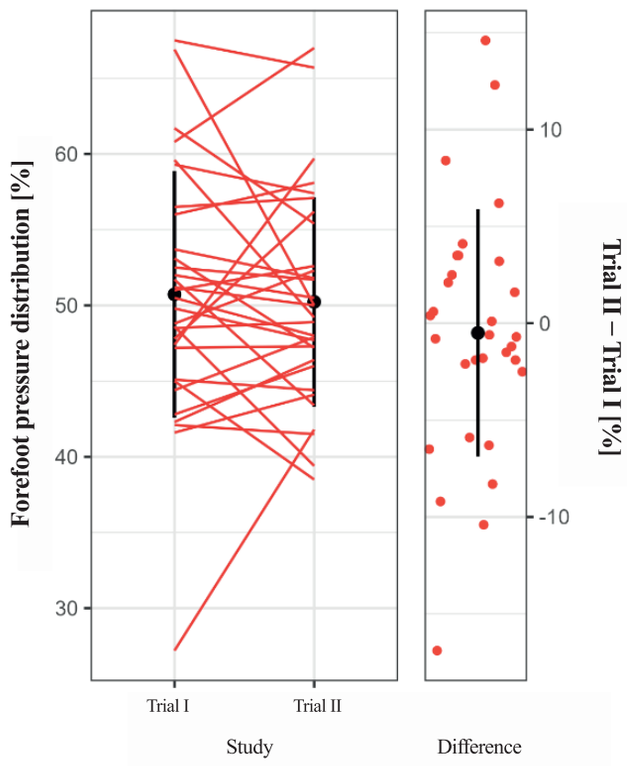

Fig. 7a. Comparative analysis of pressure distribution from the front to the back

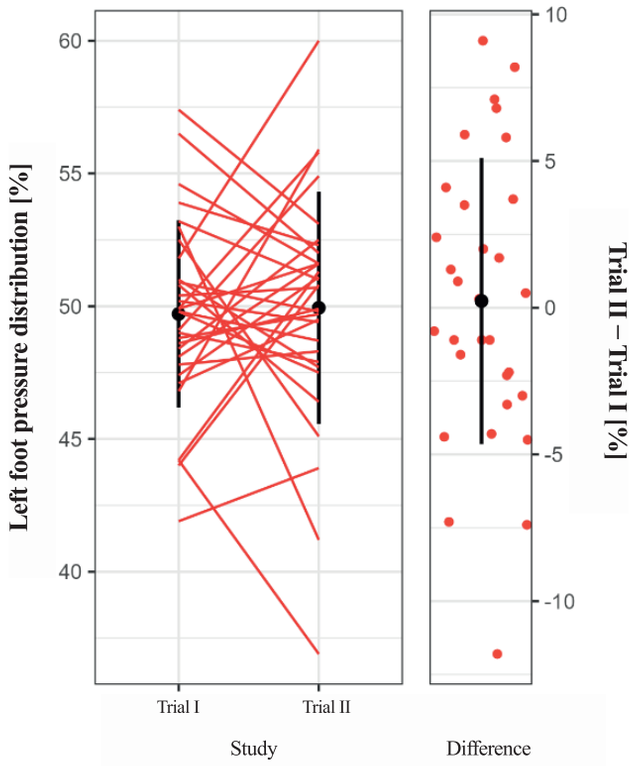

Fig. 7b. Comparative analysis of pressure distribution from the side (i.e. left-right)

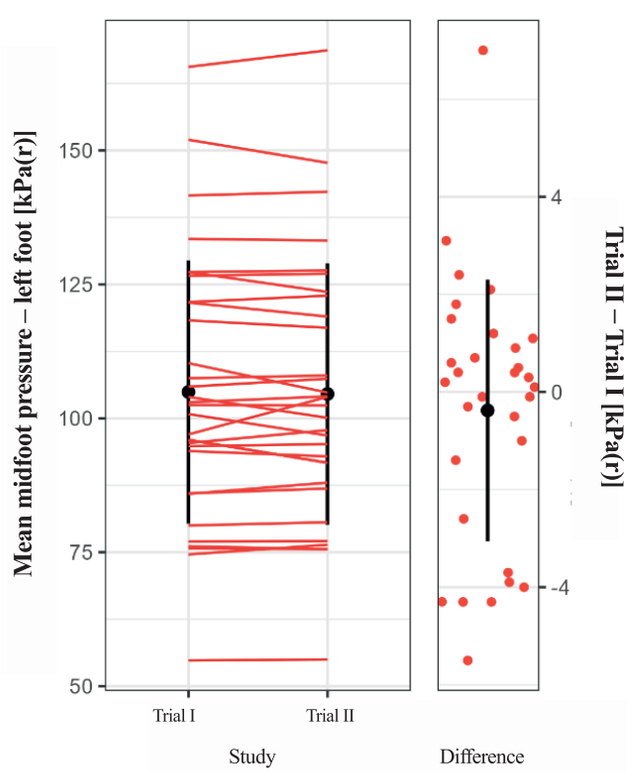

Fig. 8a. Comparative analysis of the average pressure on the left foot (walk)

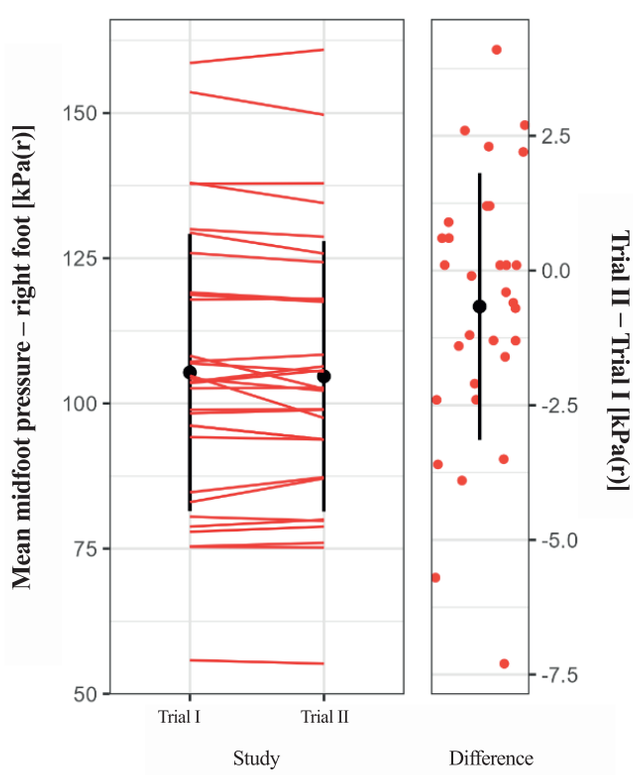

Fig. 8b. Comparative analysis of average pressure on the right foot (walk)

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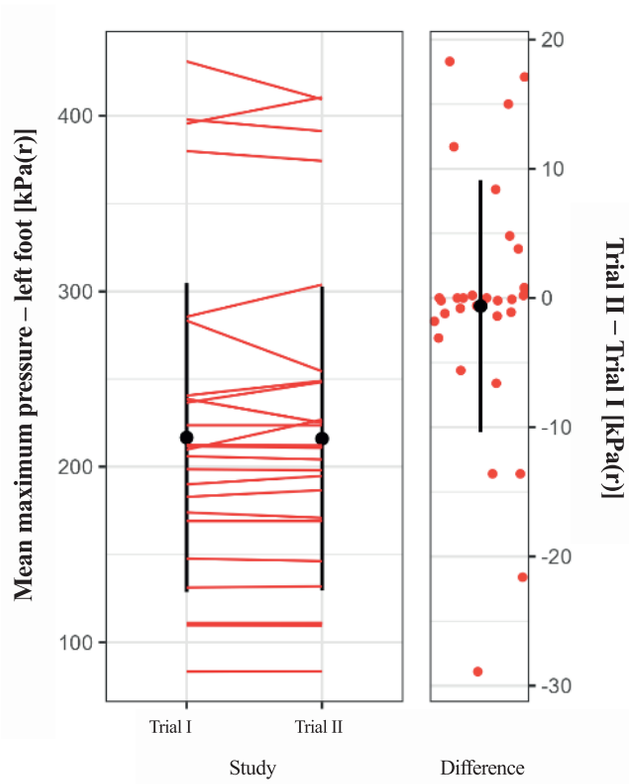

Fig. 8c. Comparative analysis of maximum pressure on the left foot (walk)

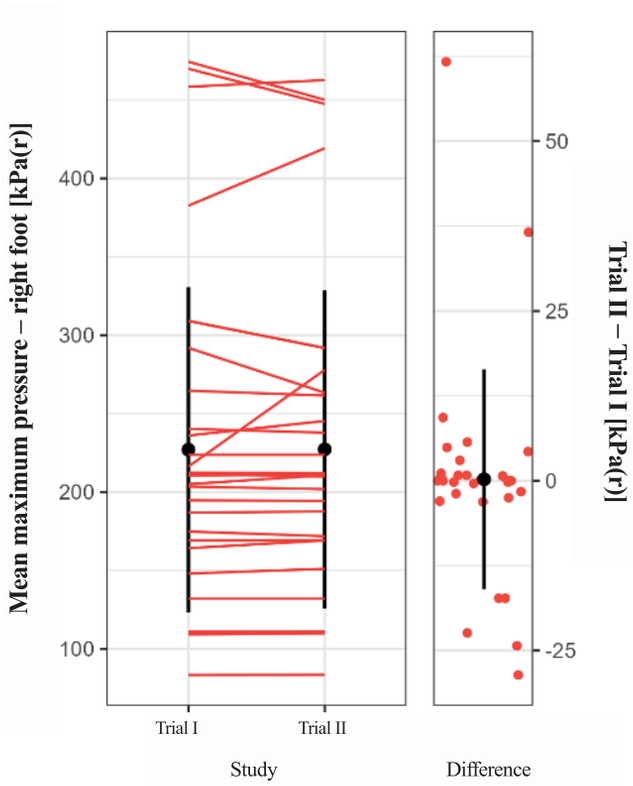

Fig. 8d. Comparative analysis of maximum pressure on the right foot (walk)

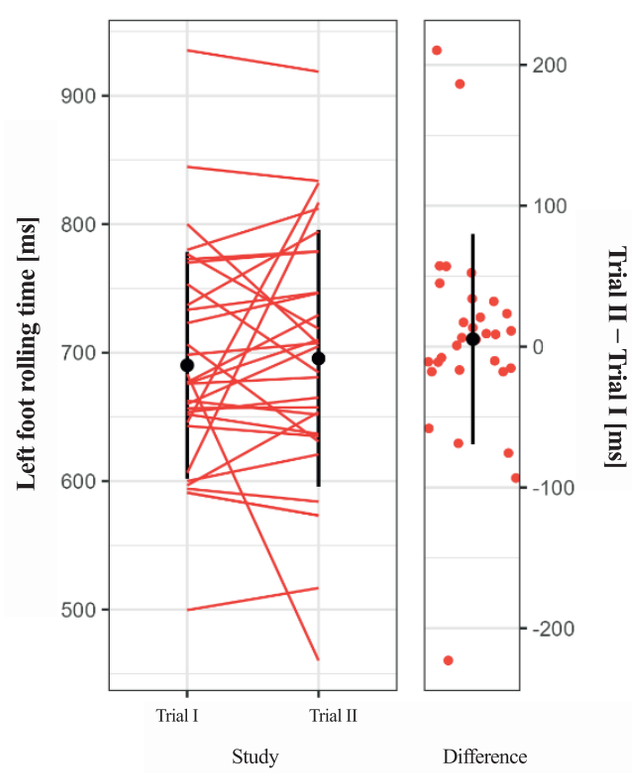

Fig. 9a. Comparative analysis of the average pressure on the left foot (walk)

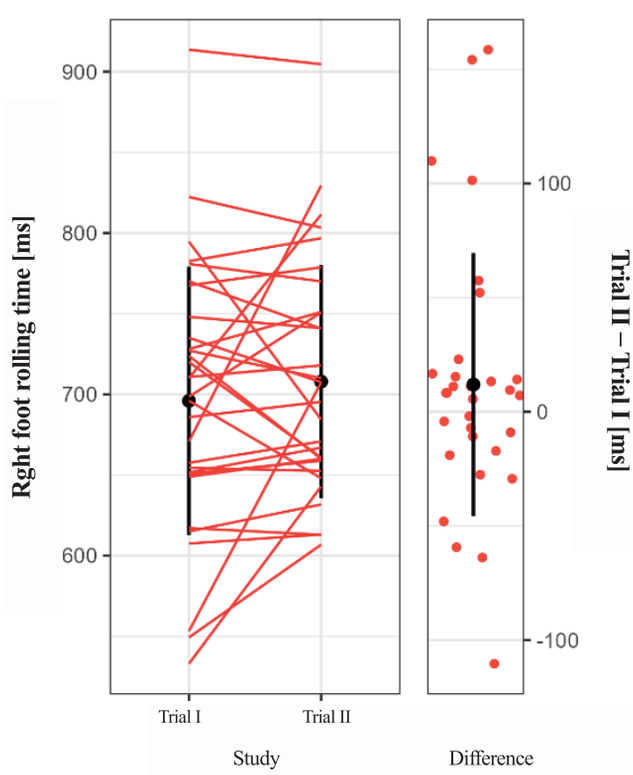

Fig. 9b. Comparative analysis of rolling time of the right foot

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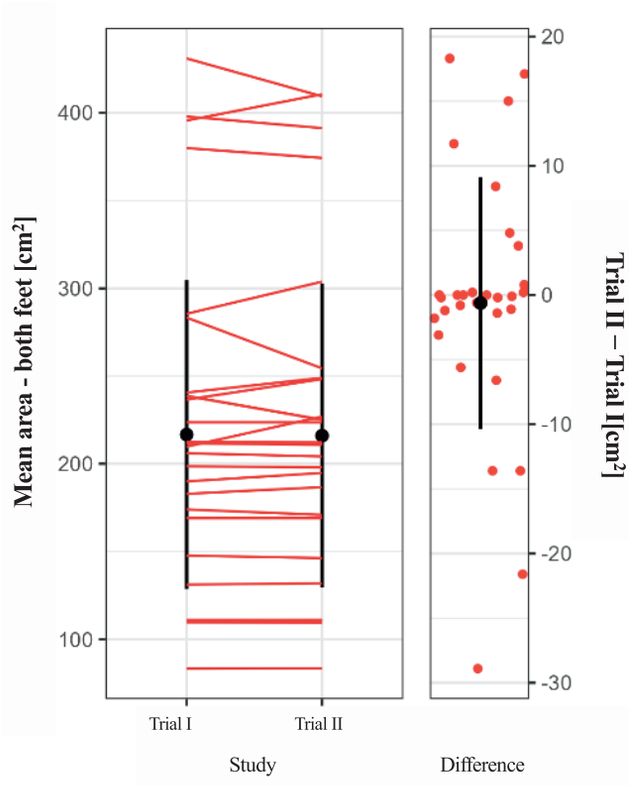

Fig 10. Average foot area (total left and right while walking)

Graphical results of the comparative statistical analyzes shown in Fig. 5-7 show very minor changes in these characteristics. In combination with the results of the descriptive results aimed at assessing the significance of the impact of trauma exposure on gait, they allow the conclusion that the exposure does not significantly affect human gait in the post-traumatic perspective in terms of pressure (average and maximum) and the time of contact of the foot with the ground. However, statistically significant changes were observed in the average plane of placing the feet on the ground, considering both feet together (i.e. left and right together) ($p = 0.029$).

Discussion

In the introduction to the study, the study of literature showed that research on the impact of stress and its consequences on the musculoskeletal system is of an analytical nature, in particular regarding the impact of stress on neurohormonal changes, changes in the brain, and degradation changes in the neurological system. There are no studies found that would indicate, for example, changes in body posture that occur under the influence of psychotherapy.

Most studies assessing the impact of stressors on body posture were carried out using pedobarography [22, 60, 61, 65– 69], although no studies were found that assessed gait (which is also possible to analyze using pedobarography). Most of these studies were carried out using experiments, i.e. in fictitious conditions. The study conducted by T.M Azevedo et al. (2005) during which subjects were exposed to unpleasant photos (and, comparatively, to neutral and positive photos), a reduction in the range of body fluctuations (anterior-posterior and lateral) was recorded [60]. A similar nature of research and results were obtained by L.D. Facchinetti et al. (2006) [66], F.L. Lopes et al. (2009), K. Roelofs et al. (2002 and 2010) [22, 61].

In research. J.F. Stins and P.J. Beek analyzed body balance in a two-legged and one-legged standing position, and as a result, unlike other studies, they showed a small effect on body oscillations, with a tendency to shorten the oscillation path, which they justified by confirming research indicating the freezing strategy [68]. Research by M.G. Carpenter et al (2004) that examined multi-level muscles (i.e. limbs, trunk, shoulder), showed an increased amplitude of balance-correcting reactions (120-220 ms), and therefore increased and faster muscle tension via data obtained using electromyography. Subjects were subjected to low- and high-threat conditions [65]. Research conducted by J. F. Stins, M. Roerdink, P. J. Beek showed significant differences in test results under the influence of a single and double cognitive stimulus.

All these studies concluded about the freezing effect as a reaction to unpleasant stimuli. This conclusion was based on research results indicating a reduction in body oscillations in a standing position. Undeniably, the results obtained in this study differ significantly from those of the researchers. The obtained test results indicate a significant difference in whole body oscillations in the most important parameters for assessing postural balance while standing, i.e.:

I. Standard deviations from the mean COP position are significantly greater in the body balance test after exposure to a traumatic event.

II. COP distance – i.e. the length of the COP movement trajectory is significantly greater after exposure to a traumatic event.

III. The speed of fluctuations after exposure to a traumatic event increases significantly more after exposure to a traumatic event.

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IV. Foot barycenters and COP are significantly greater after exposure to a traumatic event.

It should be noted that these are completely opposite results to those indicated in literature reports, which showed the so-called "freezing effect" (i.e. reduced body fluctuations). However, the study of literature indicated that the previous research was an experiment, i.e. it was carried out in fictitious conditions, i.e.: the exposure consisted of photos with unpleasant/drastic content, and this content did not in any way concern the experiences experienced by the subject. In this case, a conclusion can be drawn that the methodology selected in this way does not allow for drawing conclusions about post-traumatic reactions. The subject becomes acquainted with the drastic content only during the examination. That is considering the fact that the content is "foreign" to the subject according to the authors. It is also questionable to draw conclusions about the impact of this content on the stress response.

In the present research, the subjects were asked to recall the trauma they had actually experienced (real conditions), and then it was indicated that the card would symbolize this trauma (simulation "that the subject is standing and walking after the trauma, i.e. in this time and circumstances"). The study was therefore focused on the experience experienced by the subject, which was assessed by him or her as "traumatic". The obtained test results and statistical significance indicated a clear increase in body fluctuations, i.e. a result opposite to freezing. This area requires further research according to the authors, especially in the field of cognitive conditions and experiences experienced by the respondents.

Drilling down the details, the research also showed a lack of statistical significance in the average values of pressure distribution (i.e. in the anterior-posterior view "average COP position" and lateral view "pressure on the right and left foot"). The logical analysis of the average results carried out in the "results" section allows for the conclusion that the average values are not sensitive enough to assess the significance of the impact of exposure to a traumatic event. They do not provide any information about standard deviations from the mean and changes that occur in the ranges of COP movement. This conclusion is proven by the descriptive and graphical analysis of COP standard deviations, COP distances, COP fluctuation velocities and barycenters. Therefore, it should be made clear that body balance tests should take into account such detailed results of stabilometric tests. A literature review conducted by the authors on the merits of the issue showed no reports on changes in the average values of body balance parameters. The research conducted by the team B.E. Maki et al. showed that people exposed to stress increase their body tilt forward. However, the analysis carried out by the researchers was focused on the activation of the tibialis anterior muscle [49]. The forward tilt of the body is an important aspect in assessing the impact of stress/trauma on body posture, as it causes an increase in the load on the front part of the foot relative to the hindfoot. Although this study showed no significant change in the anterior-posterior perspective, it should be emphasized that in response to exposure to the trauma experienced by the subjects, the results in this area changed dynamically. However, this distribution was chaotic (it decreased or increased significantly), so once again it should be concluded that it is necessary to analyze not average values, but detailed results of the full range of motion, and in this case, the change taking place. This area is a postulate for further research into the impact of experienced trauma on body posture.

The study also included a detailed analysis of gait biomechanics, in particular spatiotemporal parameters (foot contact time with the ground, plane of foot contact with the ground) and the values of average and maximum pressure. The obtained results, both descriptive and graphic, showed no significant impact of exposure to the experienced trauma on the subject's gait in terms of time and average and maximum pressure. However, statistically significant changes were observed in the average plane of placing the feet on the ground, considering both feet together (i.e. left and right together) ($p = 0.029$). This is considering the fact that the plane of application of the feet is an important parameter correlating with postural defects and dysfunctions (especially of the feet and lower limbs), conclusions in this area require further research. Empirically, an important research area seems to be the impact of post-traumatic symptoms on gait stability, and the plane where the foot is placed on the ground is an important parameter in the assessment of gait stability or instability.

A literature review showed no publications in a similar research area. Only studies conducted by A. Charlett et al. were shown. (1998), showing a significant relationship between walking performance and increased cortisol levels in healthy people. The authors showed that longer steps, which result in better postural control, are significantly associated with lower cortisol levels [45]. Nevertheless, the research area of A. Charlett's team and this study differs significantly (i.e. cortisol testing was not carried out in this study), therefore it is not possible to draw conclusions (even empirical ones) based on the indicated publication.

Common knowledge indicates that stress affects increased excitability and increased vertical exploration (studies on rats) [42, 43]. Chronic stress has the opposite effect [25]. These conclusions, however, are most often based on empirical knowledge which is based on research on rats. However, it has been shown that people with a history of chronic stress perform motor tasks with increased reaction times and increased speed of action when experiencing a stressful or anxious state [48]. Gait tests performed during this study showed no effect on the biomechanical parameters of gait. A one-to-one graphical analysis of the results clearly showed no changes.

Conclusions

1. Exposure to the trauma experienced by the subject significantly affects the body's balance in a standing position.
2. The research showed no influence of exposure to the experienced trauma on the subject's gait in the area of the time of contact of the feet with the ground and on the values of maximum and average pressure; The area of the plane where the feet are placed on the ground changes significantly before and after exposure to the trauma experienced by the subject.

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3. In research on the impact of trauma on body posture, detailed results of studies on the range of COP fluctuations in each plane should be taken into account - the study showed that the analysis of only average results may indicate an incorrect result in the assessment of body balance.
4. The study allowed for the selection of a postulate for further research in the areas of:
• the impact of exposure to a traumatic event on the distribution of anterior-posterior loads (sagittal plane),
• the impact of exposure to a traumatic event on gait, especially in the area where the feet are placed on the ground.

4. A study of literature of the impact of traumatic events on body balance, locomotion and motor functions has shown that this topic is explored by researchers to a small extent (small amount of research and scientific work carried out on the human population).

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