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Distribution of Minimal and Maximal Values of the Location of the Centre of Pressure in the Frontal and Sagittal Planes in Healthy Boys and Boys with Mild Intellectual Disability Participating in 12-Week Equestrian Classes

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ABSTRACT

Humans maintain balance in the vertical position through random movements that result from instability of the body supported in two points. These tracking movements are responsible for the motor activity focused on maintaining body balance. The role of the postural control system is to choose a strategy, that is, the behaviour as a response to stimuli and regaining the balance through coordinated activity of the muscles that stabilize the talocrural and hip joints that perform movements in the frontal and sagittal planes. The aim of this study is to evaluate the effect of equestrian classes on postural balance in the frontal and sagittal balance in healthy boys aged 15 to 17 years and boys at the same age with mild intellectual disability. The study examined 100 randomized boys aged 15 to 17 years with mild intellectual disability and healthy boys. The study participants were divided into two groups: experimental group, who participated for 12 weeks in equestrian classes and the control group, with boys attending outdoor or indoor physical education classes. Before and after completion of the study, both experimental and control groups were diagnosed by means of Accu SwayPlus force plate. Maximum and minimum locations of the position of the centre of pressure (COP) with respect to the base of support on the platform were evaluated in the frontal and sagittal planes. The description of the parameters was based on the arithmetic mean, maximal and minimal value, scatter diagram and percentage distribution of values. Correlation of the parameters was also evaluated. Significant changes were found in the experimental groups after horse-riding classes, which pointed to the improvement in balance response, particularly in the sagittal plane, both in terms of minimal and maximal values. The character of these changes was similar: value of body sway in the sagittal plane was reduced and the higher percentage of minimal values was recorded for each parameter in both planes after the equestrian effect. Correlations were found between maximum position of the centre of pressure (COP) in the frontal plane and minimal and maximal position of the centre of pressure in the sagittal plane. All the significant changes and trends found for the experimental group which occurred after 12 weeks of equestrian classes suggest improved parameters of balance. The lack of changes in balance parameters in the control group shows that the equestrian classes help develop balance abilities in healthy boys aged 15 to 17 years and, to a lesser extent, in those with mild intellectual disability.

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Introduction

The ability to maintain balance in various conditions depends on individual factors of a person. These factors can be compared with factors observed in other people and can be developed through a specific learning process until a certain limit that depends on specific aptitudes of a person is reached, depending on the body built, age and health status[1]. The prerequisite for explanation of the mechanism behind balance control in standing position is an assumption that maintaining balance represents a dynamic process. Human body moves permanently and is subject to constant sway while evaluation of the process of maintaining balance results from the analysis of the level of displacements of the point where ground reaction forces are applied, representing the centre of gravity[2].

Maintaining and regulation of body balance is closely related to the process of motor learning. Both processes occur in the nervous system based on the same system of receptors and effectors. The learning process is controlled in human body by the sensory system, which is closely correlated to the system that processes information (the central nervous system) and motor system, which is used to perform a particular activity[3].

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[1] A. C. Alonso, L. Mochizuki, N.M. Luna, F Barbieri, J. Greve, *The importance of sensory information for the postural control: is the inverted pendulum important for the static balance control,* "International Society of Biomechanics- Brasil- Balance", Gait & Locomotion 2013; G. Jaśkiewicz, M. Golema, *Próba obiektywizacji cech człowieka warunkujących utrzymanie równowagi*, Rozprawy Naukowe AWF, Wrocław 1983, nr 21, p. 135–167; M. Golema, *Biomechaniczne badania regulacji równowagi u człowieka*, Studia i Monografie AWF, Wrocław 1988, nr 2, p. 48–67; M.R. Kalina, W. Jageiłło, B.J. Barczyński, *The method evaluate the body balance disturbation tolerance skills-validation procedure of the "Rotational Test"*, "Archives of Budo" 2013, nr 9, p. 59–80; F. Qiu, M.H. Cole, K.W. Davids, *Enhanced somatosensory information decreases postural sway in older people,* "Gait& Posture" 2012, nr 35 (4), p. 630–635; M. Sedliak, J. Cvečka, V. Tirpakova, S. Löfler, S. Nejc, H. Kern, D. Hamar, *Reliability of novel postural sway task test*, "European Journal Translational Myology- Basic Applied Myology" 2013, nr 23 (3), p. 81–84.

[2] G. Juras, *Koordynacyjne uwarunkowania procesu uczenia się utrzymywania równowagi ciała*, AWF, Katowice 2003, p. 23–35; O. Dzurkova, F. Hlavacka, *Velocity of Body Lean Evoked by Leg muscle Vibration Potentiate the Effects of Vestibular Stimulation on Posture,* "Physiol. Res" 2007, nr 56, p. 829–832; N. Adamcova, F. Hlavacka, *Modification of human postural responses to soleus muscle vibration by rotation of visual scene*, "Gait & Posture" 2007, nr 25, p. 99–105.

[3] B. Czabański, *Wybrane zagadnienia uczenia się i nauczania techniki sportowej*, Wydawnictwa AWF, Wrocław 1991, II ed; M. Held-Ziółkowska, *Organizacja zmysłowa i biomechanika układu równowagi*, „Magazyn Otolaryngologiczny" 2006, nr 5, p. 39–46; A. Wit. (ed.), *Wartości normatywne do oceny asymetrii chodu i postawy stojącej człowieka*, Studia i Monografie AWF, Warszawa 2012, p. 101–126.

Maintaining of balanced posture represents the effect of using the mechanism of corrective adjustment[4]. This type of postural adjustment is a response to the stimuli received from proprioceptors that provide information about disturbing factors. They have a character of compensatory reactions for the motor system controlled by the nervous system[5]. Muscular activity during standing on both feet has to be controlled in order to maintain the centre of mass over the base of support. The base of support is the area of support for feet, while the centre of gravity moves in the sagittal and frontal planes[6]. However, the heuristic model of human balance assumes that there is an auxiliary safety margin, which means that the area of stability is greater than the base of support[7].

The balancing reactions can be considered as an internal (closed) motor habit, with the stimuli originating from the internal environment of human body and external (open), which represents the response to the external stimuli[8]. Motor activity that humans experience during horse-riding

[4] G. Juras, *Koordynacyjne uwarunkowania procesu uczenia się utrzymywania równowagi ciała*, AWF, Katowice 2003, p. 23–35.

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[6] M. Golema, *Stabilność pozycji stojącej*, Studia i Monografie AWF, Wrocław 1987, nr 17, p. 5–19; D. A. Winter, *Stiffness Control of Balance in quiet Standing,* "J. Neurophysiol" 1998, nr 80 (3), p. 1211–1221; Cz. Giemza, T. Skolimowski, B. Ostrowska, *Równowaga ciała u osób ze zmianami zwyrodnieniowymi w stawach biodrowych*, „Medycyna Sportowa" 2000, nr 12, p. 9–11; Cz. Giemza, B. Ostrowska, K. Barczyk, *Porównanie poziomu równowagi statycznej młodych łyżwiarzy figurowych z ich rówieśnikami, którzy nie uprawiają sportu*, „Medycyna Sportowa" 2007, nr 1, p. 42–45; A. Mazur-Rylska, T. Ambroży, *Zmienność równowagi i postawy ciała u młodzieży uczestniczących w zajęciach hippicznych*, EAS, Kraków 2010, p. 1–181; A.C. Kasse, G.G. Santana, C.R. Scharlack, *Results from the Balance Rehabilitation Unit in Benign Paraxymal Position Vertigo*, "Braz J Otorhinolaryngol" 2010, nr 76 (5), p. 623–629; N. Kessler, M.H. Gonanaca, F.C. Gonanca, *Balance Rehabilitation unit (BRUTM) posturography in relapsing remitting multiple sclerosis*, "*Arq Neuropsiquiatar*" 2011, nr 69 (3), p. 485–490.

[7] J.W. Błaszczyk, L. Czerwosz, *Stabilność posturalna w procesie starzenia*, "Gerontologia Polska", 2005, nr 13, p. 25–36.

[8] A. Polonyova, F. Hlavacka, *Human postural responses to different frequency vibrations of lowe leg muscle*, "Physial Res" 2001, nr 50, p. 405–410; S. Gomez, M. Patel, M. Magnusson, L. Johansson, E. Einarsoon, P. Fransson, *Differences between body movement adaptation to calf and neck muscle vibratory proprioceptive stimulation*, "Gait & Posture" 2009, nr 30 (1), p. 93–99; N. Adamcova, F. Hlavacka, *Modification of human postural responses to soleus muscle vibration by rotation of visual scene,* "Gait & Posture" 2007, nr 25, p. 99–105.

represent a source of external stimuli received through the plane of contact of buttocks with the horse's back and transferred through the pelvis in the central position to the analyser in order to return feedback from the receiver to the horse in the form of the motor response. With each step of a horse, the rider moves according to a specific pattern that makes him or her moving to the front or back, to the side, up and down. This type of effect on the pelvis and body trunk is significant for development of a stable, balanced posture[9].

Horse riding is not only restricted to healthy children. Children with mild intellectual disability (F70, II=50–69 according to the International Classification of Diseases and Related Health Problems ICD–10 created by the World Health Organization) show poorer psychomotor activity that depends on the level of disability, which also translates into their balance reactions[10]. Physical and motor development of disabled children is affected by the same factors as development of healthy children. However, the effect of these factors is disturbed, which is most likely to be caused by the factors responsible for intellectual disability. Intellectual disability is considered from the standpoint of dynamic categories since a specific development potential is observed in people affected by this problem[11]. The substantial im-

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[10] L. Boratto, P. Morasso. C. Re, *A new look at posturographic analysis in the clinical context: sway- density vs. other parameterization techniques*, "Motor Control" 2002 nr 6, p. 246–270; A. Czownicka, *Upośledzenie umysłowe: szczególny przypadek zaburzenia rozwoju,* [in:] A. Strumińska (ed.) *Psychopedagogiczne aspekty hipoterapii dzieci i młodzieży niepełnosprawnej intelektualnie*, PWRiL, Kraków, 2003, p. 47–65; T.P. Alloway, K.J. Temple, *A comparison of working memory skills and learning in children with developmental coordination disorder and moderate learning difficulties*, "Applied Cognitive Psyhology" 2007, nr 21, p. 473–487; A. Mazur-Rylska, T. Ambroży, *Zmienność równowagi i postawy ciała u młodzieży uczestniczących w zajęciach hippicznych,* EAS, Kraków 2010, p. 1–181; A. Zafeiridis, P. Giagazouglou, K. Dipla, K. Salonikidis, C. Karra, E. Kellis, *Muscle fatigue during entrtiment exercise individuals with mental retardation*, "Research on Developmental Disabilities" 2010, nr 31, p. 388–396.

[11] E. Zosgórnik, *Zróżnicowanie rozwoju somatycznego i motorycznego uczniów szkół normalnych i specjalnych dla umysłowo upośledzonych*, "Wych Fiz i Sport" 1989, nr 41,

provement of certain motor skills in people with intellectual disability can be achieved through motor rehabilitation, such as equestrian classes aimed at receiving all motor stimulation of the horse and transforming horse-riding into sensorimotor training to ensure proper and balanced posture.

Aim of the Study

The purpose of this study was to determine changes in development of balance in boys aged 15 to 17 with mild intellectual disability and healthy boys through comparison of maximal and minimal positions of the centre of pressure in the frontal and sagittal planes during relaxed standing before and after 12 weeks of equestrian classes. We also asked the specific research questions:

1. How did the value of the position of the centre of pressure in the sagittal plane change in the free standing position following 12 weeks of equestrian classes in healthy children and children with mild intellectual disability?
2. How did the value of the position of the centre of pressure in the frontal plane change in the free standing position following 12 weeks of equestrian classes in healthy children and children with mild intellectual disability?
3. Are there correlations between stabilographic parameters in healthy children and those with mild intellectual disability who participated in the 12-week equestrian classes?

The following research hypotheses were adopted:

1. Equestrian classes should improve control of the process of maintaining balance in the free standing position in the sagittal plane in both healthy children and children with mild intellectual disability.
2. Equestrian classes should improve control of the process of maintaining balance in the free standing position in the frontal plane in both healthy children and children with mild intellectual disability.
3. The likelihood of certain correlations between the parameters was assumed.

p. 41–63; M. Łazuga, *Znaczenie aktywności fizycznej w rehabilitacji psychospołecznej osób z niepełnosprawnością,* "Med Sportiva" 2004, nr 8, Supp 2, p. 78; J. Piłat, *Hipoterapia a słownik bierny dzieci z niepełnosprawnością intelektualną,* "Przegląd Hipoterapeutyczny" 2006, nr 2, p. 8–11; M. Moghadam, H. Ashayeri, M. *Salavati, Reliability of center of pressure measures of postural stability in health older adults: effects of postural task difficulty and cognitive load,* "Gait & Posture" 2011, nr 33 (4), p. 651–655; P. Giagazoglou, F. Arabatzi, K. Dipla, M. Liga, E. Kellis, *Effect of a hippotherapy intervention program on static balance and strength in adolescents with intellectual disabilities,* "Res Dev Disabil" 2012, nr 33, p. 2265–2270.

Material and Methods

The experiment was approved by the Bioethics Committee of the Medical Chamber (No. 3/2009). The study examined 50 students with mild intellectual disability from the Special Education Centre in Leżajsk, Poland and 50 students from the Agricultural School Complex – Centre of Vocational Training in Nawojowa, Poland. All of them were boys aged 15 to 17. The inclusion criteria for the experiment was mild intellectual disability diagnosed by a psychologist and school guidance counsellor in the case of the group of children with intellectual disability and consent obtained from parents or legal guardians of all the participants of the equestrian classes. Each group was divided into the control and experimental subgroups. The experimental groups with 25 participants were involved in equestrian classes for 12 week, three times a week for 45 minutes in the Equestrian Centre in Leżajsk, Poland (the group of children with mild intellectual disability) and in the Student's Horse-Riding Club in Nawojowa (group of healthy children). The groups of healthy and intellectually disabled people with 25 participants were control groups and participated in the physical exercise classes with the same duration as the experimental group, based on general fitness exercises according to the curricula used in schools. The characterization of the research material is presented in Table 1.

Table 1. Characterization of the research groups: experimental and control groups of boys with mild intellectual disability and healthy boys aged 15 to 17 years

	Healthy boys		Boys with intellectual disability	
	Control group	**Experimental group**	**Control group**	**Experimental group**
Body Mass [kg]	60.7±13.29	58.7±7.73	62.2±12.8	61.3±12.52
Body Height [cm]	168.8±7.47	170.3±6.61	170.3±6.35	166.8±8.98
Age [years]	163.2±0.86	16.5±0.80	16.2±0.81	16.8±0.72
Number of participants	25	25	25	25

The curriculum was developed according to the recommendations of the Polish Hippotherapy Society and Polish Equestrian Association and included balance exercises during both horse's walk and horse's trot and coordination exercises. Before and after completion of the study, both experimental and control groups were diagnosed by means of Accu SwayPlus force plate. The force plate platform was also used to determine alterations in the position of the centre of pressure (COP) with respect to the base of support (BOS) on the platform in the frontal and sagittal planes in the relaxed standing position with feet spread to the shoulder width and with eye control.

Reliability of the measurement equipment was maintained using the procedure of resetting before each measurement. The measurement of each parameter took ca. 30s. Each participant was informed about the details of the test.

A statistical analysis was performed for the selected parameters of Bio Soft software for balance analysis, which recorded the natural sway of the centre of gravity in the frontal and sagittal planes.

Comparison of the results includes:

1. Statistical analysis based on the Statistica 8 software package. The descriptive statistics of the documented data was used: arithmetic mean, standard deviation, median, minimum and maximum values:
   – COP-X Max (cm): maximal position of the centre of pressure (COP) in the frontal plane X,
   – COP-X Min (cm): minimal position of the centre of pressure (COP) in the frontal plane X,
   – COP-Y Max (cm): maximal position of the centre of pressure (COP) in the sagittal plane Y,
   – COP- Y Min (cm)- minimal position of the centre of pressure (COP) in the sagittal plane Y, measured before and after equestrian classes and its effects with evaluation of the statistical significance (statistically significant effect at $p<0.05$),
2. Comparison of the level of the characteristic compared before and after the equestrian classes and the effects of horse riding by means of the scatter diagram,
3. Graphical representation of the distribution of a measure of ability before and after horse riding in the form of histogram,

4. Determination of correlations between the values of sway in the frontal and sagittal plane for the parameters studied by means of Spearman's rank correlation coefficient.

The analysis of distribution of the variables was also conducted. This analysis demonstrated the lack of normal distribution and homogeneity of variance. Therefore, in order to evaluate intergroup differences, we used the Mann-Whitney U-test, whereas in order to find significant intragroup changes, we employed Wilcoxon test for dependent samples, performed twice, before the classes and after 12 weeks. Comparative analysis carried out for the initial test between the control and experimental groups in the group of healthy children and children with intellectual disability revealed no statistically significant differences in the stabilographic parameters between the group of healthy and disabled study participants (see Tab. 2).

Table 2. Values of stabilographic parameters (mean and standard deviation) in the first test for the experimental and control groups of healthy boys and boys with mild intellectual disability (*statistically significant differences Mann-Whitney U test $p<0.05$)

Stabilographic parameter	Healthy boys		Boys with intellectual disability	
	Control group	Experimental group	Control group	Experimental group
COP-X Max [cm.]	0.83± 0.54	0.72±0.49	1.27± 0.99*	1.35± 0.92*
COP-X Min [cm.]	-0.87 ±0.75	-0.98± 0.89	-1.24± 0.51*	-1.17± 0.55*
COP-Y Max [cm.]	4.64± 1.86	4.86± 1.93	5.32± 2.26*	5.20 ±2.32*
COP-Y Min [cm.]	-1.49 ± 0.59	-1.53± 0.56	-1.64± 0.55*	-1.66± 0.51*

Results

After completion of the 12-week equestrian classes, the participants from the control group were examined again and no changes with respect to the parameters studied were found (see Tab. 3).

Table 3. Values of stabilographic parameters (means and standard deviations) in the second test for the control group of healthy boys and boys with intellectual disability (Wilcoxon test)

Stabilo-graphic parameter	Healthy boys		Boys with intellectual disability	
	Examination 1	Examination 2	Test 1	Examination 2
COP-X Max [cm.]	0.83± 0.54	0.83±0.49	1.27± 0.99	1.31± 0.95
COP-X Min [cm.]	-0.87 ±0.75	-0.88± 0.89	-1.24± 0.51	-1.23± 0.51
COP-Y Max [cm.]	4.69± 1.86	4.75± 1.93	5.32± 2.26	5.30 ±2.31
COP-Y Min [cm.]	-1.49 ± 0.59	-1.51± 0.56	-1.64± 0.55	-1.66± 0.51

We carried out detailed analysis of the stabilographic parameters obtained during the second examination of the experimental groups after completion of the equestrian classes. The position of the centre of pressure (COP) in the frontal plane (COP-X Max) was found in both healthy boys and boys with intellectual disability. However, these results are statistically significant, which is also reflected by the scatter diagram for COP-X Max (see Figs. 1, 2). Mean values of the parameter studied were lower in healthy boys, both before and after the experiment (0.73 cm and 0.72cm) compared to disabled boys (1.35 cm and 1.32 cm). However, the group of the disabled boys was characterized by greater maximal values of this parameter: 3.97 cm and 4.53 cm and minimum: 0.37 cm and 0.47 cm (Tab. 4).

s with intellectual disability h before (Examination 1) and after (Examination 2) equestrian classes (Mann-Whitney U test)

COP-X Max		Healthy boys					Boys with intellectual disability				
		$\bar{x}$	Me	s	min	max	$\bar{x}$	Me	s	min	max
Examination 1		0.73	0.62	0.48	0.28	2.29	1.35	0.96	0.93	0.37	3.97
Examination 2		0.72	0.58	0.73	0.34	2.77	1.32	0.93	1.02	0.47	4.53
Effects of classes	p=0.7918						-0.03	-0.05	1.18	-2.41	3.65
	p=0.4236	-0.17	-0.03	0.56	-0.55	2.18					

Fig.1. Scatter diagram for COP-X Max values in the experimental group before and after equestrian classes in boys with mild intellectual disability

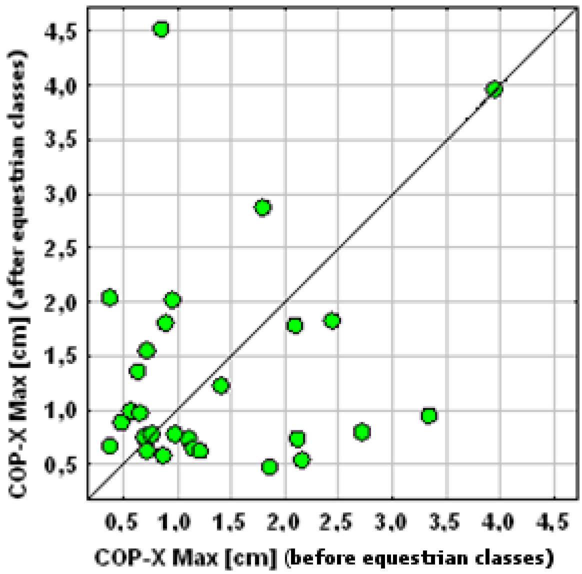
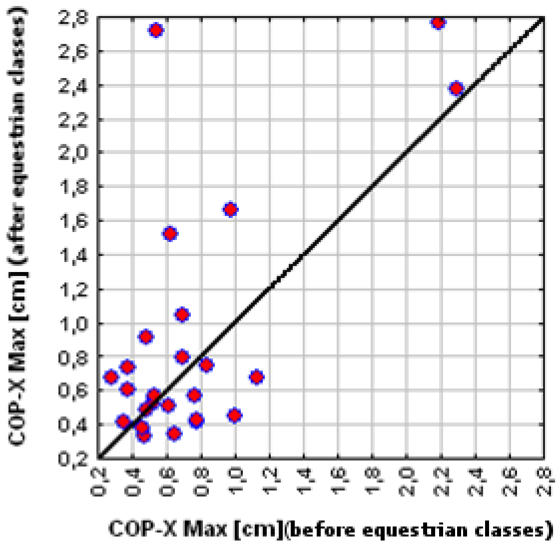


Fig. 2. Scatter diagram for COP-X Max values in the experimental group before and after equestrian classes in healthy boys



Percentage distributions of sway for the stabilogram curve in both groups point to an insignificant improvement in the ranges of sway for maximal positions of the centre of pressure (COP) in the frontal plane. However, they are statistically insignificant. The greatest improvement (by 12%) in the group of intellectually disabled children was observed for the sway range of 0.5 to 1.0cm (Fig. 3). In the group of healthy children, the most participants i.e. 60% before and 58% after the classes were those with values of maximum position of the centre of pressure (COP) in the frontal plane, from 0.4 to 0.8cm (see Fig. 4).

Fig. 3 Distribution of the COP- X Max values in the experimental group before and after equestrian classes in boys with mild intellectual disability

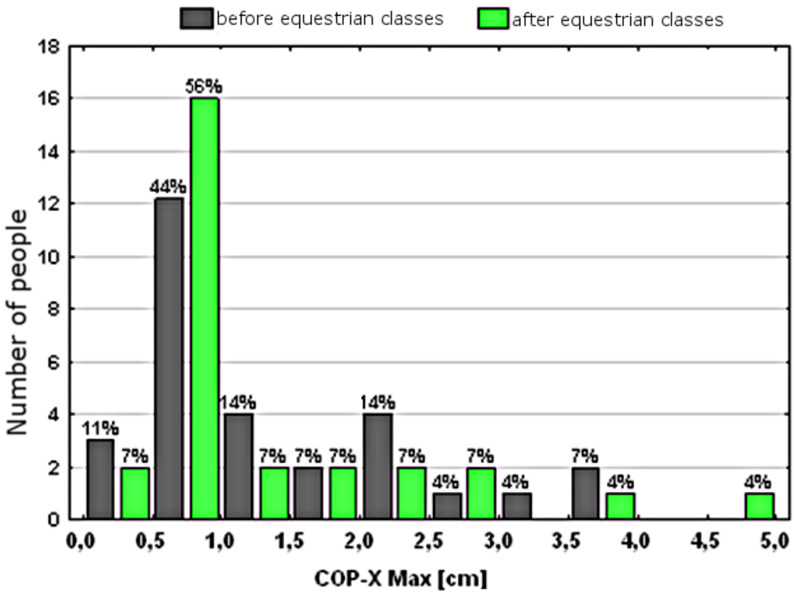
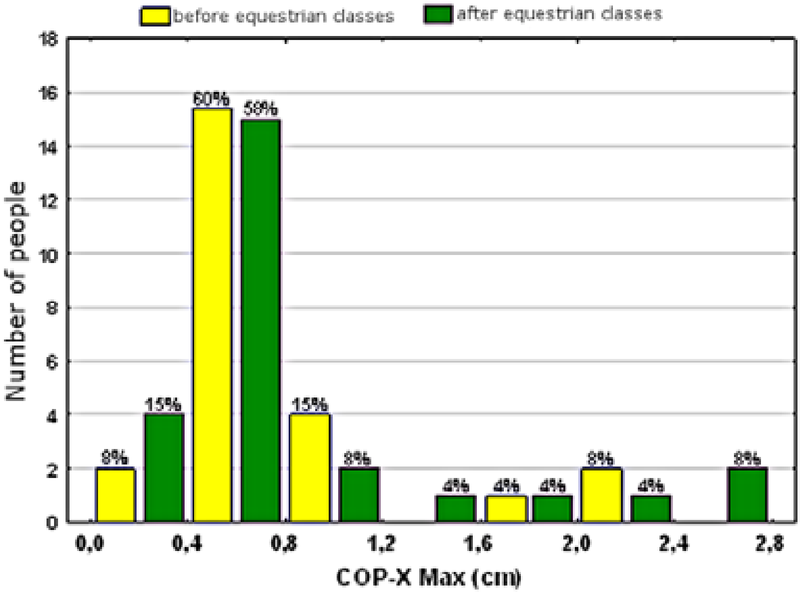


Fig. 4. Distribution of the COP- X Max values in the experimental group before and after equestrian classes in healthy boys



Similar tendencies were documented for the parameter of minimal position of the centre of pressure (COP) in the frontal plane (COP -X Min). 12-week classes of horse-riding did not cause a significant improvement in this parameter in both groups studied, as indicated by the scatter diagram for the COP-X Min values (Fig. 5,6). Mean values of the parameter studied were lower in healthy boys, both before and after the experiment (-0.98 cm and -1.28 cm) compared to disabled boys (-1.17 cm and 1.11 cm). However, disabled children were characterized by greater minimal values of this parameter before the classes: 0.32cm and after classes: (–0.43 cm) and maximal: -4.69 cm and -5.75 cm (Tab. 5).

Table 5. Values of minimal position of the centre of pressure (COP) in the frontal plane (COP-X Min) in healthy boys and boys with intellectual disability before (Examination 1) and after (Examination 2) equestrian classes

COP-X Min [cm]		Healthy boys					Boys with intellectual disability				
		$\bar{x}$	Me	s	min	max	$\bar{x}$	Me	s	min	max
Examination 1		-0.98	-0.67	0.89	-0.29	-2.55	-1.17	-0.95	0.55	-0,32	-4.69
Examination 2		-1.28	-0.75	1.50	-0.39	-2.41	-1.11	-0.99	0.49	-0.43	-5.75
Effects of classes	p=0.2437						-0.10	-0.16	0.76	-1.69	1.69
	p=0.5009	-0.34	-0.06	1.44	-0.90	1.30					

Fig. 5 Scatter diagram for COP-X Min values in the experimental group before and after equestrian classes in boys with mild intellectual disability

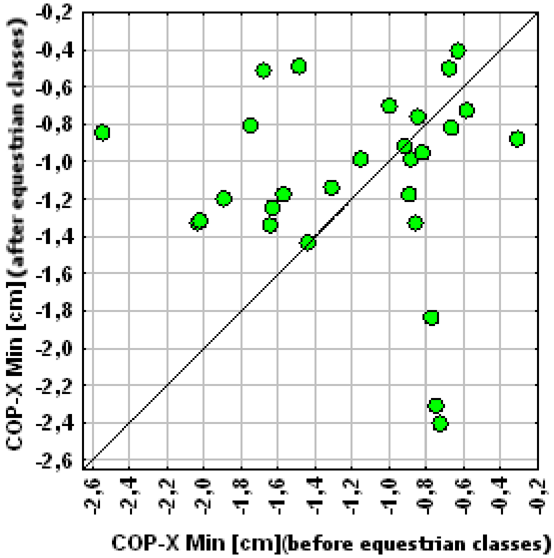
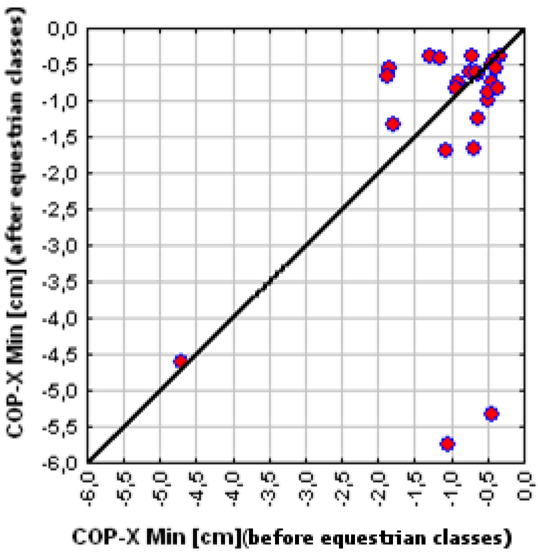
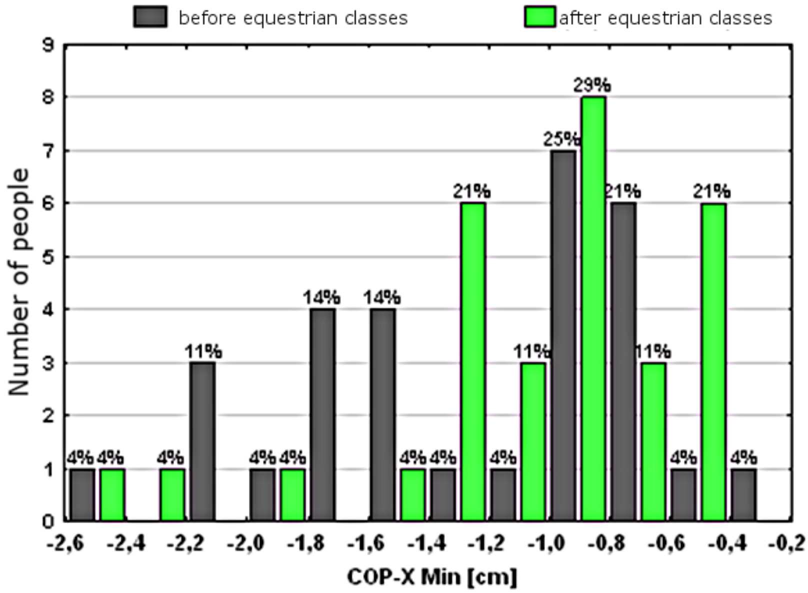


Fig. 6 Scatter diagram for COP-X Min values in the experimental group before and after equestrian classes in healthy boys



Analysis of the percentage distributions of sway for the stabilogram curve in both groups points to a slight improvement in the sway range for minimal positions of the centre of pressure (COP) in the frontal plane, which are statistically insignificant. The highest improvement was found for the following ranges: -1.4- -1.2 cm by 17%, -1.2- -1.0 cm by 7%, -0.6 – 0.4 cm by 17% in boys with mild intellectual disability and in the range of -1.0- -0.5 cm by 20% (Figs. 7, 8).

Fig. 7 Distribution of the COP- X Min values in the experimental group before and after equestrian classes in boys with mild intellectual disability



Statistically significant changes were recorded for sway of position of the centre of pressure (COP) in the sagittal plane, which is presented in the scatter diagram for COP- Y Max value (Tab. 6,7). Mean value of maximum position of the centre of pressure in the sagittal plane Y was improved after the equestrian classes, both in the group of intellectually disabled boys: 5.22- 4.20 cm and healthy boys: 4.86–3.57 cm. Lower minimal and maximal values in healthy boys (8.96- 8.32 cm and 0.65–0.56 cm) than in boys with intellectual disability (10.94–7.72 cm and 1.47- 1.02 cm) before and after equestrian classes point to the improvement in the parameter (see Tab. 6). The results obtained are statistically significant, which is reflected by the scatter diagrams for COP-Y Max values (Fig. 9, 10).

Fig. 8 Distribution of the COP- X Min values in the experimental group before and after equestrian classes in healthy boys

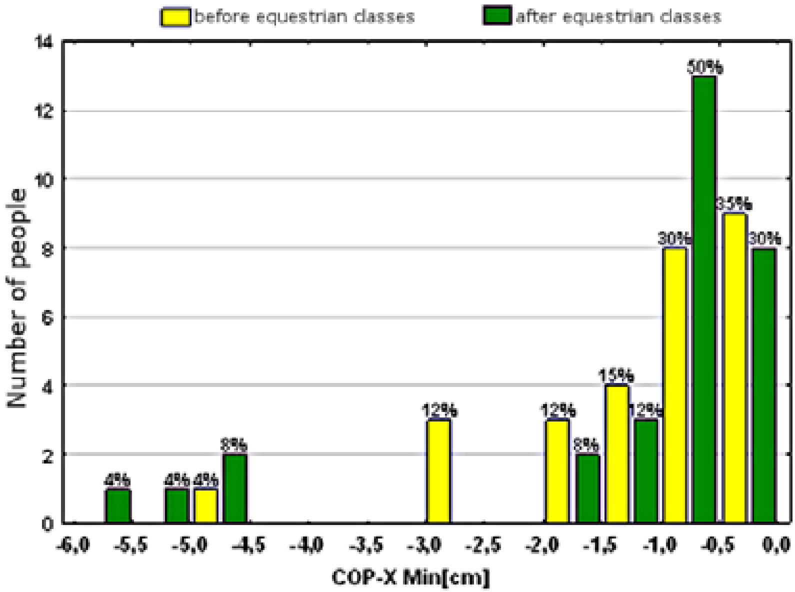


Table 6. Values of maximal position of the centre of pressure (COP) in the sagittal plane (COP-X Max) in healthy boys and boys with intellectual disability before (Examination 1) and after (Examination 2) the equestrian classes

COP- Y Max [cm]		Healthy boys					Boys with intellectual disability				
		$\bar{x}$	Me	s	min	max	$\bar{x}$	Me	s	min	max
Examination 1		4.86	5.44	1.92	0.65	8.96	5.22	4.71	2.32	1.47	10.94
Examination 2		3.55	2.94	2.35	0.56	8.32	4.20	3.97	1.77	1.02	7.72
Effects of classes	p=0.0238*						-1.00	-0.83	2.42	-8.73	3.34
	p=0.0042**	-1.31	-1.84	2.24	-5.65	5.36					

Fig. 9 Scatter diagram for COP-Y Max values in the experimental group before and after equestrian classes in boys with mild intellectual disability

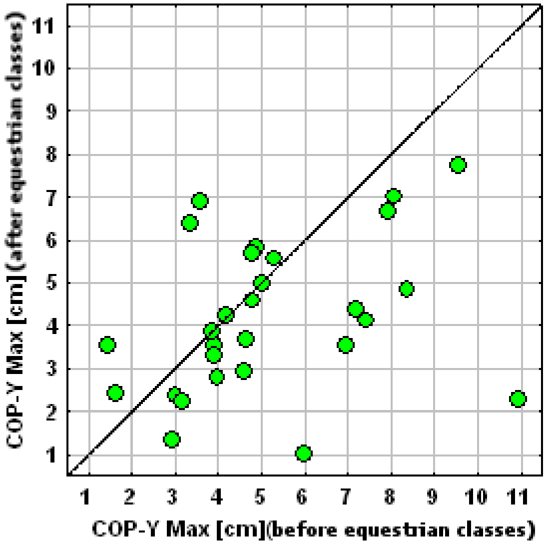
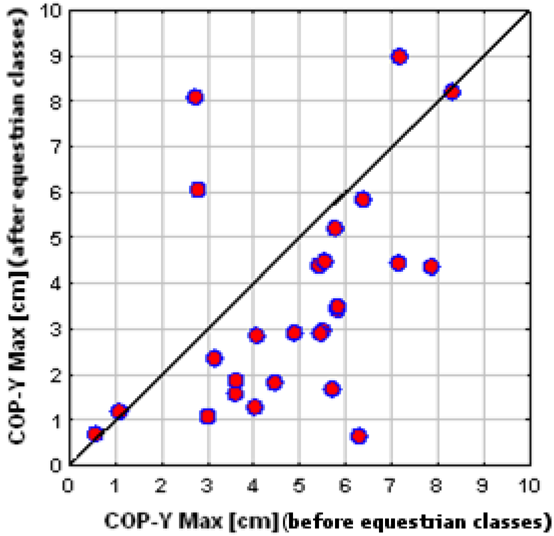


Fig. 10 Scatter diagram for COP-Y Max values in the experimental group before and after equestrian classes in healthy boys



Percentage distributions of sway for the stabilogram curve in both groups point to a substantial improvement in the sway ranges for maximal positions of the centre of pressure (COP) in the sagittal plane. In intellectually disabled boys, maximal values of COP-Y were not found in the range of 8 to 11cm. However, the percentage of people with minimal values in the range of from 2 to 7cm was increased, with the highest percentage (21%) found for the range from 2 to 5 cm. In the group of healthy boys, the highest percentage (30%) was observed for the range of values of 1 to 2 cm (improvement by 26%) and the percentage of people with minimal values of this parameter in the range of from 1 to 3 cm was increased (Fig. 11, 12).

Fig. 11 Distribution of the COP- Y Max values in the experimental group before and after equestrian classes in boys with mild intellectual disability

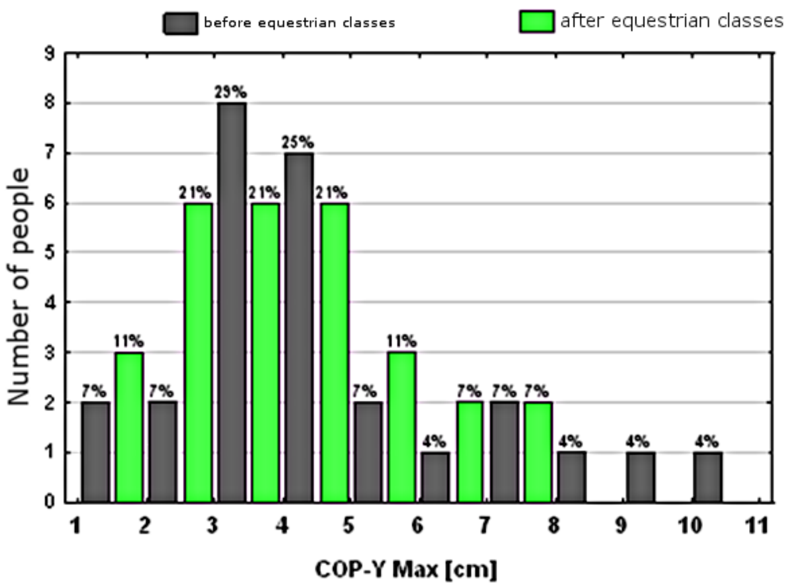
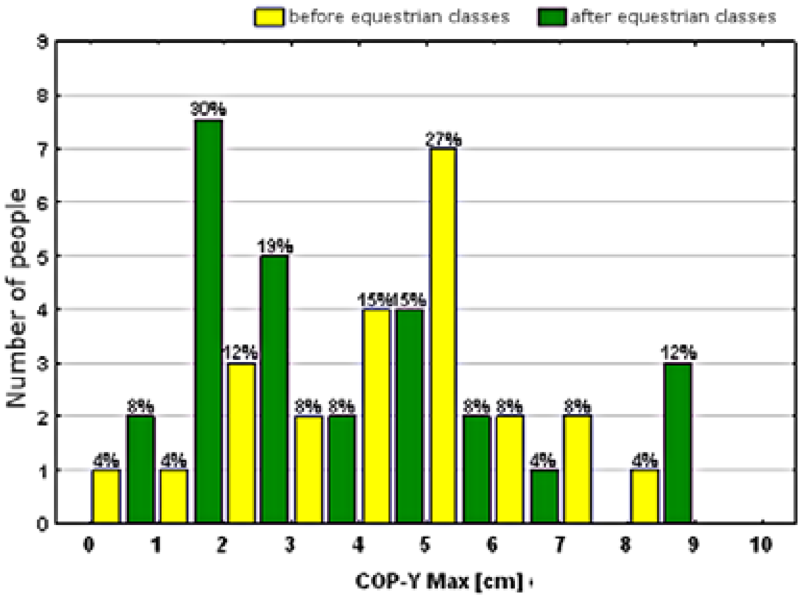


Fig. 12 Distribution of the COP- Y Max values in the experimental group before and after equestrian classes in healthy boys



Similar tendencies were found for the minimum position of the centre of pressure (COP) in the sagittal plane Y (COP-Y Min). The improvement in the value of this parameter occurred in the experimental group of healthy children and it was statistically significant, as indicated by the scatter diagram for COP-Y Min values (Figs. 13, 14). This fact is indicated by mean values, both before and after the experiment: (-1.53 cm and -1,22 cm), and extreme values for the group of healthy children before and after the experiment. Minimum: 0.83cm and 0.63cm and maximum: – 3.21cm and -3.12cm (see Tab. 7).

Table 7. Values of minimal position of the centre of pressure (COP) in the sagittal plane (COP-Y Min) in healthy boys and boys with intellectual disability before (Examination 1) and after (Examination 2) the equestrian classes

COP- Y Min [cm]		Healthy boys					Boys with intellectual disability				
		$\bar{x}$	Me	s	min	max	$\bar{x}$	Me	s	min	max
Examination 1		-1.53	-1.37	0.56	-0.83	-3.21	-1.64	-1.55	0.51	-0.70	-2.94
Examination 2		-1.22	-1.01	0.63	-0.63	-3.12	-1.63	-1.53	0.67	-0.54	-3.47
Effects of classes	p=0.5482						0.01	0.11	0.81	-2.31	1.73
	p=0.0138*	0.31	0.25	0.71	-1.67	1.90					

Fig. 13. Scatter diagram for COP-Y Min values in the experimental group before and after equestrian classes in boys with mild intellectual disability

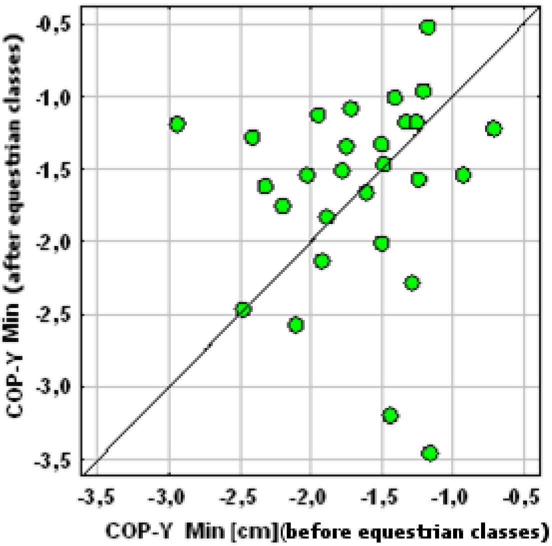
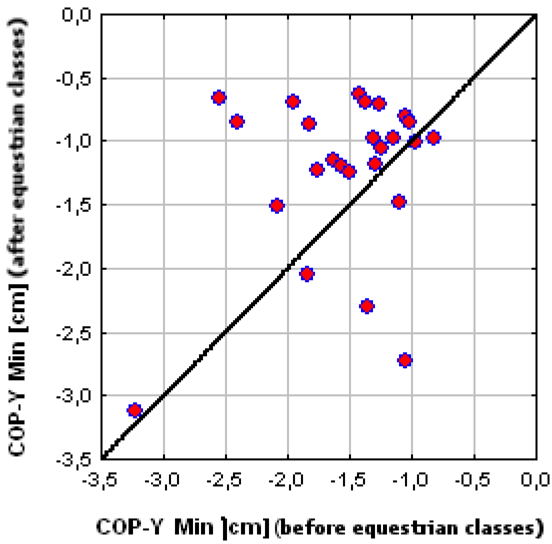
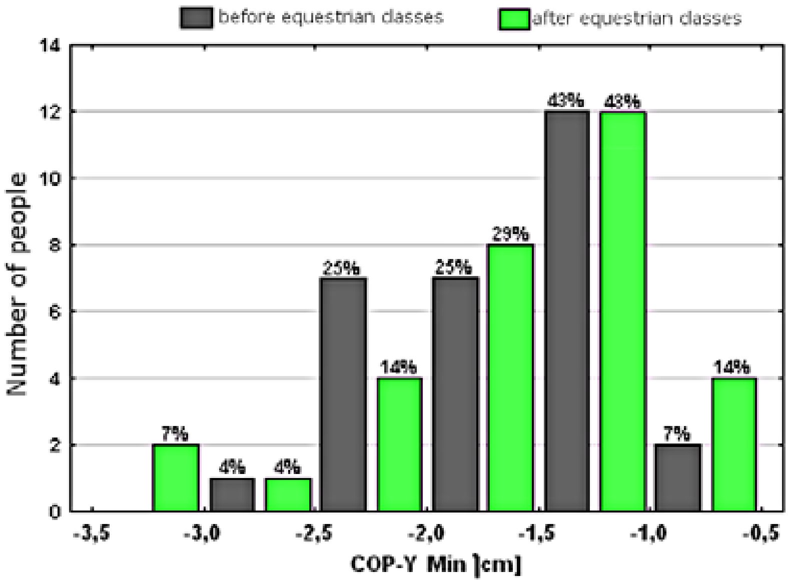


Fig. 14. Scatter diagram for COP-Y Min values in the experimental group before and after equestrian classes in healthy boys



The percentage distributions of sway for the stabilogram curve in both groups point to a substantial improvement in the sway ranges for maximal positions of the centre of pressure (COP) in the sagittal plane. The percentage distributions in boys with intellectual disability point to variation of the values obtained. However, the most of the boys (29% and 43%) were characterized by the range of values from -2.0- -1.0 cm. In the group of healthy boys, the ranges of -1.5 to 0.5cm are observed in 40 to 46% of the participants (Figs. 15,16).

Fig. 15. Distribution of the COP- Y Min values in the experimental group before and after equestrian classes in boys with mild intellectual disability



Analysis of the relationships between the position of the centre of pressure (COP) in the frontal (X) and sagittal (Y) planes revealed a correlation between maximum position of the centre of pressure in the frontal plane (COP-X Max) and minimum and maximum position of the COP in the sagittal plane (COP -Y Min and COP -Y Max). Values of correlation coefficients were not high, reaching R (0.50–0.41) in healthy boys and R (0.31–0.35) in boys with mild intellectual disability (Tab. 8).

Fig. 16. Distribution of the COP- Y Min values in the experimental group before and after equestrian classes in healthy boys

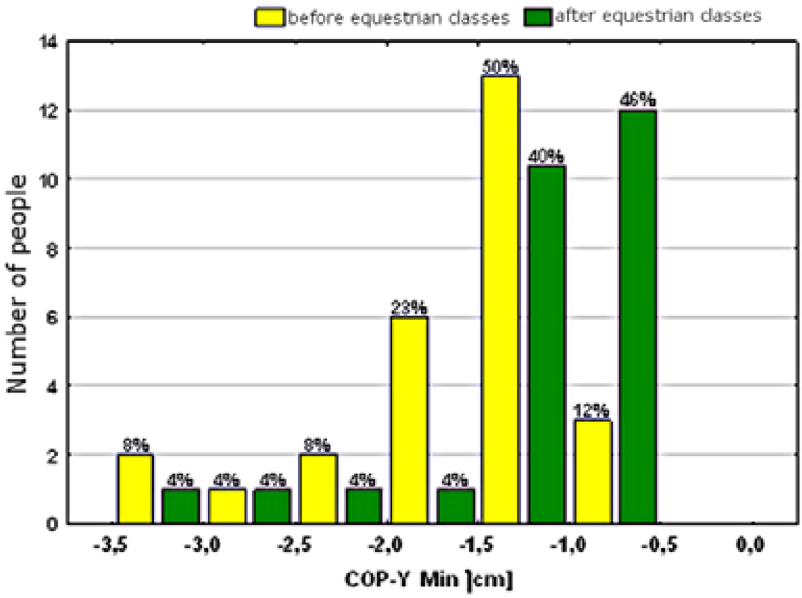


Table 8. Correlation coefficients between stabilographic parameters in the sagittal and frontal planes in healthy boys and boys with mild intellectual disability

Healthy boys/boys with mild intellectual disability	COP Y –Max	COP Y –Min
COP X-Max	0.50/0.35	0.41/0.30
COP X- Min	0.25/0.21	0.23/0.20

(R<0.3- no correlation; 0.3≤R<0.5- poor correlation; 0.5≤R<0.7- average correlation)

Discussion

The balance control system in humans, which involves numerous structures of the central nervous system, can be approached as a control system with three inputs used to determine spatial position of the centre of gravity. Spatial position of the COG is a controllable parameter, that is, it represents the output signal for this control[12]. In the upright position, the projection of human centre of gravity remains in the specific restricted area of the feet support while maintaining the centre of gravity in this area does not require much muscular effort. The position of the centre of gravity in standing on both feet moves in the sagittal and frontal planes[13].

The differences observed in body balance control in healthy people analysed in our study and those with mild intellectual disability might point to different function of the balance system. Boys are characterized by greater values of maximal and minimal position of the centre of pressure (COP) both in the frontal and sagittal planes compared to healthy peers. Furthermore, more substantial displacements in the sagittal plane on the base of support reflect the general principle connected with the strategies of work of the ankle and hip joints. While experiencing horse-riding, humans attempt to find balance in motion and have opportunities of learning balance-related reactions. A horse rider without support with feet senses changes in position of balance of his or her body while attempting to adjust to these changes. The swinging motion transferred on his or her body results from alternating occurrence of acceleration at the moment of horse legs losing contact with the ground and being lifted up, and braking effect caused by placing the legs on the ground. These forces make the rider moving to the front and back. This helps learning how to adjust movements in the sagittal plane. After the classes, lower values of maximal and minimal positions of the centre of pressure (COP) in the sagittal plane were observed in healthy boys, while in the boys with intellectual disability, only the minimal value was reduced, which might suggest an improvement in balance reactions. Improper function of the nervous system, being the cause of intellectual disability, might represent an obstacle for performing regulatory functions compared to the group of healthy par-

12 M. Golema, *Stabilność pozycji stojącej*, Studia i Monografie AWF, Wrocław 1987, nr 17, p. 5–19; M. Golema, *Biomechaniczne badania regulacji równowagi u człowieka*, Studia i Monografie AWF, Wrocław 1988, nr 2, p. 48–67; G. Juras, *Koordynacyjne uwarunkowania procesu uczenia się utrzymywania równowagi ciała*, AWF, Katowice 2003, p. 23–35; J.W. Błaszczyk, L. Czerwosz, *Stabilność posturalna w procesie starzenia*, "Gerontologia Polska" 2005, nr 13, p. 25–36.

13 G. Juras, *Koordynacyjne uwarunkowania procesu uczenia się utrzymywania równowagi ciała,* AWF, Katowice 2003, p. 23–35; T.P. Alloway, K.J. Temple, *A comparison of working memory skills and learning in children with developmental coordination disorder and moderate learning difficulties*, "Applied Cognitive Psyhology" 2007, nr 21, p. 473–487.

ticipants. Furthermore, percentage distributions of the value of the above parameters in the sagittal plane point to greater contribution of smaller maximal and minimal values of the centre of gravity in both healthy children and those with intellectual disability, although the results are better in the group of healthy people.

In the case of maximal and minimal values of the position of the centre of pressure (COP) in the frontal plane, we did not find similar tendency. The maximal value was reduced in healthy boys. However, this result is not statistically significant. Percentage distribution of the COP-X Max values turned out to be favourable since the number of minimal and maximal values for the position of the centre of pressure was increased. The smallest changes were found for minimal value of the centre of pressure in the frontal plane COP-X Min, pointing to the irregular direction of changes.

Examination of the correlations between parameters in the sagittal plane Y and frontal plane X pointed to the relationship between maximal position of the COP in the frontal plane and sagittal plane and maximal position of the COP in the frontal plane with higher correlation strength in favour of the healthy boys. It was found that the values of parameters of sway in the frontal and sagittal plane are correlated with each other[14].

Human body that experiences horse riding improves balance reactions through re-establishment of new motor patterns, which is based on the balanced body posture. The classes oriented towards acquisition and establishment of balance reactions is connected with reception and processing of information concerning new motor sensations. During the classes, participants were allowed to practice the balanced body posture for many times. Horse riding improves balance abilities both in healthy boys and boys with mild intellectual disability within the boundaries offered by the nervous system.

Conclusion

1. The values of the centre of pressure in the sagittal plane Y were reduced in both experimental groups, pointing to an improvement. Chang-

[14] M. Golema, *Biomechaniczne badania regulacji równowagi u człowieka*, Studia i Monografie AWF, Wrocław 1988, nr 2, p. 48–67; M. Golema, *Stabilność pozycji stojącej*, Studia i Monografie AWF, Wrocław 1987, nr 17, p. 5–19; P. Giagazoglou, F. Arabatzi, K. Dipla, M. Liga, E. Kellis, *Effect of a hippotherapy intervention program on static balance and strength in adolescents with intellectual disabilities*, "Res Dev Disabil" 2012, nr 33, p. 2265–2270.

es in maximal values of this parameter were statistically significant in both groups, whereas minimal value was significant only in the group of healthy boys.

2. No statistically significant changes in maximal and minimal values of the centre of pressure were found for the frontal plane X.
3. A correlation was found between maximal and minimal position of the centre of pressure in the sagittal plane X and maximal position of the centre of pressure in the sagittal plane Y.

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