Original paper

The influence of auditory stimuli (shots) and visual stimuli (SMS texting) on the parameters of the detection of the centre of gravity and the reaction of the ground forces in the static and dynamic test on the stabilometric platform – cohort studies

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Abstract

Introduction: Daily use of smartphones and personal listening devices (PLDs) generates destabilising conditions for the human body, especially in terms of balance. The multitude of external stimuli, such as sounds and texting, increases the risk of losing balance.
Aim of the research: The aim of the study was to assess the parameters of balance and reaction of substrate forces in a static and dynamic test under different conditions.
Material and methods: The study was conducted in a group of 52 people. The study included 3 attempts × 30 s: I-in conditions of relative silence (RS), II-with the sound of a shot (S), and III-while texting (SMS), carried out in both static and dynamic conditions. The Zebris PDM-L stabilometric platform was used.
Results: Comparisons made for the free-standing test in the tests did not show significant relationships between the analysed variables ($p > 0.05$). The mean value of velocity of center of pressure (COP) when SMS texting in the dynamic test was 3.7 ±0.5 km/h, in the S test it was higher (4.4 ±0.5 km/h), and in the RS test it was 4.2 ±0.5 km/h ($p < 0.001$). The average number of steps per minute was the lowest in SMS test (104.5 ±7.9 steps/min), the highest in S test (109.6 ±7.3 steps/min) ($p < 0.001$). The average length of the COP path for both lower limbs was shortest in SMS test and longest in S test ($p < 0.05$).
Conclusions: The sound of a shot and texting did not affect the body's balance under static conditions. In the dynamic test, the shot sound increased most of the parameters conditioning the gait, and texting resulted in greater concentration, slowing down the gait and stabilising the body.

Introduction

Body balance and postural stability are integral and basic components of all forms of human physical activity, guaranteeing the functional efficiency of the body [1]. It is of great importance in movement, daily activities, motor development, sport, and rehabilitation [2]. Balance can be determined as the state of a body in which the sum of the forces that act on it is equal to zero, i.e. the effect of the nervous system on the muscular system should be equal to the destabilizing external forces [3].

The balance of the human body should be considered in two aspects: as a static balance, related to maintaining the state of balance of the body remaining motionless, and dynamic, occurring during movement, which is most often gait [1, 4, 5]. The factors disturbing the body's balance can be divided into external and internal. The former are mechanical in nature, e.g. changing the position of the body to carry out movement. Internal factors are those that result from the process of regulation and control of the human body [5].

The efficiency of the motor system and the correct integration, processing, and coordination of visual stimuli coming from the body periphery, stimuli from the balance organ, and signals from proprioceptors allow the projection of the body's centre of gravity to be maintained (COG) within the quadrilateral area of support [6, 7]. In physiological conditions, when standing freely, the COG does not remain in one point but makes small random movements with an amplitude of several millimetres. This is an indicator of the proper functioning of the balance control system [8–11].

The body's ability to maintain balance is also affected by body composition, age, genetic traits, and environment [12]. The greatest development of the ability to balance occurs at around 7–11 years of age and most likely never repeats itself again [13]. Around the age of 11–13 years, there are quick and significant changes in the appearance of the figure, which negatively affects the balance processes. After the maturation process, the stability of the body normalises, and after the age of 30 years, it gradually degrades [14, 15], resulting in reduced mobility and a greater risk of falls [1, 16–18].

Holding an upright posture while carrying out parallel tasks is a common activity. This means the so-called two-task efficiency. In the literature, it is reported that postural stability increases during two-task activities, when the respondent, in addition to maintaining a stable vertical position, needs to focus on another cognitive task [19, 20]. The rapid development of smartphones and interactive technologies has led to a greater demand for multitasking during daily activities. Examples of such activities are attempts to type text messages while standing and walking quietly [21–25].

Technological progress has made the smartphone a necessity for everyday use, but using the smartphone in combination with certain tasks can have a negative impact on health and safety [25]. Studies in which the impact of smartphone use on balance and postural stability was assessed, especially in the group of seniors or people with neurological symptoms, seem to be an important aspect in the analysis of the risk of falls [1, 16, 17, 21–24, 26].

In recent years, there have been scientific reports assessing the impact of smartphone use on postural stability, but these studies mainly concern the impact of visual stimuli on healthy people, while studies assessing the impact of acoustic stimuli on postural stability in healthy people are not unambiguous [21, 23, 26–29].

Approximately 80% of young people use personal listening devices (PLDs) [30]. Despite unequivocal reports about the negative impact of exposure to the sound levels (dB) produced by PLDs with noise-induced hearing loss, there is no decrease in the use of these devices [31, 32].

Considering the gap in empirical research, the authors attempted to assess the impact of sound and visual stimuli on the reaction of ground forces during a static test (stationary standing position) and gait among people of working age, analysing the impact of the sound of a shot and texting as destabilising stimuli for the human body. Balance parameters and individual gait phases were analysed.

Aim of the research

The main objective of the study was to assess the impact of auditory and visual stimuli on the reactions of ground forces in the static and dynamic test analysed using the Zebris PDM-L stabilometric platform.

Material and methods

The study was conducted in a group of 52 people. The inclusion criteria for the study were as follows: age 18 years and over, healthy people without diagnosed chronic diseases. The criterion for exclusion from the study was: age below 18 years, musculoskeletal injuries and disability preventing the correct carrying out the static and dynamic test on the Zebris PDM-L platform, visual impairment, and disturbance and imbalance.

The Zebris PDM-L platform enabled the analysis of parameters in static and dynamic conditions. From individual measurements performed on the Zebris PDM-L platform, reports were obtained indicating stabilometric parameters (Figures 1–3). The data were supplemented with data on gender, age, body weight, and height, on the basis of which the body mass index (BMI) was calculated.

The analysed parameters in static test are as follows [7]:

- 95% confidence ellipse area [mm^2] – defines the size of the area marked by the center of pressure (COP); ellipse area includes 95% of the COP measurement points; this parameter makes it possible to assess the size of the area of the COP movement on the support surface.
- COP path length [mm] – defines the total length of the path marked by the COP; the sum of distances between the locations of the COP constitutes the path length.
- COP average velocity [mm/s] – defines the mean velocity at which the COP moves; this parameter indicates the speed of changes in the COP location, which reflects the speed of postural reactions while standing.
- Forefoot force L [%] – describes the reaction of the ground forces for the forefoot of the left limb.
- Backfoot force L [%] – describes the reaction of the ground forces for the backfoot of the left limb.
- Total force L [%] – indicates the overall load on the left limb.
- Forefoot force R [%] – describes the reaction of ground forces for the forefoot of the right limb.
- Backfoot force R [%] – describes the reaction of ground forces for the backfoot of the right limb.
- Total force R [%] – indicates the overall load on the right limb [7].

The analysed parameters in the dynamic test are as follows:

- Forefoot L/R [%] – describes the reaction of ground forces on the forefoot of the foot L/R.
- Backfoot L/R [%] – describes the reaction of ground forces on the hindfoot of the foot L/R.
- Step length L/R [cm] – describes the distance between the contact of the heel with the ground of one lower limb and the contact of the heel of the other limb.
- Stride length L/R [cm] – describes the distance between the heel contact with the ground of one lower limb and the heel contact of the same limb again.
- Step width [cm] – describes the distance between the right and left feet.

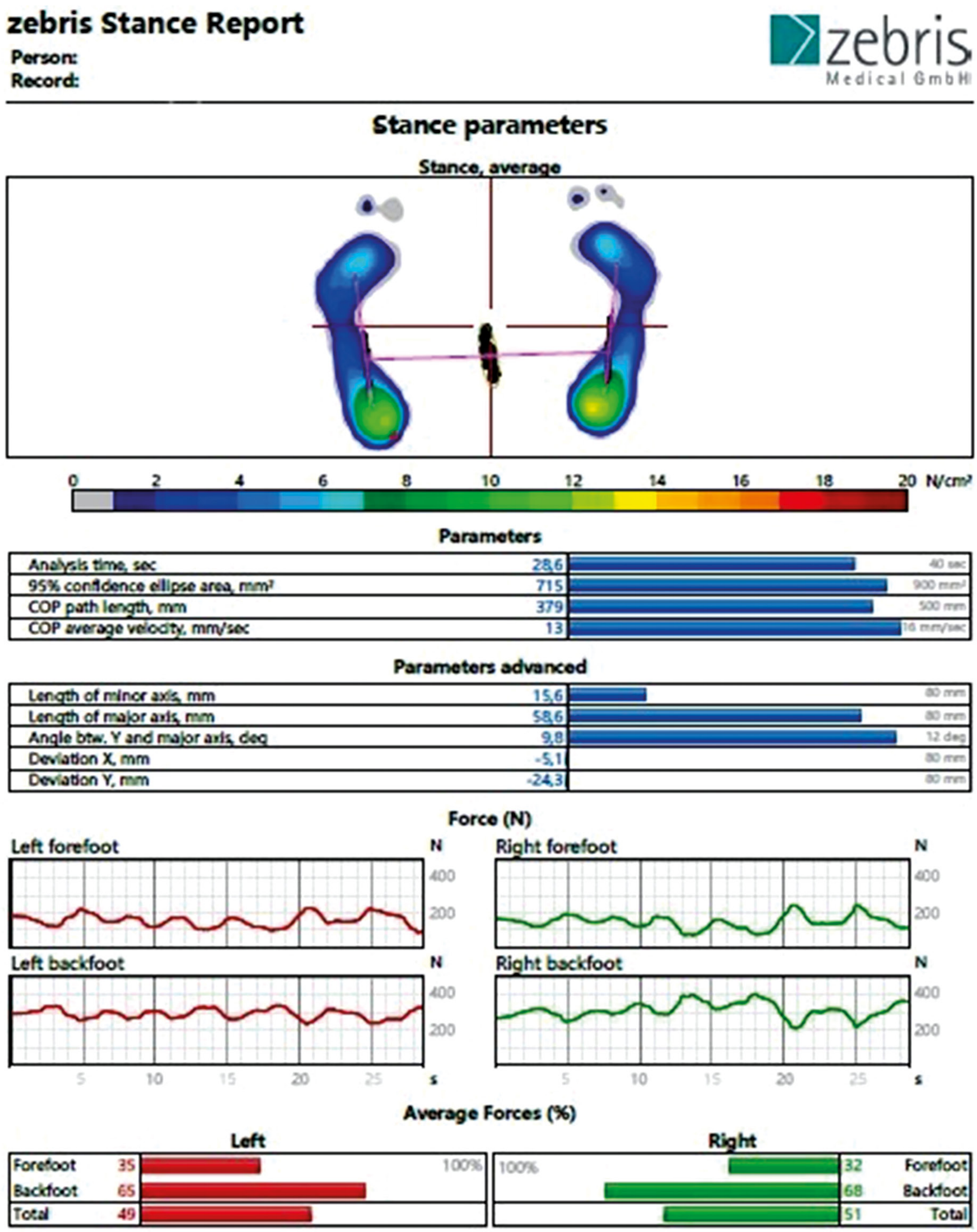

Figure 1. Part of the Zebris PDM-L report – static trial

- Step time [s].
- Cadence [steps/min] – step frequency.
- Velocity [km/h] – gait speed.
- Length of gait line L/R [mm] – describes the length of the gait line.
- Single support line L/R [mm].
- Ant/post position [mm].
- Lateral symmetry [mm] – describes lateral gait symmetries.
- Max gait line velocity [cm/s].

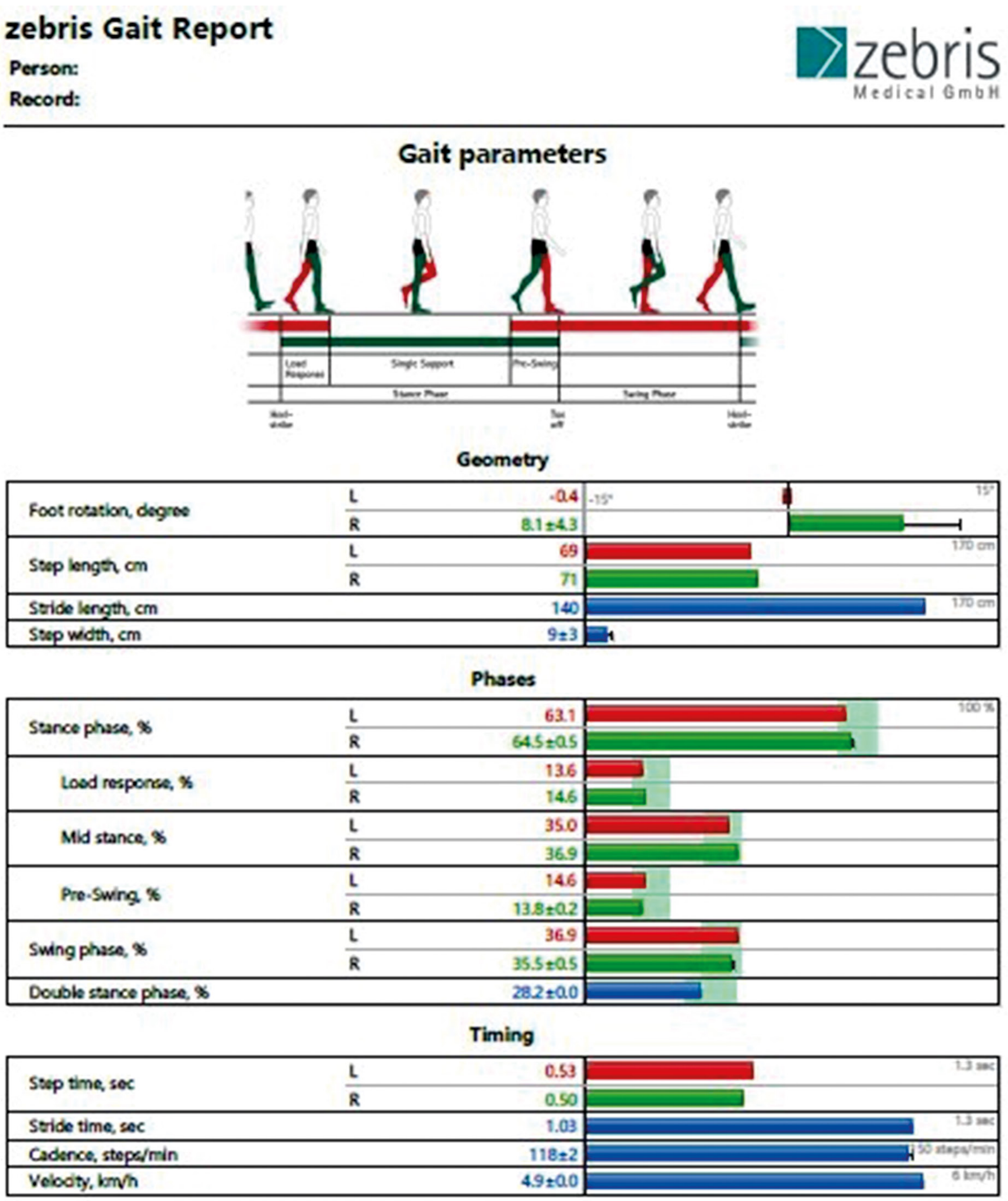

Figure 2. Part of the Zebris PDM-L report – dynamic trial (1)

– Maximum pressure Forefoot/ Midfoot/Heel L/R [N/cm²] – describes the maximum vertical reaction force of the substrate.
– Time maximum force Forefoot/ Midfoot/Heel L/R [% of stance time] – describes the time of maximum vertical reaction force of the substrate.
– Contact time Forefoot/ Midfoot/Heel L/R [% of stance time].

During the dynamic test, the platform also records and analyses in detail the load on the foot in individual phases of gait [%], such as:
– Stance phase [%] – support phase.

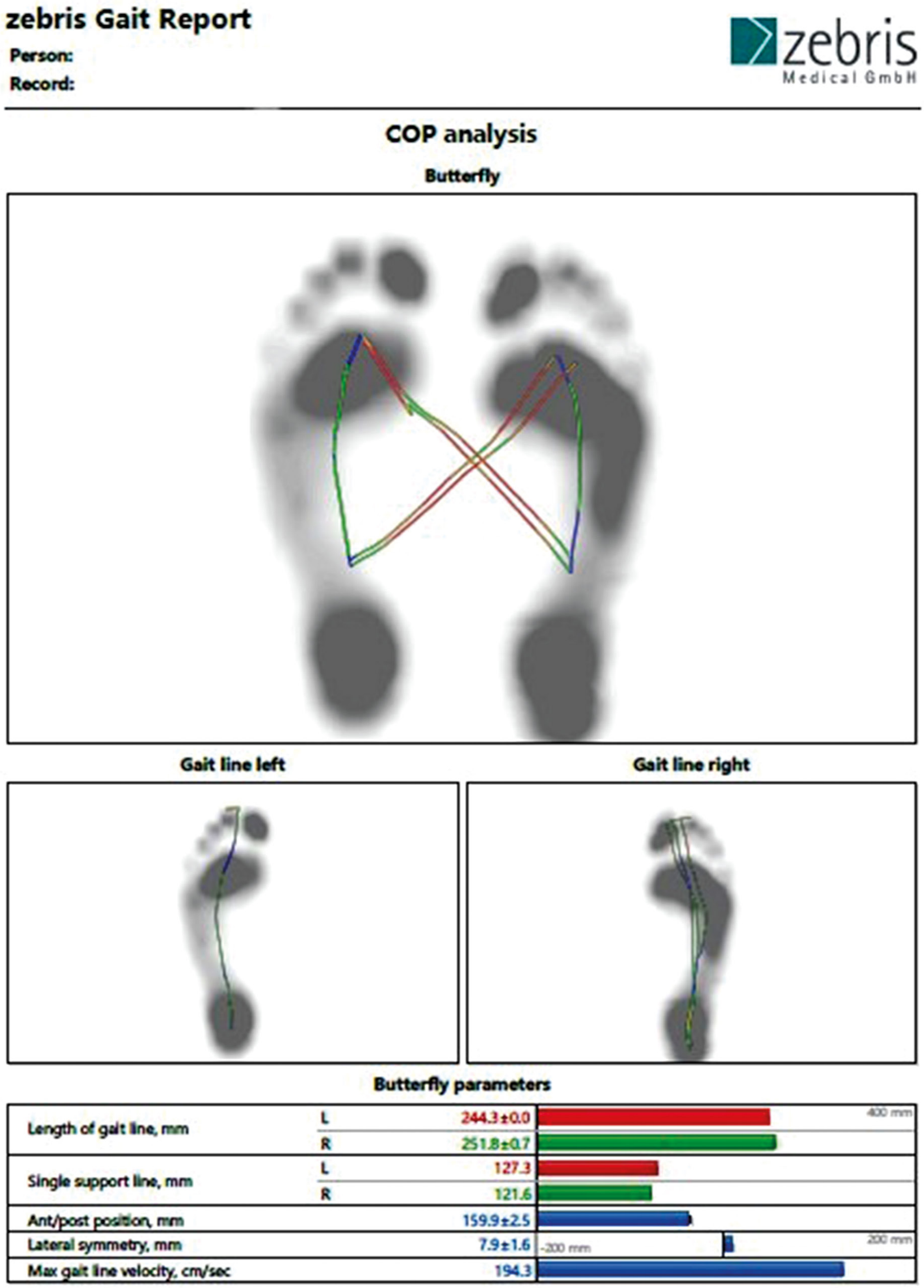

Figure 3. Part of the Zebris PDM-L report – dynamic trial (2)

– Load response [%] – eccentric braking phase.
– Mid-stance [%] – middle support phase.
– Pre-swing [%] – initial swing phase.
– Swing phase [%] – transfer phase.
– Double stance phase [%] – double support phase [7].

Organisation of the study

The research was conducted in April–July 2023. The study was conducted in a room, where the person participating in the study and the researcher were located. The study was conducted using the Zebris PDM-L platform by ZebrisMedical GmbH with dimensions of 1370 mm × 535 mm × 15 mm (l × b × h). The active surface of the substrate force response analyses includes an area of 1220 mm × 474 mm (l × b). It allowed us to assess the reaction of the ground forces and the deviations of the centre of gravity of the respondents. The Zebris PDM-L platform is made of a matrix containing 8064 individually calibrated, capacitive force sensors that enable the analysis of forces under the feet while standing and walking. In addition, the parameters of the platform allow an accuracy of 5% (FS) in the measuring range of 120 N/cm^2, with a sampling frequency of 120 Hz [7, 33] (Figure 4).

The study included carrying out a static and dynamic test. The static test was carried out 3 times: measurement I in conditions of relative silence (RS), measurement II with the sound of a shot (S), and measurement III, during which the respondents wrote a text message saying "Hi, what's up?"(SmS). Ensuring repeatability of the stop setting on the platform during the static test, permanent lines were marked on the surface of the platform, glued to the platform, defining the centre line of the platform, which in subsequent attempts coincided with the centre line of the test body. The test with the sound of a shot included a test carried out in conditions of relative silence with the sound of a shot being administered successively every 3 and 5 seconds with different sound intensity. The variability of the sound delivery time allowed us to reduce the influence of the subject's predictability as to the time when the sound would appear.

The dynamic test was carried out 3 times under dynamic conditions, taking into account the same stimuli used in the static test. The first dynamic test was carried out in conditions of relative silence (RS), the second test with the sound of a shot (S), and the third attempt to pass the designated distance was made while texting a message with the same content (SMS). The dynamic test distance was 6 metres; the Zebris PDM-L platform was located in the middle of this distance.

During the tests carried out in dynamic conditions, the number of corrections to the track was additionally assessed with the help of sight. The total number of vision corrections carried out by one person in all measurements of dynamic tests (tests I–III) carried out during the study was counted. The duration of each of the static and dynamic tests was equal to 30 seconds.

Figure 4. The stabilometric platform – Zebris PDM – L

The subject and the examiner were present during the tests in the room.

Prior to commencement of the study, the respondent voluntarily agreed to participate in the study. The respondent was informed about the purpose and anonymity of the study and about the possibility of resigning from participation in the study at any stage.

The study was carried out in accordance with the Helsinki Declaration (WMA Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects). The study did not bear any risk for the study participant. Positive consent was obtained from the Bioethics Committee of the Academy of Zamosc, no. KBAZ/3U/2025.

Study group

The study group consisted of 52 people (F: 31; M: 21). The average age of the studied people was 25.6 ±5.04 years. Among the respondents, 27 people corrected their eyesight during the dynamic test (M: 2.8 ±1.5 times). Detailed data are described in Table 1. The individual stages of the selection of the study group are presented by flowchart (Figure 5).

Statistical analysis

Only valid data were included in the proper analysis. Records with missing data were removed from

Table 1. General characteristics of the study group

Variable			***n***	**%**		
Gender (*n* = 52), female/male			31/21	59.6/40.4		
Place of residence (*n* = 52), city/village			32/20	61.5/38.5		
Variable	X (-95 CI; +CI)	SD (–95 CI; +CI)	Me	Reference (Min.–max.)	Q1	Q3
Age (*n* = 52)	25.6 (24.2; 24.2)	5.04 (4.2; 6.2)	24.0	19.0–37.0	22.0	28.0
BMI (*n* = 52)	24.5 (23.4; 25.6)	4.0 (3.4; 5.0)	24.4	17.7–38.4	21.9	26.5
Frequency of vision correction (*n* = 27)	2.8 (2.2; 3.4)	1.5 (1.2; 2.1)	2.0	1.0–7.0	2.0	4.0

**X – average, -95 CI/+95Cl – 95% confidence interval of average or standard deviation, SD – standard deviation, Me – median, References (Min – Max) – minimum and maximum value, Q1 – lower quartile, Q3 – upper quartile.*

the database. Qualitative variables were presented as number and percentage. Quantitative variables were presented as follows: mean, standard deviation and 95% confidence intervals, median (Me), references – minimum and maximum value (Min.–max.), lower quartile (Q1), and upper quartile (Q3). Assumptions regarding the normality of the distribution of the tested measurable variable with a normal distribution were verified using the Wolf W-Shapiro test. The lack of a normal distribution conditioned the use of nonparametric analysis for the analysed variables. Equality of variances was assessed using Leven's test. To assess more than 2 measurements ($k > 2$) of the tested variable (dependent variables) in different conditions, the nonparametric Friedman ANOVA test was used. The basis for the statistical analysis was a comparison of 3 dependent measurements for a variable without a normal distribution. A 5% inference error was assumed, which was equivalent to considering the relationships whose significance level was $p \leq 0.05$ as statistically significant. Statistical analysis was conducted using the Statistica 13.0 PL program.

Results

The analysis considers the comparison of the parameters of the static test for 3 consecutive dependent tests. When comparing the test of free standing in conditions of relative silence (RS), in the test with the sound of a shot (S), and the test with SMS texting (SMS), the analysis did not show any significant relationships between the analysed variables ($p > 0.05$).

However, it should be noted that in the 95% confidence ellipse area and COP path length parameter,

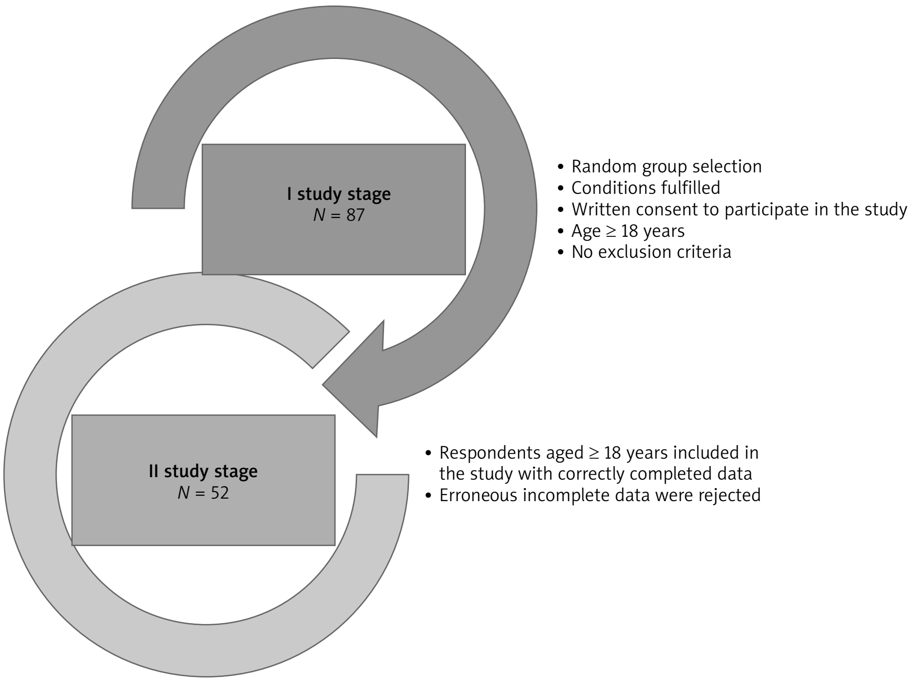

Figure 5. Flowchart of the participants' selection process

Table 2. Influence of auditory and visual stimuli on the average parameters of equilibrium and reaction of ground forces in a static test

Parameters Trial Static	Group						*P*-value
	RS		S		SmS		
	x	SD	*x*	SD	*x*	SD	
95% confidence ellipse area [mm²]	244.0	199.8	339.4	621.6	243.0	346.2	0.316
COP path length [mm]	220.8	91.1	230.5	124.7	218.9	119.7	0.578
VCOP average velocity [mm/sec]	7.6	3.1	7.9	4.3	7.6	4.2	0.628
Forefoot force L [%]	41.6	11.1	41.3	10.1	41.1	9.8	0.673
Backfoot force L [%]	58.4	11.1	58.7	10.1	58.9	9.8	0.673
Total force L [%]	51.9	6.0	51.5	3.3	51.9	3.7	0.659
Forefoot force R [%]	42.5	10.8	42.7	12.6	41.7	12.1	0.669
Backfoot force R [%]	57.5	10.8	57.3	12.6	58.3	12.1	0.669
Total force R [%]	48.1	6.0	48.5	3.3	48.1	3.7	0.659

X – mean, SD – standard deviation, L – left foot, R – right foot, RS – test in conditions of relative silence, S – test with the sound of a shot, SMS – test with texting, ANOVA Friedman test.

the values obtained in the shot sound test were higher than in the RS and SMS tests (Table 2).

Comparative analysis of equilibrium and gait parameters in the dynamic test showed significant differences between dynamic tests carried out in conditions of relative silence, during a shot, and while texting ($p < 0.05$). The percentage average value of the foreload (Forefoot L/R [%]) and hindfoot (Backfoot L/R [%]) differed significantly in the analysed tests. The lowest average load values in each of the parameters were recorded in the SMS test, successively in the RS test. The highest average values of load parameters were recorded in the case of the test carried out during the shot sound (S). The average load on the lower limbs in individual phases of gait was analysed. Significant differences were noted in the case of the pre-swing and double stance phases. Both in the case of the pre-swing phase for the limb L (> 0.001) and R (0.005) and double stance phase (0.004), the lowest average percentages of parameters were recorded in the S test, successively in the MS test and in the SMS test.

The analysis of step length parameters for the lower limb L and R showed significant differences in the compared 3 tests (< 0.001). The average values of both parameters were the lowest in the SMS test, successively for the RS test. The highest mean values of parameters were recorded in the S test. The analysed stride length showed that the stride length when SMS texting was significantly shorter (118.7 ±15.8 cm) compared to the test carried out in relative silence (130.0 ±11.7 cm) and during shooting (132.5 ±10.6 cm) (< 0.001).

The load response analysis for the lower limb L (0.013) and R (< 0.001) confirmed significant differences. The lowest average value of parameters was recorded in the test carried out in relative silence conditions, successively in the test while SMS texting and the highest average values during the shot. In the case of step time for limbs L (0.003) and R (0.007), the lowest average value was recorded in the S test, successively in the MS test, and the highest average values were recorded when SMS texting. The analysis of the cadence parameter indicated that the average smallest number of steps per minute was recorded in the SMS test (104 ±7.9), consecutively in the MS test (108.3 ±7.1), and the highest average number of steps was carried out in the S test (109.6 ±7.3) (< 0.001).

Velocity was also analysed, indicating that the lowest speed was recorded in the SMS test (3.7 ±0.5 km/h), successively in the RS test (4.2 ±0.5 km/h), and the highest speed was recorded during the shot test (4.4 ±0.5 km/h). The length of gait line analysis for the lower limb L (0.014) and R (0.001) showed significantly the lowest values of the parameter in the SMS test, successively in the RS, and the highest average values in the S test. Detailed data are presented in Table 3.

The average load on the lower limbs in individual phases of gait was analysed. The differences in the load of the lower limb L and R in the following parameters did not show significant differences between the mean values of the parameters in the compared tests ($p > 0.05$).

The study also analysed the impact of vision correction on equilibrium parameters in the dynamic test, but no significant relationships were found except for individual parameters including foot rotation.

Discussion

The studies using force platforms to assess the distribution of foot pressure on the ground provide a number of objective numerical data, which are a very important aspect in research on gait and pos-

Table 3. Influence of auditory and visual stimuli on the average parameters of balance and reaction of ground forces in the dynamic test

Parameters Trial Dynamic	Group						*P*-value
	RS		S		SmS		
	x	SD	*x*	SD	*x*	SD	
Forefoot L [%]	791.9	153.9	799.3	150.3	778.8	144.6	< 0.001
Forefoot R [%]	798.0	152.9	800.6	149.7	782.4	149.8	< 0.001
Backfoot L [%]	605.7	126.9	621.7	131.7	597.0	119.7	0.003
Backfoot R [%]	601.5	117.1	624.9	122.4	597.7	110.6	< 0.001
Pre-Swing L [%]	13.2	1.4	12.6	1.2	13.7	2.0	< 0.001
Pre-Swing R [%]	13.3	1.4	13.0	1.4	13.8	1.7	0.005
Double stance phase [%]	26.5	2.4	25.5	2.3	27.6	3.6	0.004
Step length L [cm]	65.3	6.7	65.8	7.4	58.2	8.9	< 0.001
Step length R [cm]	64.7	5.9	66.7	5.3	60.4	8.8	< 0.001
Stride length [cm]	130.0	11.7	132.5	10.6	118.7	15.8	< 0.001
Load response L [%]	13.3	1.5	14.8	13.1	13.8	1.9	0.013
Load response R [%]	13.1	1.7	14.5	13.1	13.7	2.1	<0.001
Step time L [sec]	0.56	0.04	0.55	0.04	0.58	0.06	0.003
Step time R [sec]	0.56	0.04	0.55	0.04	0.57	0.05	0.007
Cadence [steps/min]	108.3	7.1	109.6	7.3	104.5	7.9	< 0.001
Velocity [km/h]	4.2	0.5	4.4	0.5	3.7	0.5	< 0.001
Length of gait line L [mm]	232.8	18.3	233.9	17.8	230.8	20.1	0.014
Length of gait line R [mm]	231.7	26.7	235.1	18.0	228.8	19.4	0.001
Single support line L [mm]	120.3	16.3	124.9	13.9	115.7	16.4	0.004
Ant/post position [mm]	141.2	10.3	141.2	10.1	143.4	10.5	0.013
Maximum pressure Midfoot L [N/cm^2]	19.2	14.4	18.4	11.5	19.7	10.7	0.017
Maximum pressure Heel L [N/cm^2]	36.8	7.3	38.4	9.5	35.2	7.9	< 0.001
Maximum pressure Heel R [N/cm^2]	36.0	6.9	37.2	7.0	33.7	6.6	< 0.001
Time maximum force Forefoot L [% of stance time]	76.5	1.6	76.5	1.5	77.2	1.8	< 0.001
Time maximum force Forefoot R [% of stance time]	76.5	1.3	76.6	1.6	77.2	1.3	< 0.001
Time maximum force Midfoot L [% of stance time]	44.7	9.7	46.4	10.0	49.3	9.7	< 0.001
Time maximum force Heel L [% of stance time]	18.9	2.8	19.2	2.7	20.1	2.6	< 0.001
Time maximum force Heel R [% of stance time]	18.8	3.1	19.3	3.2	20.9	2.7	0.007
Contact time Forefoot L [% of stance time]	89.4	2.7	89.0	2.1	90.3	2.3	< 0.001
Contact time Forefoot R [% of stance time]	89.6	2.7	89.2	2.1	90.3	2.3	0.003
Contact time Midfoot L [% of stance time]	74.9	5.4	74.3	4.5	77.2	4.3	< 0.001
Contact time Midfoot R [% of stance time]	75.1	4.9	74.6	4.4	77.3	3.9	< 0.001
Contact time Heel L [% of stance time]	59.9	7.1	60.7	6.5	63.8	5.5	< 0.001
Contact time Heel R [% of stance time]	59.0	7.0	60.3	6.4	64.0	4.4	< 0.001

*X – mean, SD – standard deviation, L – left foot, R – right foot, RS – test in conditions of relative silence, S – test with the sound of a shot, SMS – test with texting, *ANOVA Friedman test.*

ture, to diagnose lower limb problems or to program the therapeutic process. The efficiency of the body's balance control system can be verified by introducing destabilising elements into the study, such as the sound of a shot or a cognitive task, e.g. SMS texting, which force the examined person to launch an automatic reaction to restore balance [9].

Our own study showed significant differences between dynamic tests carried out in conditions of relative silence, during the sound of a shot, and while SMS texting ($p < 0.05$).

Analysis of foot loading parameters during individual phases of the gait cycle is used to determine the dynamic equilibrium capacity of people for whom the risk of falls should be assessed [34, 35]. It allows for precise detection of current stability disorders related to various motor activities that could not be detected in static tests due to properly functioning and well-established compensation mechanisms in statics [9, 36, 37]. In our own study, in the case of static tests carried out on the Zebris PDM-L platform, there were no statistically significant relationships between individual measurements, which may indicate properly functioning mechanisms of posture control in statistics, especially since the study group consisted of young people. As de Castro reports, research conducted on a group of young individuals aims to provide valuable foundational information on postural balance [38]. Other researchers, based on standardised tests, observed slight and insignificant correlations between static and dynamic balance measurements in children ($-0.302 \leq r \leq 0.245$), teenagers ($-0.276 \leq r \leq 0.202$), and young adults ($-0.120 \leq r \leq 0.161$). Balance maintenance is not stable throughout life, as it increases during youth, reaches a peak in young adults, and declines in seniors [39]. Standing freely on 2 feet is a complex task that requires the engagement of appropriate muscle groups. Any voluntary contraction may lead to a deterioration in standing balance [40]. Other studies on the AMT (Advanced Mechanical Technology Inc., Watertown, MA, USA) platform demonstrate that the postural stability control of young adults is not influenced by personality traits but rather by visual control and the size of the support area [41]. The demand for such studies is continually increasing, as their number is relatively low [42].

In the literature, it is reported that postural stability increases during two-task activities [19, 20, 23, 24]. The results of the study indicate that the concentration process can facilitate static control of posture [24], which is confirmed in the authors' own study, where in static tests with SMS texting the results obtained in terms of all parameters were very similar to those obtained in the MS test.

Safe use of a phone while carrying out everyday activities requires both cognitive and motor skills as well as divisibility of attention [25, 43]. The literature reports that, like other dual tasks, texting while walking causes both gait and texting to deteriorate. This is most likely due to the increased requirements for visual tasks and motor skills of the individual [43–48].

The most common parameter that changes when carrying out two activities at the same time is the gait speed [25, 43]. According to the literature, the reliability of this parameter is good or excellent. Reducing gait speed can be a compensatory behaviour to ensure a safe gait [49, 50]; at the same time, it can be associated with a significant increase in gait variability and cause the risk of falls [51]. In our study, a statistically significant reduction in walking speed was noted in the SMS texting test.

Scientific reports also prove that stabilometric parameters such as the length of the COP path and the maximum speed are extended when SMS texting. It has been suggested that young people who text messages on a smartphone have difficulty maintaining balance in a standing position [25]. Other studies in healthy young people also show that the activity of texting on a smartphone affects the deterioration of balance parameters, at the same time causing lengthening of the stride [52], lower gait speed, extension of the support phase, and increased width of the step [53]. Similar results were presented by Kim *et al.* on a GAITRite treadmill. Compared to walking without using a smartphone, the participants moved at a slower pace and speed, altered their step length and gait cycle, and spent more time in the heel contact phase with the ground [54]. Visual information plays a crucial role in human locomotion by providing feedback on motor activities [55]. Visual information regarding the lower visual field contributes to guiding the trajectory of the lower limbs or positioning the foot while walking [56]. A smartphone positioned in front of the visual field blocks visual information related to the front of the foot by the device and the upper limb. The reduction of visual stimuli affects movement control and may lead to instability situations [57].

This proves that, despite adaptation strategies resulting from carrying out a double task, the parameters of the gait cycle deteriorate [53].

The author's analysis of the cadence parameter indicated that the average smallest number of steps per minute was recorded in the SMS texting test; in addition, the gait speed, stride length, and step length for both lower limbs were significantly reduced during the SMS texting test. In the case of step time for the L and R limb, an extension of this parameter was noted during the test with SMS testing.

In recent years, there has been increasing exposure to noise, which may contribute to an increased risk of noise-induced hearing loss, especially in youths and young people [31, 32]. Approximately 80% of young people use personal listening devices (PLDs) [30]. Scientific evidence suggests that auditory information plays a role in the regulation of postural control in healthy individuals and individuals with various medical conditions [58], but it is still unclear to what extent [59, 60].

In this paper, one-second acoustic signals of shots during calm standing and gait were used. This stimulus was intentionally used as a negative stimulus, appearing unexpectedly, thus intended to cause destabilisation of the examined body. Similar signals were used in the literature, where a woman's scream and the sound of a car braking were used as negative sounds [61]. Studies have shown that sounds with a shorter time than the postural reaction caused postural destabilisation [61]. Researchers came to similar conclusions in these reports. It was proven that the stimulus of the shot during the dynamic test resulted in the highest average values of foot loading parameters. The average load on the lower limbs in individual gait phases was analysed, and a significant shortening of the double stance phase and pre-swing was noted in the test with the sound of a shot. In addition, the average frequency of steps per minute as well as the gait speed increased.

In the literature, we find reports that changes in tone have an impact on the emotional state of the respondents and on the parameters of postural stability. The deep timbre of the sound affects the self-confidence of the participants, the position of the body, and the speed of movement. In addition, it was proven that young women achieved significantly better balance parameters during sound exposure [62]. In this study, differences in foot loading under the influence of sound depending on gender were not verified. The sound of the shot in the study group caused a significant increase in the anterior and posterior load of both lower limbs during the dynamic test, which coincides with the tests cited above. In the test with the sound of a shot (S), a statistically significant shortening of the stride length and step length parameters for both lower limbs was proven. The length of gait line analysis for both lower limbs showed significantly the highest mean values of this parameter in the S test, which proves that the sounds of the shot caused deterioration of stabilisation and control of body position.

The study also has some limitations. The Zebris PDM-L platform allows for the assessment of one step during a dynamic test, which may, in a somewhat limited way, show the analysis of gait and its individual phases along with the reaction parameters of ground forces. However, this device is used for such analyses also in clinical settings. Another aspect of the centre of gravity deflections that was not included in the analysis was the upper limbs extended forward, in which the subjects held the phone and wrote text messages. The length of the arm and the angle of forward extension of the limbs were not analysed – this was not the subject of the authors' research due to the attempt to assess natural positions in everyday conditions, where there is no process of analysing the length of the arm and its influence on the inclination of the centre of gravity. Nevertheless, it is a factor that may disturb the body's ability to maintain balance. An important aspect in these considerations is the height of the subject's body and the length of the arm. However, in natural conditions it is not possible to change these parameters; hence, the verification can only show differences in the risk of falls for taller and shorter people when carrying out the analysed activities. It will not constitute any recommendations in this regard. However, the variable factor – the angle of the limb relative to the body plane – may be a factor that is modifiable and may contribute to better stabilisation of the body during the analysed activities and may constitute a future research goal.

For anatomical reasons and the inability to change the length of the arm, authors plan to expand the research in this area by deliberately changing the angle of the forearm in relation to the upper arm and, overall, the upper limb in relation to the frontal plane of the torso, to demonstrate how the final positioning angle of the upper limb may influence the reduction of fall risk. The inclusion of electromyography (EMG) methodology in subsequent studies will also allow for the assessment of the nervous system's reactions.

The main goal of the study was to conduct analyses in a group of young and healthy individuals. This assumption may pose a limitation, and expanding the study group to include older individuals and neurological patients may provide more significant evidence regarding reactions to centre of gravity shifts. However, the factors included in the study, such as heavy metal music and texting, may pose significant risks to neurological patients; therefore, an attempt was made to verify ground force reactions among healthy and young subjects to assess how strongly these factors influence body balance, especially since the Zebris PDM-L platform is being used for the first time in research.

The stepwise approach to the study allows for a more detailed analysis of centre of gravity shifts and the reduction of study risks in other participant groups, particularly among neurological patients, where directing gaze to a screen, along with a change in arm length affecting the position of the body's centre of gravity, under intense music, may prove dangerous to the subject's health or difficult to perform. Understanding the mechanisms of these reactions will enable the proper establishment of exclusion criteria for studies involving patients with neurological disorders in future research.

Conclusions

The analysis of free-standing tests in conditions of relative silence, in the test with the sound of a shot, and in the test with texting did not reveal any significant relationships. Auditory and visual stimuli did not affect body balance in static conditions in the tested group of young healthy people. In the dynamic test, the shot increased most of the parameters determining gait. The shot caused significant body shake and balance disturbances in the tested group of young healthy people. Texting while walking (dynamic test) resulted in greater concentration, slower walking, and stabilisation of the subject's body assessed on the basis of balance parameters and ground force reactions in the tested group of young healthy people.

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Ethical approval

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Conflict of interest

The authors declare no conflict of interest.

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