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Original article

The effects of speed and terrain characteristics on the distribution of force and plantar pressure during the gait of children with different levels of physical activity

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Summary

Introduction. The adoption of correct walking patterns is an indicator of the locomotor system readiness to establish optimal interaction between body force and the surface, and the way of creating pressure exerted by the feet during the walking cycle. The aim was to examine how the speed and characteristics of the terrain affect the distribution of force and plantar pressure during the gait of children with different levels of physical activity.

Methods. A prospective comparative study included 150 students aged 11–12 years and their parents from Banja Luka. According to the protocol, each group of subjects walked at average and maximum speed on flat and 5% inclined terrain. For the purposes of the research, the Physical Activity Questionnaire PAQ-C (The Physical Activity Questionnaire for Older Children), a survey questionnaire for parents, measurement of anthropometric parameters and Zebris strips (Zebris Medical GmbH, Germany) were used for gait analysis.

Results. When walking at maximum speed in inactive subjects, the maximum force on the left ($F(148) = 14.878$, $p < 0.001$) and right ($F(148) = 8.204$, $p < 0.001$) heel decreased, while in moderately and highly active subjects it grew moderately. In highly active subjects, the highest value of maximum pressure was registered ($d = -1.41$ for the left leg and $d = 1.36$ for the right leg). When the slope of the terrain changes in inactive subjects, the maximum force on the front part of both feet decreased ($F(148) = 5.043$, $p = 0.008$, $d = 0$). The influence of terrain characteristics was such that walking on a 5% incline almost as a rule had greater effects on inactive children, while moderately and highly physically active children gave an adequate response when walking on the 5% incline.

Conclusion. Urbanization and new developments in society impose the need to involve children in organized activities so that children acquire the skills and demonstrate the competence they face in their environment.

Keywords: children of primary school age, physical activity, gait analysis, gait speed, terrain characteristics

Introduction

Physical activity (FA) is defined as any type of physical activity that moves the body using skeletal muscles with an energy consumption that is significantly higher than the consumption in the resting phase. The World Health Organization (WHO, 2010) has provided recommendations and guidelines on the type and frequency of physical activity for optimal health benefits for youth, adults and the elderly [1]. Physical activity can be achieved through different forms of activity: walking, cycling, sports, active forms of recreation such as dancing, yoga, tai chi or as part of work (lifting, carrying or other active tasks), and as part of household chores (cleaning, carrying). A large number of people replaced walking and cycling with personal motorized transport [2]. Considering the increasingly urbanized world, where more than 70% of the world's population lives in urban centers, cities have a special responsibility and the possibility of contributing to the improvement of urban design and the maintenance of active transport [3, 4]. It is needed to investing in physical activity, not only for its direct health benefits, but for the fact that increasing walking, cycling, active recreation, sport and play can lead to a more just, sustainable and prosperous world [5]. Diseases due to lack of movement and physical inactivity can be considered a significant pathogenic condition factor [6]. The type of surface on which the child moves on the way to school, the slope of the terrain, obstacles such as stairs and the way of movement (walking, fast walking, running, jumping, etc.) can be a risk [7]. Walking speed as a generic indicator of health status [8] indicates the state of physical fitness of an individual and the response of spatiotemporal parameters when walking at different speeds. In children and adolescents, a strong inverse correlation between plantar pressure and level of physical activity was recorded [9, 10]. Assessment of plantar pressure can signal different postural changes of the foot, related to forces at the level of the foot while standing and walking, both in healthy subjects and in various pathologies such as obesity. Sports and all forms of exercise have a confirmed health-preventive effect in order to increase general motor ability, which has an important task in moving individual organs, as well as the whole body [11]. How will a young organism of different levels of physical activity, which is entering a period of accelerated growth and development respond to efforts, it is necessary to observe the movement of the center of pressure on changing terrains, slopes, load regimes and speeds [12].

The aim of the research was to examine how the speed (average and maximum) and the characteristics of the terrain (flat, under a slope of 5%) affect the distribution of force and plantar pressure during the gait of children with different levels of physical activity.

Methods

The research represented a prospective comparative study according to the PICO methodology (Patient/Population, Intervention, Comparison, Outcome). Using the cluster sampling method, the study included 150 students of both sexes and their parents aged 11 to 12, from seven city elementary schools in Banja Luka. After meeting the inclusion criteria and testing students with the Physical Activity Questionnaire PAQ-C (The Physical Activity Questionnaire for Older Children) [13, 14], the subjects and their parents successively entered the study and were divided into three groups: insufficiently, moderately and highly physically active children. Permuted blocks formed two strata according to gender. Sampling took place until the expected number of 150 respondents was filled. The first 25 boys and the first 25 girls within the corresponding group were included in the study. Each group had 50 respondents.

Inclusion criteria: children aged 11–12, both sexes, children with signed written consent from parents or legal representatives, children who gave consent and signed written consent to participate and children who had the ability to walk independently.

Exclusion criteria: children with intellectual disabilities, epilepsy, cerebral palsy, hemiparesis, diabetes mellitus, diseases of the heart and blood flow, respiratory organs, children with a history of fractures or injuries of the lower extremities in the last year, children without the signed written consent of their parents or legal guardian representatives, children who did not give their consent to participate, children using mobility aids, having fatigue, pain and inability to adapt to the work of the Zebris tape.

The research was approved by the Ministry of Education and Culture of Republic of Srpska and the Ethics Committee of the Faculty of Medicine of the University of Banja Luka. All respondents and parents gave voluntary consent, which, in addition to the oral explanation, was contained in the informed consent and written information for parents and students. The research was conducted during the 2019/2020 and 2020/2021 school years. Subjective and objective tests were used for research purposes.

Subjective tests

The PAQ-C physical activity questionnaire consisted of nine questions separately evaluated on a 5-point scale. The total result of physical activity was predicted at the level of the arithmetic mean of the given answers, evaluated separately on a scale from 1 to 5. The questionnaire enabled the classification of respondents (score 1 to 2 - inactive, 3 - averagely active and 4 to 5 - active children) according to the given criteria [13, 14].

The survey questionnaire for parents was designed based on previous research [15], in order to assess parents' awareness of the factors associated with carrying a school bag, as well as which specifications are key when choosing a school bag. The questionnaire consisted of 37 questions. From the survey questionnaire, we selected items related to the types of terrain by slope, children used for walking from home to school.

Objective tests

Body mass index (BMI) is calculated as the ratio of body mass to the square of body height. Body mass (BW) is expressed in kilograms, and body height (HW) in meters (WHO, 2018). Nutritional status was assessed using the standard body mass index according to criteria (WHO, 2000), and by classifying values according to percentile curves for boys and girls aged 5 to 19 years (WHO, 2007) according to standard threshold values. The obtained result classifies the child into five categories: obese, increased body weight, normal body weight, malnourished and undernourished [16].

Gait performance was assessed on a multifunctional Zebris treadmill (Zebris Medical GmbH, Germany) for training and gait analysis. The Zebris system consists of a walking belt with a diameter of 158 x 60.1 cm, which contains a sensor surface with a diameter of 149 x 54.2 cm with 11264 sensors, technical and computer elements. Recording on the Zebris tape requires the preparation of the subject. After a 10-minute adaptation phase, the system is ready for recording that lasts 30 seconds. Due to the high density of sensors, the leg is mapped with high resolution, which enables the registration of subtle changes in the distribution of force and pressure [17–20].

The predictor variables in our research represent the value of the total score of physical activity (inactive, averagely active and active children), and the dependent variables represent length of gait line, antero-posterior position variability, lateral symmetry variability, contact time, maximum force, time of maximum force, maximum pressure determined separately for the rear, middle and front parts of the foot, as well as load transfer time for which the load is transferred from the rear to the front of the foot bilaterally.

Children were tested with the PAQ-C physical activity questionnaire and parents were interviewed in agreement with the physical education teacher. Objective measurements were taken in the Gait Analysis Cabinet at the Institute for Physical Medicine, Rehabilitation and Orthopedic Surgery "Dr. Miroslav Zotović" in Banja Luka, Republic of Srpska, Bosnia and Herzegovina. Each subject was required to: eat two hours before the test, take in enough liquid and perform physiological needs. The procedure on the Zebris tape was explained to each respondent individually in accordance with the recommendations for the use of the Zebris Software Manual Zebris FDM [21]. The research was carried out by a research team consisting of the main researcher, an occupational therapist-physiotherapist, an occupational therapist intern, a physical education teacher and a doctor. The measurement on the Zebris tape was performed by one measurer, and the measurement of anthropometric parameters by two measurers. Before the very beginning, training was conducted by the main researcher.

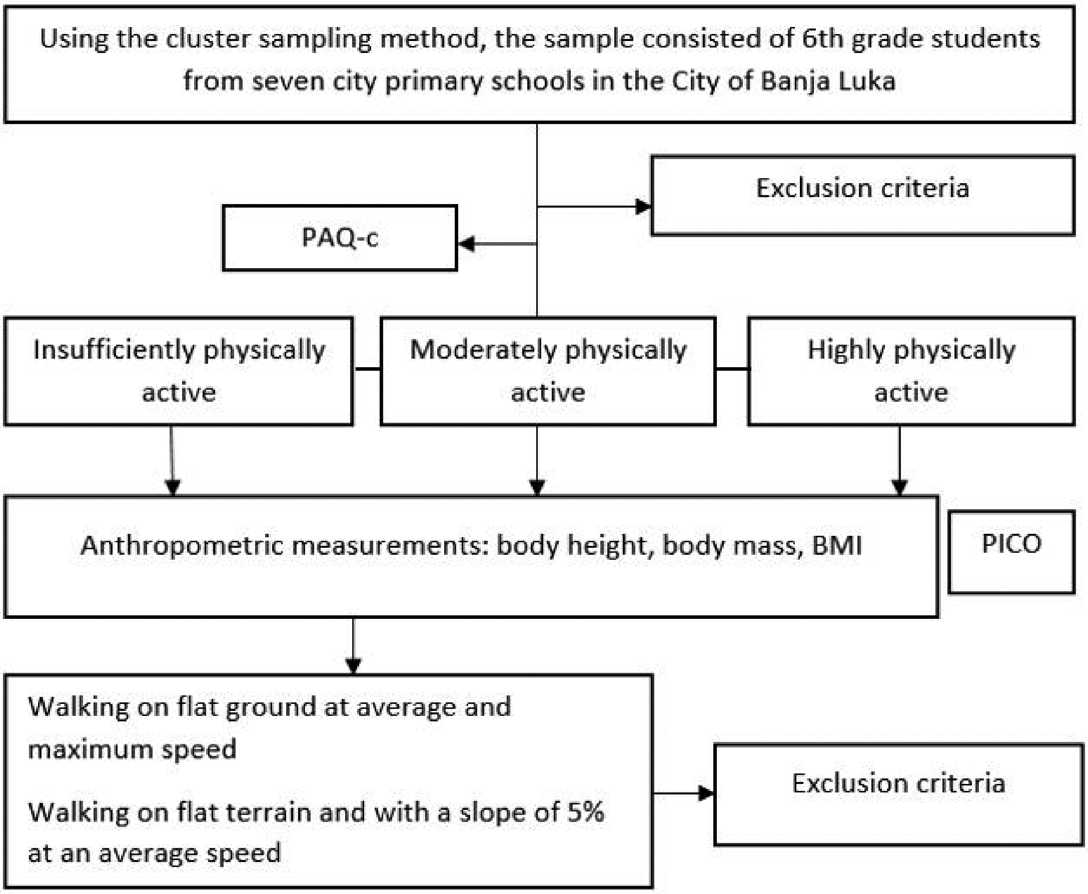

Figure 1. Study population, sampling, and protocol

Statistical analysis

The complete statistical data processing was done with the SPSS 23.0 statistical software package. Most of the variables are presented in textual and tabular form as frequency (%) of individual categories. In the case of continuous data, variables are presented as mean ± standard deviation (SD), minimum and maximum values. The normality of the distribution of numerical variables and the residuals of the variance analysis model was checked with the help of the Q-Q plot and the Kolmogorov-Smirnov test. Statistical significance of differences between groups was checked by two-way mixed analysis of variance. Statistically significant results were considered results which p value during significance testing was less than 5% ($p < .05$). Differences between two groups were examined using Paired samples t-test, with Cohen's d value as effect size, except in cases where assumptions for the use of parametric indicators were violated, in which case we used Wilcoxon signed rank test, with rank biserial correlation coefficient as indicator of effect size.

Results

The description of the sample, values of anthropometric parameters and types of terrain by slope on which children walk from home to school have been tabulated (Tables 1. and 2) with regard to gender and total population. Tables 3 and 4 show the results of a two-way mixed analysis of variance, the influence of walking speed (average and maximum) and terrain characteristics (flat, 5% slope) on force distribution and plantar pressure only where there is a statistically significant difference between the three predictors and the 32 dependent variables.

The average age of boys was 11.8 ± 0.4, and of girls 11.7 ± 0.4 years, and this difference was not statistically significant ($t(148) = 1.282$, $p = 0.202$). The average value of body mass was 49.3 kg. Girls (50.3 kg) in the sample were on average heavier than boys (48.4 kg), but also higher, where the average height of girls was 158.8 cm, and of boys 155.5 cm. However, statistically significant gender differences were not found for weight ($t(148) = -0.979$, $p = 0.329$), while they were found for height ($t(148) = -2.765$, $p = 0.006$). The average value of the body mass index was 19.8. Boys (19.8) on average had higher average values of body mass index than girls (19.8) (Table 1).

Table 1. Descriptive analysis of anthropometric parameters of the sample for the total population and by sex. Values are expressed as MIN, MAX and AS ± SD

Parameter	Gender											
	Boys				Girls				Total			
	M	SD	Min	Max	M	SD	Min	Max	M	SD	Min	Max
Body weight (BM) in kg	48.4	12.3	28.4	89.1	50.3	12	27.5	82.8	49.3	12.1	27.5	89.1
Body height in cm	155.5	6.8	136	170	158.8	7.5	140	174	157.1	7.3	136	174
Age	11.8	0.4	11.1	12.9	11.7	0.4	11.1	12.7	11.8	0.4	11.1	12.9
Body index mass (BMI)	19.9	4.0	14.7	35.8	19.8	3.9	14.1	30.0	19.8	3.9	14.1	35.8

Table 2 shows the types of terrain by slope, on which children walk from home to school.

From table 2, we see that flat terrain is represented in the majority of cases - 80.0%, while 25.3% of children walk uphill, and 8.0% of children walk on uneven terrain.

The manipulation of walking speed consisted in instructing the children in one situation to walk at normal speed and then at maximum speed. The analysis showed that for the parameters shown in table 3 there was a significant interaction between the speed at which the students walked and the level of their physical activity, and the table itself showed the results of the t-test analysis for repeated measurements separately by level of physical activity.

Table 2. Distribution of respondents' responses according to the slope of the terrain on which the child walks while going from home to school

Parameter	Category	N	%
Flat	yes	120	80.0
	no	30	20.0
	Total	150	100.0
Uneven	yes	12	8.0
	no	138	92.0
	Total	150	100.0
Uphill	yes	38	25.3
	no	112	74.7
	Total	150	100.0

The differences could be best seen through the effect sizes (Table 3), where we saw that the effect of the instruction to walk at maximum speed, although large[1] in all subgroups of physical activity levels, was greater by 0.25–0.35 Cohen's d for moderately and highly active children compared to inactive. For ant/post position variability, a significant interaction of walking speed and level of physical activity ($F(148) = 3.552$, $p = 0.031$) was reflected in the fact that there was a greater reduction of this parameter for inactive (rc = 0.74) and moderately active children (rc = 0.69), compared to highly active children (rc = 0.41). A similar pattern was observed for contact time with the right heel ($F(148) = 3.083$, $p = 0.049$), which moderately decreased in inactive children ($d = 0.75$) when walking speed increased, while the effect of walking speed was large in moderately ($d = 1.15$) and highly ($d = 1.39$) active children. When it came to the maximum force on the left ($F(148) = 14.878$, $p < 0.001$) and right ($F(148) = 8.204$, $p < 0.001$) heel, it decreased in inactive subjects ($d = 0.22$ for the left and $d = 0.45$ for the right heel), while in moderately active subjects it increased slightly with increasing speed ($d = -0.41$ for the left and $d = -0.30$ for the right heel), as well as in highly active subjects ($d = -0.89$ for the left and $d = -0.30$ for the right heel).

For maximum pressure, the interaction of walking speed and physical activity level (Table 3) was significant for the forefoot and heel of both legs. In the forefoot of the left ($F(148) = 4.872$, $p = 0.009$) as well as the right ($F(148) = 4.408$, $p = 0.014$) leg, there was a large increase in pressure (observed in standard Cohen's d values) for all subgroups of respondents. In inactive subjects, the increase in maximum pressure was the least ($d = -0.85$ for the left and $d = -0.99$ for the right leg), and it was greater in the moderately active ($d = -1.35$ for the left and $d = -1.20$ for the right leg) and the highest in the highly active subjects ($d = -1.41$ for the left and $d = 1.36$ for the right leg). On the left ($F(148) = 12.800$, $p < 0.001$) and right ($F(148) = 17.277$, $p < 0.001$) heel, the pressure change patterns were different than on the forefoot. Namely, on the heels of inactive subjects there were no changes in pressure with increasing walking speed ($d = -0.11$ for the left and $d = 0.04$ for the right heel), while in moderately active subjects there was a moderate increase in pressure ($d = -0.83$ for the left and $d = -0.62$ for the right heel), and in the highly active there was a large increase in pressure ($d = -1.09$ for the left and $d = -1.07$ for the right heel).

[1]When interpreting Cohen's d values, we took reference limits, where the value less than 0.2 Cohen's d is considered negligible, values between 0.2 and 0.5 are low, between 0.5 and 0.8 are high, and values greater than 0.8 Cohen's d are high values of standardized differences between arithmetic means.

Table 3. Data on the main effects of walking speed by physical activity level for parameters for which there is a significant interaction between walking speed and physical activity level

Parameter	Level of physical activity	statistic	p	effect size	Speed average M (SD)	Speed maximum M (SD)
		exact		rc		
Ant/post position variability, mm[a]	Inactive	1024.5	**<0.001**	0.74	11.24 (9.83)	5.24 (3.70)
	Average active	1080.5	**<0.001**	0.69	9.86 (11.90)	4.87 (4.16)
	Active	863.0	**0.013**	0.41	5.49 (4.11)	3.76 (1.70)
Lateral symmetry variability, mm[a]	Inactive	1110.5	**<0.001**	0.74	17.81 (13.78)	8.20 (8.11)
	Average active	1122.0	**<0.001**	0.83	14.23 (16.59)	6.25 (7.21)
	Active	1044.5	**<0.001**	0.64	7.65 (6.79)	4.10 (2.13)
		t(49)	p	d_{cohen}		
Contact time % of stance time: heel right	Inactive	5.285	**<0.001**	0.8	71.99 (7.44)	67.79 (8.89)
	Average active	8.115	**<0.001**	1.2	70.03 (6.04)	63.25 (7.58)
	Active	9.833	**<0.001**	1.4	68.08 (7.71)	62.05 (7.52)
Max force: heel left (N)	Inactive	1.589	0.118	0.2	338.20 (78.87)	328.31 (78.10)
	Average active	-2.885	**0.006**	-0.4	308.98 (76.87)	323.23 (85.78)
	Active	-6.263	**<0.001**	-0.9	323.42 (66.56)	355.47 (78.45)
Max force heel right (N)	Inactive	3.175	**0.003**	0.5	341.21 (80.15)	324.68 (77.11)
	Average active	-2.119	**0.039**	-0.3	311.26 (67.98)	322.86 (80.43)
	Active	-2.309	**0.025**	-0.3	322.47 (62.24)	343.30 (86.46)
Max pressure: forefoot left (N/cm2)	Inactive	-6.014	**<0.001**	-0.9	17.41 (4.97)	20.94 (4.62)
	Average active	-9.561	**<0.001**	-1.4	17.58 (4.44)	22.48 (6.18)
	Active	-9.984	**<0.001**	-1.4	20.16 (5.32)	26.20 (6.57)
Max pressure: forefoot right (N/cm^2)	Inactive	-6.975	**<0.001**	-1.0	17.71 (5.00)	21.14 (4.60)
	Average active	-8.484	**<0.001**	-1.2	18.26 (5.53)	22.79 (5.59)
	Active	-9.616	**<0.001**	-1.4	20.07 (5.42)	25.78 (6.73)
Max pressure: heel left (N/cm^2)	Inactive	-0.776	0.442	-0.1	24.21 (5.57)	24.58 (5.75)
	Average active	-5.896	**<0.001**	-0.8	22.98 (5.59)	25.24 (5.58)
	Active	-7.678	**<0.001**	-1.1	24.72 (5.12)	28.28 (5.90)
Max pressure: heel left (N/cm^2)	Inactive	0.257	0.798	0.0	23.76 (5.07)	23.67 (5.08)
	Average active	-4.396	**<0.001**	-0.6	22.07 (3.88)	23.66 (4.22)
	Active	-7.532	**<0.001**	-1.1	24.11 (4.72)	26.99 (5.30)

Note: bold letters indicate p values that are statistically significant at the 0.05 level, the number of subjects in each category of physical activity was N = 50.
acalculated non-parametric Wilcoxon Signed Rank test, due to violation of parametric assumptions.
rc - rank biserial correlation coefficient

A two-way mixed analysis of variance with slope as a repeated factor and level of physical activity as a non-repeated factor shows that for the parameters listed in table 4 there is a significant interaction between the slope of the terrain and the level of their physical activity, and the table shows the results of the t-test analysis for repeated measurements by physical activity levels.

Table 4. Data on main effects of slope by physical activity levels for parameters for which there is a significant interaction between terrain slope and physical activity level

Parameter	Level of physical activity	statistic	p	effect size	Terrain flat M (SD)	Terrain slope 5% M (SD)
		exact		rc		
Ant/post position variability, mm[a]	Inactive	310.0	**0.002**	-0.49	11.24 (9.83)	15.89 (13.51)
	Average active	474.5	0.246	-0.19	9.86 (11.90)	9.64 (8.38)
	Active	458.5	0.085	-0.28	5.49 (4.11)	6.08 (3.87)
		t(49)	p	d_{cohen}		
Contact time % of stance time: heel left	Inactive	-2.94	**0.005**	-0.42	72.29 (7.37)	74.48 (5.15)
	Average active	-0.23	0.819	-0.03	69.33 (7.60)	69.50 (7.07)
	Active	1.00	0.321	0.14	67.81 (8.18)	67.23 (7.31)
Contact time % of stance time: heel right	Inactive	-2.96	**0.005**	-0.42	71.99 (7.44)	74.01 (6.32)
	Average active	1.00	0.321	0.14	70.03 (6.04)	69.35 (6.60)
	Active	2.00	0.051	0.28	68.08 (7.71)	66.89 (7.68)
Max force: forefoot left	Inactive	2.37	**0.022**	0.34	340.43 (96.58)	319.10 (93.10)
	Average active	-0.66	0.51	-0.09	349.01 (85.30)	353.55 (87.98)
	Active	-1.62	0.111	-0.23	389.96 (101.08)	401.66 (106.30)
Max force forefoot right (N)	Inactive	3.16	**0.003**	0.45	352.63 (96.97)	321.25 (94.44)
	Average active	-1.43	0.159	-0.2	350.51 (92.81)	361.85 (90.98)
	Active	-1.42	0.161	-0.2	394.38 (107.33)	403.40 (105.20)
Max force time % of stance time: heel left	Inactive	-4.74	<0.001	-0.67	31.46 (5.30)	35.34 (7.00)
	Average active	-1.78	0.081	-0.25	31.04 (5.58)	32.36 (6.82)
	Active	-2.75	**0.008**	-0.39	29.00 (4.01)	30.26 (5.02)
Max force time % of stance time: heel right	Inactive	-5.57	<0.001	-0.79	32.31 (4.75)	36.16 (7.28)
	Average active	-2.21	**0.032**	-0.31	30.76 (4.88)	32.05 (6.25)
	Active	-1.62	0.112	-0.23	29.31 (3.80)	30.34 (5.11)
Max pressure: forefoot right (N/cm^2)	Inactive	2.89	**0.006**	0.41	17.71 (5.00)	16.26 (4.68)
	Average active	-0.59	0.556	-0.08	18.26 (5.53)	18.55 (5.02)
	Active	0.01	0.992	0	20.07 (5.42)	20.07 (4.90)
Time change heel to forefoot sec left	Inactive	-3.47	**0.001**	-0.49	0.62 (0.19)	0.69 (0.21)
	Average active	-3.68	**0.001**	-0.52	0.56 (0.17)	0.62 (0.20)
	Active	-0.92	0.362	-0.13	0.50 (0.10)	0.51 (0.10)

Note: bold letters indicate p values that are statistically significant at the 0.05 level, the number of subjects in each category of physical activity was N = 50.
acalculated non-parametric Wilcoxon Signed Rank test, due to violation of parametric assumptions.
rc - rank biserial correlation coefficient

When it came to dynamic parameters, the ant/post position variability increased in inactive subjects (F(148) = 3.517, p = 0.032, rc = -0.49), as well as the contact time with the right (F(148) = 4.285, p = 0.016 , d = -0.42) and the left heel (F(148) = 6.955, p = 0.001, d = -0.42), while the maximum force on the front part of both feet decreased (F(148) = 5.043, p = 0.008, d =0), and the duration of this force on the heels increased. In highly physically active subjects, there were no changes in the previously mentioned dynamic pressure parameters when changing the slope of the terrain (Table 4).

Discussion

A large number of previous researches on the topic of physical activity focused on identifying risk factors associated with the presence of pain, exhaustion, back curvature and the appearance of fatigue using statistical indicators [22, 23]. Nevertheless, a certain number of studies reported the results of the analysis of the interaction between the legs and the surface during walking [24–27]. The representative sample (N=150) constituted 10% of the included sample, in which there was an equal number of highly active, moderately active and inactive respondents of both sexes aged 11 to 12 years from seven primary schools of the local government of the City of Banja Luka. Statistically significant gender differences among the respondents were not found for body mass, but were found for height implying that there were more girls than boys in the population for which the sample was representative. The results of our study were consistent with the scientific literature that observed a higher prevalence of overweight and obesity among boys than girls and that girls in our study were more active than boys [28]. Compared to their peers from Serbia, they had a higher average TM, but the same values of TV, but compared to their peers from Montenegro, they had approximately the same average values of TM and lower average TV values [29]. On average, boys had higher average values of body mass index than girls. Through research, we wanted to check how walking speed (average speed and maximum speed) affected the distribution of force and plantar pressure during walking (on flat ground) of children with different levels of physical activity. Ant/post position variability became positive at maximum speed, while at average speed its value was negative. The maximum pressure on the middle part of both legs was reduced. Authors Scott and Kevin (2007) noted that slow walking speed required active control that was not in phase with movement in order to slow down the natural dynamics of the passive system. Thus, most of the variabilities is related to kinematic perturbations, implying that it may be temporally less stable at slow walking speed than during fast walking, but spatially more stable at low speed. Nevertheless, the results suggested that the neuro-control system more efficiently controled kinematic disturbances at low speed than during fast walking [30]. Studies have reported that a decline in walking speed correlates with a decline in muscle strength [31]. Higher variability and instability are considered to be indicators of a higher risk of falling in the elderly [32]. Ant/post position variability and lateral symmetry variability in the situation of walking at normal speed were the highest in inactive children, and the influence of walking at maximum speed was such that those parameters decreased the most in inactive children, and therefore the differences in them between children according to activity levels were almost lost when children walk at maximum speed.

The maximum force on the heels did not change or decrease in inactive children, and it increased in moderately and highly active children, while the maximum pressure on certain areas of the foot increased more pronounced in moderately and highly active subjects with increasing speed. Our assumption is that subjects with different levels of physical activity when walking on different terrain (flat, under a slope of 5%) will have different values of force distribution and plantar pressure when walking at an average walking speed. Previous research has shown that joint work (positive, negative, absolute) of the hip, knee and ankle joints is significant during walking on an incline. As the incline increases, there is positive joint work for the ankle and hip during uphill walking. Absolute work increases during walking uphill (all joints) and downhill (ankle and knee joints). Joint work is more pronounced when walking up an incline with lower incline levels [33]. In inactive subjects, the duration of ant/post position variability increased, as well as the contact time of the left and right heels, the duration of the maximum force on the left heel and the time of load transfer on the left leg, the maximum force on the front part of both feet decreased, as well as the maximum pressure on the front part of the right foot in inactive subjects. Moderately active subjects had a prolonged duration of maximum force on the right heel and load transfer time on the left leg, duration of maximum force on the right heel and load transfer time on the left leg. Highly physically active subjects had no changes in dynamic pressure parameters when changing the slope of the terrain. Through organized curricular and extracurricular activities, children use different surfaces and directions of movement. It develops better proprioception and better awareness of the position of the body segment in space, and thus not only motor skills are developed, but also processing skills. If we look at our sample, in 70% of cases the terrain on which children walk every day from home to school is flat, which indicates that life in urban areas imposes an inevitable need for children to develop and improve adaptive mechanisms through organized and guided movement activities. The authors Kasović, Zvonar and Sebera (2014) reported that walking on hard asphalt and concrete surfaces put a uniform load on the child's feet and body, which is why there was a lack of appropriate muscle stimulation enabling proper development of the arches of the feet and overall posture [34], which could also be confirmed by the results of our study.

Conclusion

Physically inactive subjects had the greatest variations and deviations in gait when walking at the usual average speed on flat ground. There were no differences between subjects in terms of physical activity levels when they walked at maximum speed on flat, level ground. During contact of the heel with the ground in inactive subjects, the muscles were insufficiently elongated in the negative phase and their force either did not change or slightly decreased, which may signal the suitability for the development of various postural changes on the foot. Walking on a slope of 5% almost as a rule had greater effects on inactive subjects. Highly physically active respondents gave an adequate response to a slope of 5%, because daily involvement in different forms of physical activity represented the preparedness of the hip joint and ankle joint for positive joint work, which came to the fore in walking with an incline at lower incline levels. The inclusion of children in regular and organized physical activity is important so that during walking activities they adequately respond and demonstrate competence to the demands they encounter in the environment during development.

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Ethical approval. The Ethics Committee of the Faculty of Medicine of the University of Banja Luka approved the study, and all subjects and their parents gave their consent to participate in the study. The research was conducted in accordance with the Helsinki Declaration.

Conflict of interest. The authors declare that they have no conflict of interest.

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Efekti brzine i karakteristika terena na distribuciju sile i plantarnog pritiska tokom hoda djece različitog nivoa fizičke aktivnosti

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Uvod. Usvajanje pravilnih obrazaca hoda pokazatelj je spremnosti lokomotornog sistema za uspostavljanje optimalne interreakcije sile tijela i podloge, te načina stvaranja pritiska koje stopala vrše tokom ciklusa hoda. Cilj istraživanja je bio da se ispita kako brzina i karakteristike terena utiču na distribuciju sile i plantarnog pritiska tokom hoda djece različitog nivoa fizičke aktivnosti.

Metode. Prospektivna komparativna studija obuhvatila je 150 učenika uzrasta od 11 od 12 godina i njihove roditelje iz Banje Luke. Prema protokolu svaka grupa ispitanika je hodala prosječnom i maksimalnom brzinom po ravnom i terenu pod nagibom od 5%. Za potrebe istraživanja korišćen je Upitnik fizičke aktivnosti PAQ-C (The Physical Activity Questionnaire for Older Children), anketni upitnik za roditelje, mjerenje antropometrijskih parametara i Zebris traka (Zebris Medical GmbH, Germany) za analizu hoda.

Rezultati. Pri hodu maksimalnom brzinom kod neaktivnih ispitanika, maksimalna sila na lijevoj ($F(148) = 14,878$, $p < 0,001$) i desnoj ($F(148) = 8,204$, $p < 0,001$) peti se smanjuje, dok kod umjereno i visoko aktivnih ispitanika umjereno raste. Kod visoko aktivnih ispitanika registrovana je najveća vrijednost maksimalnih pritisaka ($d = -1,41$ za lijevu i $d = 1,36$ za desnu nogu). Pri promjeni nagiba terena kod neaktivnih ispitanika maksimalna sila na prednjem dijelu oba stopala se smanjuje $F(148) = 5,043$, $p = 0,008$, $d = 0$). Uticaj karakteristika terena je takav da hod pod nagibom od 5% gotovo u pravilu ima veće efekte na neaktivnu djecu, dok umjereno i visoko fizički aktivna djeca daju adekvatan odgovor pri hodu pod nagibom od 5%.

Zaključak. Urbanizacija i nove tekovine društva nameću potrebu za uključivanjem djece u organizovane vannastavne aktivnosti kako bi djeca usvajala vještine i ispoljila valjanu kompetentnost pred zahtjevima sa kojima se susreću u okruženju.

Ključne riječi: djeca osnovno-školskog uzrasta, fizička aktivnost, analiza hoda, brzina hoda, karakteristike terena