Original paper

Body posture in the sagittal plane and the path length among girls and boys at school age

Postawa ciała w płaszczyźnie strzałkowej a długość ścieżki u dziewcząt i chłopców w wieku szkolnym

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Key words: body posture, the centre of feet pressure, path length.

Słowa kluczowe: postawa ciała, środek nacisku stóp, długość ścieżki.

Abstract

Introduction: The most frequently studied and most valuable postural reactions include the path length.
Aim of the research study: The analysis of the relation between the quality of postures in the sagittal plane and the path length ofposturograms in girls and boys at school age.
Material and methods: The research included 503 girls and boys aged 12–15 years. The research approach used a spatial photogrammetry technique using the effect of projection moiré. The path length was tested on an R50300 Cosmogamma platform by Emildue.
Results: There were significant differences in the path length between girls and boys; the path was significantly shorter in girls, both in the test with eyes open and eyes closed. A post hoc analysis (Bonferroni test) confirmed the significance. A significant effect of study options was also shown. With eyes closed there was lengthening of the path in 12-year-old girls and 12- and 15-year-old boys, whereas in the other groups it was shortened. In addition, there was demonstrated a significant interaction of gender and age, a significant interaction of gender and study options and a significant interaction of age and study options. There were no significant differences in path length in relation to age. Analysis of variance with the double classification showed no significant relation between the path length and the quality of the posture in the sagittal plane.
Conclusions: The issue of relations between body posture in the sagittal plane and the path length of the centre of feet pressure requires further research and analysis.

Streszczenie

Wstęp: Najczęściej badaną i najbardziej wartościową reakcją posturalną jest długość ścieżki.
Cel pracy: Analiza związku między jakością postawy ciała w płaszczyźnie strzałkowej a długością ścieżki posturogramu u dziewcząt i chłopców w wieku szkolnym.
Materiał i metody: Badaniami objęto grupę 503 dziewcząt i chłopców w wieku 12–15 lat. W badaniach dotyczących postawy zastosowano fotogrametrię przestrzenną wykorzystującą efekt mory projekcyjnej. Długość ścieżki badano na platformie Cosmogamma by Emildue R50300.
Wyniki: Wykazano istotne różnice w długości ścieżki między dziewczętami a chłopcami. Ścieżka była istotnie krótsza u dziewcząt zarówno w teście przy oczach otwartych, jak i zamkniętych. Analiza *post hoc* (test Bonferroniego) potwierdziła te zależności. Stwierdzono także istotny efekt rodzaju badania. Przy oczach zamkniętych ścieżka wydłużyła się u 12-letnich dziewcząt oraz 12- i 15-letnich chłopców, w pozostałych grupach nastąpiło jej skrócenie. Ponadto wykazano istotne zależności między płcią i wiekiem, płcią i rodzajem badania oraz wiekiem i opcją badania. Nie stwierdzono istotnego zróżnicowania długości ścieżki w zależności od wieku. Analiza wariancji z klasyfikacją dwukrotną nie wykazała istotnych korelacji między długością ścieżki a jakością postawy ciała w płaszczyźnie strzałkowej.
Wnioski: Zależności między postawą ciała w płaszczyźnie strzałkowej a długością ścieżki środka nacisku stóp wymagają dalszych badań.

Introduction

Body posture is a way of keeping a person in a relaxed standing position, of which the external forms of manifestations are a spatial arrangement of each segment of the body and the silhouette of the body. Posture as a way of keeping oneself is not a passive system of the body segments, but belongs to motor acts with a high degree of automation. As the way of keeping oneself, the body posture must be seen as a dynamic act, maintaining an adequate body system in spite of the force of gravity and in the conditions of unstable equilibrium. The human body is not a rigid Newtonian solid. Maintaining an upright posture is a kind of act of mobility; the ability of coordination and the development of that coordination is a long-term process, requiring a large number of repetitions [1–4]. The most frequently studied and most valuable postural reactions include the path length. The path (route), which is covered by the centre of feet pressure (COP), at the time of the test, depends on the time of imposed registration and on the motor speed of COP. Typically, incorrect balance control of standing posture is manifested by lengthening of this route. Since the deterministically chaotic movements of COP are two-dimensional, additional information on the stability of the posture can be obtained by analysing the individual components of the route of the statokinesiogram, i.e. separate sway in the sagittal plane and separate sway in the frontal plane. A separate analysis of each component of the posturogram allows us to determine in which plane the instability increases [2]. The standing posture with a standard test is characterised by larger sway in the sagittal plane. Movements of COP in the frontal plane are much smaller. The increase in instability in this plane is usually effectively compensated by the wider spacing of the feet [5–9]. The platform is used to test the postural response but can also be used for re-educating posture defects with biofeedback.

Aim of the research study

The aim of the study was the analysis of the relation between the quality of postures in the sagittal plane and the path length of the posturogram in girls and boys at school age.

Material and methods

The research included 503 girls and boys aged 12–15 years from randomly selected Primary School No. 13 and Secondary School No. 4 in Starachowice. This group consisted of 247 (49.11%) girls and 256 (50.89%) boys. There were 60 (24.29%) 12-year-old girls, 60 (24.29%) 13-year-old girls, 65 (26.32%) 14-year-old girls and 62 (25.10%) 15-year-old girls. Among the boys, there were 65 (25.39%) 12-year-olds, 61 (23.83%) 13-year-olds, 60 (23.44%) 14-year-old sand 70 (27.34%) 15-year-olds. The size distributions of age and sex groups did not differ significantly. The study was performed in November and December, 2005. The research approach used a spatial photogrammetry technique that used the effect of projection moiré (Figure 1) [10, 11]. Path length was tested on an R50300 Cosmogamma platform by Emildue (Figure 2) [12]. The path length is the total distance that the COP covered in both planes during the 30 s

Figure 1. The apparatus for the test by moiré method [11]

Figure 2. The R50300 Cosmogamma platform by Emildue [12]

test (mm). The shorter the path, the more accurate the process of postural control was.

Statistical analysis

For statistical analysis we used the following: the arithmetic mean (x), the standard deviation (s), Kruskal-Wallis's analysis of variance, the Kolmogorov-Smirnov test, and for post hoc analysis the Bonferroni test. The level of significance was assumed at $p \leq 0.05$ [13].

Results

Size distributions in the age groups did not differ significantly. The average body height of girls was 161.45 cm, the average body mass was 50.84 kg and the average body mass index (BMI) 19.43 kg/m^2. The average body height of boys was 165.41 cm, body mass 52.74 kg and BMI 19.08 kg/m^2. Analysis of variance showed significant differences in the body height in relation to sex ($p \leq 0.001$), significant differences in terms of age ($p \leq 0.001$) and significant interaction of age and gender on the height of those tested ($p \leq 0.001$). There was also a significant difference in body mass in relation to gender ($p \leq 0.03$), significant differences in terms of age ($p \leq 0.001$) and significant interaction of gender and age on the body mass of those tested ($p \leq 0.001$). There was a significant variation in BMI in relation to age ($p \leq 0.004$). No significant difference was observed for BMI in relation to gender. There was no significant interaction of gender and age on BMI. The body postures of those tested were divided based on a modification of Wolański typology into correct (K1, R2, L1 types) and defective groups. Defective posture included K2 and L2 R1P types, i.e. round, concave and flat back [4]. Two hundred ninety-seven (59.05%) correct postures were observed and 206 (40.95%) were defective. Path length for the entire studied group ranged from 490.26 mm with eyes open (OE) to 476.51 mm with eyes closed (CE). In girls the path length ranged from 476.83 mm with OE to 437.12 mm with CE, and in boys from 503.22 mm with OE to 514.52 mm with CE. Among girls in the test, with OE the path length was the lowest in 12- then 13-, 15- and 14-year-olds, respectively. In the test with CE, the path length was the lowest in 15-year-olds, then 13-, 14- and 12-year-olds, respectively. In the boys in the test with OE, the path length was lowest in 15-year-olds, then 14-, 12- and 13-year-olds, respectively. In the test with CE, the path length was the lowest in 14-year-olds, then 15-, 13- and 12-year-olds, respectively. With CE, extension of the path length in 12-year-old girls and 12- and 15-year-old boys was seen, while in the other groups its shortening was seen (Table 1, Figure 3). The path length in the correct posture with OE was 501.26 mm, but in the test with eyes closed it was 478.98 mm. The difference in the Romberg test was 22.28 mm. In defective posture the path length with OE was 474.41 mm, and in the test with CE it was 472.96 mm. The difference in Romberg test was 1.46 mm (Table 2, Figure 4).

Discussion

Among the unconditioned reflexes that a child is born with an important place is occupied by the reactions known as posture reflexes. These are numerous and can be divided into three groups: static, setting and balance reactions, with many subgroups. All of these reactions are connected and in essence provide the stability of an adopted posture (static reactions), allow the adoption of proper posture after improper position (setting and straightening reflexes) and ensure the balance of the body upon changes of the position of the centre of gravity (balance reflexes). These reflexes are somehow built into the mechanism of regulation of body posture. Earlier in the course of development, based on unconditioned reflexes, the conditioned reflexes are formed, which in turn form

Table 1. Path length

Gender, age [years]	Path length (OE) [mm]			Path length (CE) [mm]			Difference OE-CE
	x	*n*	*s*	*x*	*n*	*s*	
Girls	476.83	247	154.81	437.12	247	125.69	39.71
12	453.36	60	142.57	468.88	60	129.48	–15.52
13	456.72	60	165.54	417.09	60	147.99	39.64
14	506.43	65	152.18	447.65	65	111.40	58.77
15	487.98	62	155.55	414.74	62	106.18	73.24
Boys	503.22	256	174.20	514.52	256	170.31	–11.29
12	515.24	65	137.51	574.34	65	179.42	–59.10
13	552.79	61	240.79	510.44	61	184.71	42.34
14	486.23	60	154.24	484.10	60	151.54	2.14
15	463.44	70	140.30	488.59	70	152.19	–25.15
Total	490.26	503	165.33	476.51	503	154.84	13.75

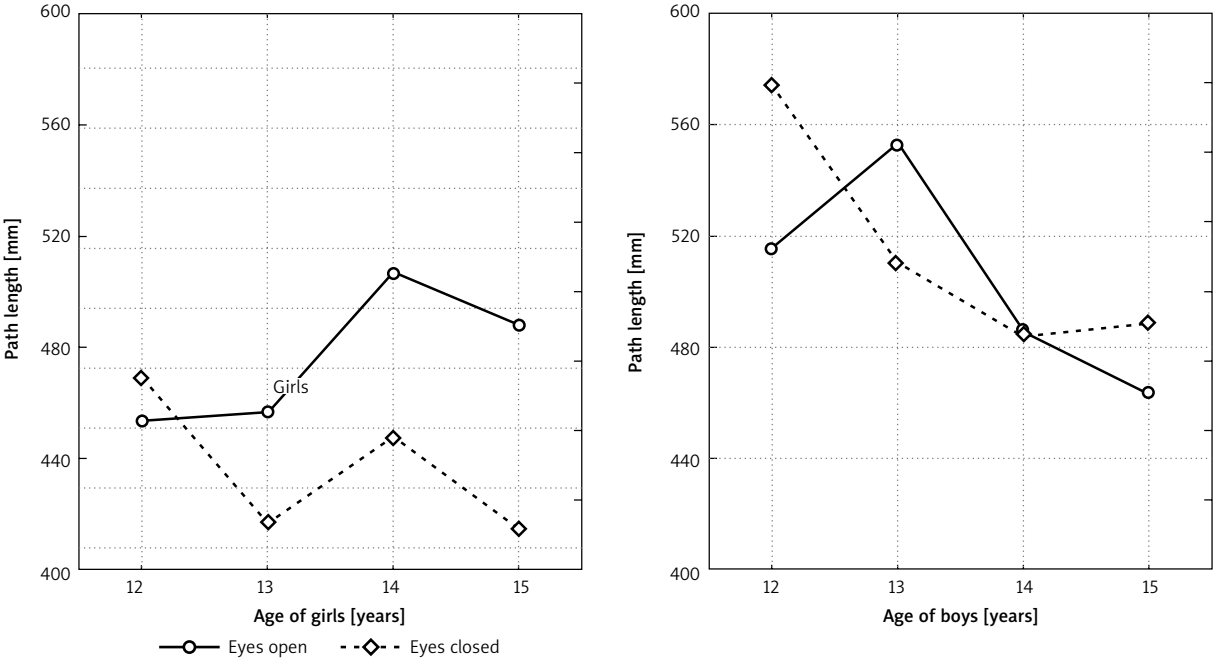

Figure 3. Path length

Table 2. The body posture in the sagittal plane vs. path length

Independent variables	Path length (OE)			Path length (CE)			Difference OE-CE
	x	*n*	*s*	*x*	*n*	*s*	
The correct posture	501.26	297	167.80	478.98	297	156.19	22.28
The defective posture	474.41	206	160.79	472.96	206	153.18	1.46
Total	490.26	503	165.33	476.51	503	154.84	13.75

a chain of reflexively conditioned actions called the dynamic stereotype. Further repetition of stimuli and responses leads to motion habits, and those, in turn, form the basis of the automation of motor actions [1]. Analysis of movement of the COP on postural platform sheds some light on the quality of the mentioned postural reflexes. The significant shortening of paths in the test with CE can be explained by the fact that in the case of momentary lack of visual control in the test children there was greater concentration and focus on the test performed. Since the parameters of balance in the test with CE do not significantly deteriorate, then we are dealing with a lack of skills in the use of vision in the process of maintaining body balance among younger children. There is a lack of adequate coordination between vision and the motor system, which, in children, is still in development. A significant feature in children is the relatively low impact of sight on the variability of COP signal. Analysis of variance revealed significant differences in path length

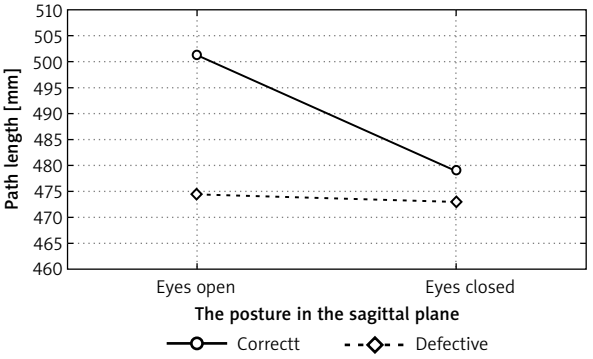

Figure 4. Path length

in relation to sex ($p \leq 0.001$). The path was significantly shorter in girls both in tests with OE and CE (Table 3). Post-hoc analysis (Bonferroni test) confirmed this significance. Analysis of variance showed also a significant effect of the test option ($p \leq 0.05$).

Table 3. Analysis of variance of path length

Independent variables	*df* the effect	MS the effect	*df* error	MS error	*F*	Value of *p*
Gender (1)	1	698996.4	495	35050.69	19.94	0.001
Age (2)	3	66237.59	495	35050.69	1.88	0.130
Test option (3)	1	53066.02	495	13532.73	3.92	0.050
Interaction of sex – age (1, 2)	3	114077.9	495	35050.69	3.25	0.020
Interaction of gender-test option (1, 3)	1	150401.6	495	13532.73	11.11	0.001
Interaction of age-test option (2, 3)	3	77276.61	495	13532.73	5.71	0.001
Interaction of gender – age – test option (1, 2, 3)	3	27279.57	495	13532.73	2.01	0.110

df – degree of freedom, MS – mean square, F – relation of MS effect to MS error, p – level of significance

Table 4. Post-hoc analysis (Bonferroni test) of the path length

No.	Gender	Age [years]	Test option	(1)	(2)	(3)	(4)	(5)	(6)
				453.36	**468.88**	**456.72**	**417.09**	**506.43**	**447.65**
1	Girls	12	DS (OE)		1.000	1.000	1.000	1.000	1.000
2	Girls	12	DS (CE)	1.000		1.000	1.000	1.000	1.000
3	Girls	13	DS (OE)	1.000	1.000		1.000	1.000	1.000
4	Girls	13	DS (CE)	1.000	1.000	1.000		0.170	1.000
5	Girls	14	DS (OE)	1.000	1.000	1.000	0.170		0.497
6	Girls	14	DS (CE)	1.000	1.000	1.000	1.000	0.497	
7	Girls	15	DS (OE)	1.000	1.000	1.000	1.000	1.000	1.000
8	Girls	15	DS (CE)	1.000	1.000	1.000	1.000	0.115	1.000
9	Boys	12	DS (OE)	1.000	1.000	1.000	0.055	1.000	1.000
10	Boys	12	DS (CE)	0.001	0.210	0.003	0.001	1.000	0.015
11	Boys	13	DS (OE)	0.438	0.378	0.595	0.001	1.000	0.019
12	Boys	13	PB (CE)	1.000	1.000	1.000	0.758	1.000	1.000
13	Boys	14	DS (OE)	1.000	1.000	1.000	1.000	1.000	1.000
14	Boys	14	DS (CE)	1.000	1.000	1.000	1.000	1.000	1.000
15	Boys	15	DS (OE)	1.000	1.000	1.000	1.000	1.000	1.000
16	Boys	15	DS (CE)	1.000	1.000	1.000	1.000	1.000	1.000

With eyes closed the path was extended in 12-year-old girls and 12- and 15-year-old boys, in the other groups it was shortened. Post-hoc analysis (Bonferroni test) confirmed this effect. In addition, analysis of variance revealed significant interaction of gender and age ($p \leq 0.02$), a significant interaction of gender and test options ($p \leq 0.001$) and a significant interaction of age and study options ($p \leq 0.001$) (Table 2). Post-hoc analysis (Bonferroni test) confirmed this interaction (Tables 4–6). Analysis of variance with double classification showed no significant relations between the path length and the quality of body posture in the sagittal plane (Table 7). Therefore, the issue of relations between body posture in the sagittal plane and the path length of the centre of feet pressure requires further research and analysis.

Conclusions

There were significant differences in the path length between girls and boys. The path was significantly shorter in girls, both in the test with OE and in the test with CE. A post hoc analysis (Bonferroni test) confirmed the significance. A significant effect of study options was also shown. With CE there was a lengthening of the path in 12-year-old girls and in 12- and 15-year-old boys, whereas in the other groups it was shortened. In addition, there was demonstrated a significant interaction of gender and age, a significant interaction of gender and study options and a significant interaction of age and study options. There were no significant differences in path length in relation to age. Analysis of variance with double classifica-

Table 5. Post-hoc analysis (Bonferroni test) of the path length

No.	Gender	Age [years]	Test option	(7)	(8)	(9)	(10)	(11)	(12)
				487.98	414.74	515.24	574.34	552.79	510.44
1	Girls	12	DS (OE)	1.000	1.000	1.000	0.001	0.438	1.000
2	Girls	12	DS (CE)	1.000	1.000	1.000	0.210	0.378	1.000
3	Girls	13	DS (OE)	1.000	1.000	1.000	0.003	0.595	1.000
4	Girls	13	DS (CE)	1.000	1.000	0.055	0.001	0.001	0.758
5	Girls	14	DS (OE)	1.000	0.115	1.000	1.000	1.000	1.000
6	Girls	14	DS (CE)	1.000	1.000	1.000	0.015	0.019	1.000
7	Girls	15	DS (OE)		0.059	1.000	0.223	1.000	1.000
8	Girls	15	DS (CE)	0.059		0.035	0.001	0.001	0.573
9	Boys	12	DS (OE)	1.000	0.035		0.473	1.000	1.000
10	Boys	12	DS (CE)	0.223	0.001	0.473		1.000	1.000
11	Boys	13	DS (OE)	1.000	0.001	1.000	1.000		1.000
12	Boys	13	PB (CE)	1.000	0.573	1.000	1.000	1.000	
13	Boys	14	DS (OE)	1.000	1.000	1.000	0.197	1.000	1.000
14	Boys	14	DS (CE)	1.000	1.000	1.000	0.879	1.000	1.000
15	Boys	15	DS (OE)	1.000	1.000	1.000	0.004	0.799	1.000
16	Boys	15	DS (CE)	1.000	1.000	1.000	0.970	1.000	1.000

Table 6. Post-hoc analysis (Bonferroni test) of the path length

No.	Gender	Age [years]	Test option	(13)	(14)	(15)	(16)
				486.23	484.09	463.44	488.59
1	Girls	12	DS (OE)	1.000	1.000	1.00000	1.000
2	Girls	12	DS (CE)	1.000	1.000	1.00000	1.000
3	Girls	13	DS (OE)	1.000	1.000	1.00000	1.000
4	Girls	13	DS (CE)	1.000	1.000	1.00000	1.000
5	Girls	14	DS (OE)	1.000	1.000	1.00000	1.000
6	Girls	14	DS (CE)	1.000	1.000	1.00000	1.000
7	Girls	15	DS (OE)	1.000	1.000	1.00000	1.000
8	Girls	15	DS (CE)	1.000	1.000	1.00000	1.000
9	Boys	12	DS (OE)	1.000	1.000	1.00000	1.000
10	Boys	12	DS (CE)	0.197	0.879	0.97066	0.970
11	Boys	13	DS (OE)	1.000	1.000	1.00000	1.000
12	Boys	13	PB (CE)	1.000	1.000	1.00000	1.000
13	Boys	14	DS (OE)		1.000	1.00000	1.000
14	Boys	14	DS (CE)	1.000		1.00000	1.000
15	Boys	15	DS (OE)	1.000	1.000	1.00000	1.000
16	Boys	15	DS (CE)	1.000	1.000		

Table 7. Analysis of variance with double classification of path length

Independent variables	*df* the effect	MS the effect	*df* error	MS error	*F*	Value of *p*
Posture	1	65701.82	501	36961.05	1.77	0.18
Test option	1	34269.79	501	14267.78	2.40	0.12
Interaction	1	26363.68	501	14267.78	1.84	0.17

tion showed no significant relation between the path length and the quality of the posture in the sagittal plane. The issue of relations between body posture in the sagittal plane and the path length of thecentre of feet pressure requires further research and analysis.

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