DISTRIBUTION OF MEAN VELOCITY VALUES OF THE CENTER OF GRAVITY (COG) AS A RESULTANT MOTION IN THE FRONTAL AND SAGITTAL PLANE WITHIN QUADRILATERAL SUPPORT IN HEALTHY AND MILDLY MENTALLY DISABLED CHILDREN PARTICIPATING IN 10-WEEK EQUESTRIAN TRAINING

Anna **MAZUR-RYLSKA**[1], Wojciech **CZARNY**[2], Marta **NIEWCZAS**[2]

1. Institute of Comparative Vertebrate Anatomy and Anthropology, Department of Biology and Agriculture, University of Rzeszow, Poland
2.Faculty of Physical Education, University of Rzeszow, Rzeszow, Poland

Key words:
- stabilographic parameters**,**
- postural stability,
- support surface,
- balance, average displacement of COG,
- mild mental disability,
- horse riding,
- hippotherapy.

Abstract:

Upright position of the human body is characterized by vertical positioning of the body axis with reference to a comparatively small support plane. This orientation and multi-segment structure of the body, its considerable height and small support surface result in disrupting the stability of a statically standing body. The body balance then is controlled by the nervous system and is permanently adjusted to the changing environment. Evaluation of the influence of horse ride on healthy and mildly intellectually disabled children has been made by the analysis of the average COG displacement as a resultant vector of inclinations in frontal and sagittal planes of the movement, as well as the average radial displacement in both planes of the sways. To measure the similar parameters in healthy and mildly intellectually disabled children we used a stabilographic platform, and the data was collected before the equestrian training, later after 10 weeks of training 3 times a week per 30 minutes.

In both groups we observed statistically significant decrease of the average value of radial vector of sways, as well as average vector of sways in sagittal plane, which changes had a decisive influence on the improvement of radial displacements despite the lack of changes of this parameter in the frontal plane. Useful changes have been proved by the distribution of the parameters measured in both research groups. The horse movements affect the development of balance reactions in 15-17 year old children, resulting in statistically significant positive changes. The scope of improvement of balance reactions measured in the size of average displacements in the planes of movement, as well as the resultant radial, are so significant that we can treat horse riding as an attractive, in many instances, way of improving the body balance which determines the quality of body movement in any age.

INTRODUCTION

A healthy person staying in an upright position keeps the point of net force feet pressure on the surface around the center of the envelope of foot prints, which, usually, is far from the limits of stability, in order to avoid the movements beyond these limits. The level of human body stability is proportional to the size of the support surface and stability shall be proportional in each of its directions when the vertical projection of COG is the farthest from the boundary of the support surface (Błaszczyk 1993, Błaszczyk et al. 1993, Riach, Starkes 1993).

A human in a free standing position in order to keep balance applies only a small part of the anatomical support surface which is the surface of the feet including the space between them. However, the limit of stability is defined as the line encompassing the surface under the feet, which the subject uses to keep the posture (Riach, Starkes 1993, Lee, Deming 1987). The shape and size of this surface depend, among others, on the structure and efficiency of the body, as well as the age, height, proper posture, muscle strength and efficiency of the nervous system (Błaszczyk, Czerwosz 2005).

The new model of balance control divides the support surface into a few areas affecting the stability control. The real limit of posture stability is divided from the mechanical (anatomical) one, i.e. envelope of feet, and is called a safety margin which depends on the efficiency of the balance system. In the central position of the limit of stability, recovery of body balance does not need to change the support surface and it is known as the so called area of sways. Keeping the COG in this area takes minimal energy consumption. In response to small stimuli violating the balance, it can be recovered through a coordinated activity of the muscle stabilizing the talo-tibial joint without lifting the feet up (Błaszczyk, Czerwosz 2005).

Reduced ability of controlling the body balance appears in many neurological illnesses, in after stroke states, central nerve core injuries, and is an associated feature of mental retardation (Zosgórnik 1989, Ślężyński 1991, Mraz, Piestrak 1995, Kwolek, Drużbicki1999, Mraz et al. 2001, Wilczyński 2005).

The direct reason of mental retardation is injury of the central nervous system which controls the balance reactions, and the study of the development of motor ability in mentally impaired people prove that the deeper the impairment is, the lower coordination ability. Acquisition of many motor skills is hampered by incomplete preparation of the body to movement activities (Zosgórnik 1989, Ślężyński 1991).

Many authors consider the possibility of reducing the scope and results of impairment pointing at usefulness of compensational and correctional exercises (Ślężyński1994, Pilecka 2001, Janota 2004). Horse riding is an activity that creates a coordinated duet in which motor perception and reaction to stimuli are of prior importance. Horse riding helps to develop coordination and then the rider has to use it all the time, while the dynamic balance is most important.

Static posturography can objectively evaluate the efficiency of the vestibular system when we observe the displacements of COG of the subject in the front and sagittal planes. Projection of COP is, therefore, registered as a point and as a dynamic parameter changing its position in time.

AIMS AND SCOPE OF THE WORK

The problem of regulation of balance reactions was analysed on 28 subjects with a mild mental disability and 28 healthy subjects participating in equestrian training. The purpose of the work is to analyse the mean values of COG displacements as a result of horse riding training treated as an alternative form of acquiring the balance reactions, which are an integral part of coordination responsible for movement activities.

MATERIAL AND METHODS

The research group is 28 children aged 15-17 participating in hippotherapy training in the horse-riding center „Equistro", Wierzawice, for about 10 weeks, three times a week per 30 minutes, while the group of healthy children was doing the same program in the school horse-riding club in Nawojowa (Tab. 1).

Table 1. Description of groups participating in the training

Horse-riding group	Weight (kg) $\bar{x}$	Height (cm) $\bar{x}$	Number
U – Children with mild mental disability	60.3	164.8	28
Z - Healthy children	58.4	170.1	28

The training program was designed according to the recommendations of the Polish Hippotherapy Society and Polish Equestrian Society. The training included the walk riding in the correct riding posture and doing the balance exercises during the stop position and the walk. The statistic analysis was made for the selected parameters of the Bio Soft program for the balance, which registered the natural COG sways. The statistic analysis was made with the Statistica 8 package. The descriptive statistics of the registered changes was used. We also analysed the distribution of the features, which indicated the lack of regular distribution and homogeneity of variance. In view of this, the Wilcoxon test was used to trace the significant changes inside the group for the dependent samples with double tests before the scheduled practice and 10 weeks after. Basing on the measurements we characterized:

- Avg. Displacement along X (cm)- average displacement of the center of gravity position in the frontal plane X,
- Avg. Displacement along Y (cm)- average displacement of the center of gravity position in the sagittal plane Y,
- Avg. Radial Displacement (cm)- average radial displacement,

as well as distribution of the given measure of ability in a histogram form.

RESULTS AND DISCUSSION

Analysis of the stabilographic parameters received from the groups before and after equestrian practice indicated the improvement in the value of the average COG displacement in the sagittal plane, as well as the mean radial displacement both in healthy children and those with mild mental disorder. The values of the mean displacement of COG in the front plane did not show significant statistic changes (Tab.2).

The percent distribution of the average displacement of COG in the front plane in both groups does not indicate statistically significant improvement in values in specific sections. In case of the healthy children group, improvement was noticed in the range of sways 0.1-0.2 cm, from 35% to 46% cases, however the marginal values 0.5-0.6 cm (Fig.1) were preserved. Likewise, in the group of mildly mentally disabled children, the distribution of values of this parameter does not indicate statistically significant positive changes either. There was noted bigger percentage variance in the ranges 0.1 – 1.0 cm (Fig 2).

Table 2. Values of stabilographic parameters before and after equestrian practice in the healthy children group (Z) and the mildly mentally disabled group (U) (* significant statistic differences– Wilcoxon test p<0.05)

Research group	Stabilographic parameters		**Avg.X (cm)**	**Avg.Y (cm)**	**Avg. Radial Displacement**
Z	$\bar{x}$	Test.1	0.26	0.96	1.03
		Test.2	0.25	0.62	0.71
	Me	Test.1.	0.24	1.03	1.06
		Test.2.	0.22	0.62	0.69
	S	Test.1.	0.12	0.34	0.32
		Test.2.	0.13	0.27	0.26
	Min	Test.1.	0.10	0.24	0.34
		Test.2	0.10	0.25	0.29
	Max	Test.1	0.55	1.57	1.61
		Test.2.	0.56	1.16	1.24
	p		0,9797	**0.0001*** **	**0.0001*** **
U	$\bar{x}$	Test.1	0.38	1.09	1.21
		Test.2.	0.34	0.86	0.98
	Me	Test.1	0.36	0.98	1.13
		Test.2	0.31	0.87	0.96
	S	Test.1	0.15	0.44	0.44
		Test.2	0.16	0.35	0.33
	Min	Test.1	0.12	0.40	0.48
		Test.2	0.15	0.17	0.36
	Max	Test.1	0.75	2.19	2.27
		Test.2	0.92	1.53	1.56
	p		0,0795	**0.0102***	**0.0143***

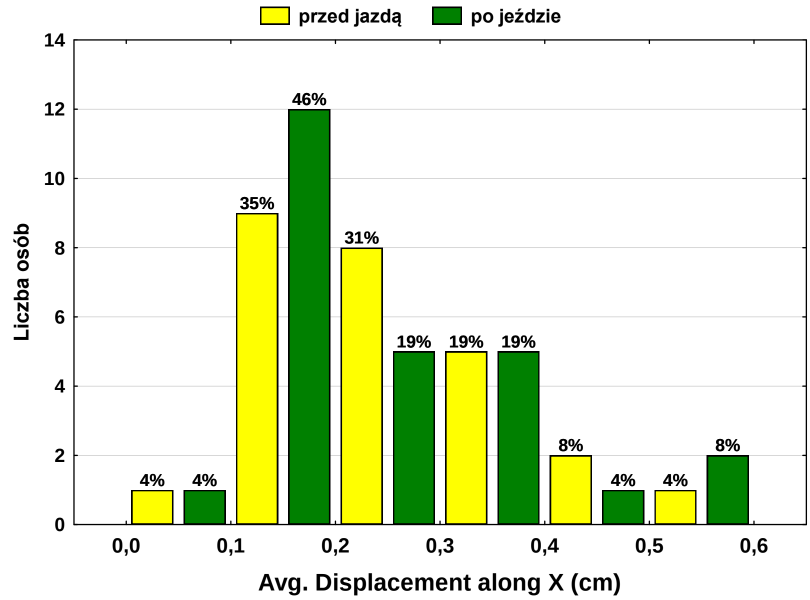

Fig. 1. Distribution of values Avg. X before and after equestrian training in the healthy children group.

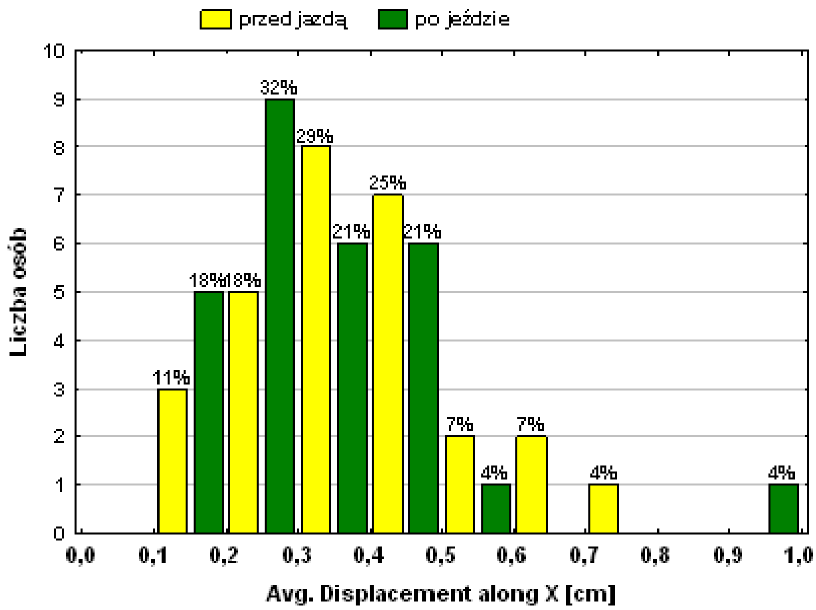

Fig. 2. Distribution of values Avg. X before and after equestrian training in the mildly mentally disabled children group.

Positive and statistically significant changes were seen in the average displacement of COG in the sagittal plane in both groups. In the healthy children group there was growth in the smaller values of the ranges: 0.2-0.4 cm from 8% to 31%, 0.4-0.6 cm from 8% to 15%, 0.6-0.8 cm from 19% to 27%, simultaneously, the range of minimal and maximal values in the ranges improved from 0.2- 1.6 cm before training to 0.2- 1.0 cm after its end (Fig.3). In the group of mildly mentally disabled children there also was noted percent growth in smaller values of the ranges: 0.2-0.4 cm from 4% to 7%, 0.4-0.6 cm from 4% to 14%, at the same time the range of minimal and maximal values in the ranges improved from 0.2- 2.2 cm before practice to 0.0- 1.6 cm after their end (Fig.4).

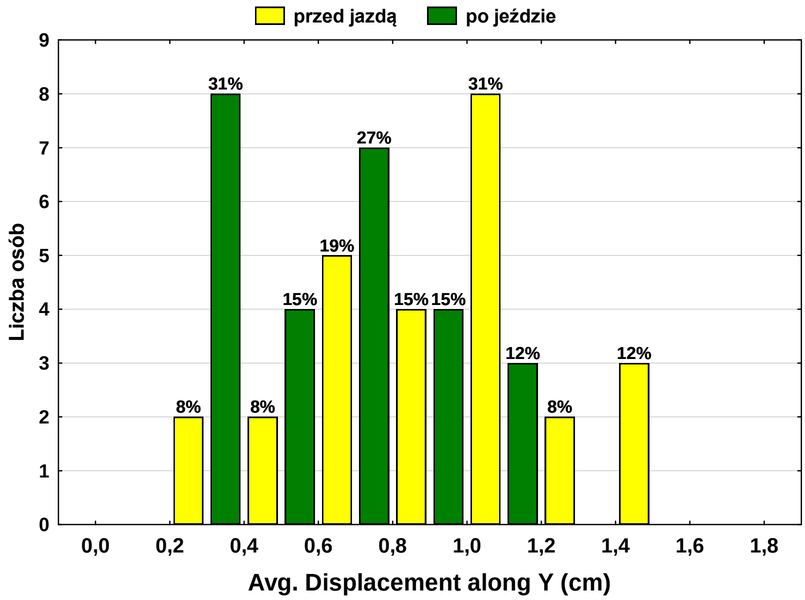

Fig. 3. Distribution of values Avg. Y before and after equestrian training in the healthy children group.

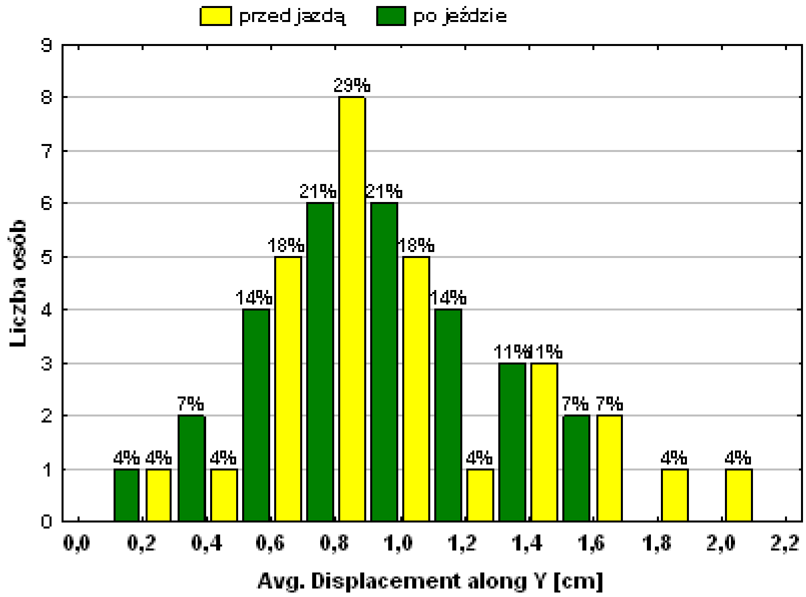

Fig. 4. Distribution of values Avg. Y before and after equestrian training in the mildly mentally disabled children group.

Despite the lack of positive changes in statistically significant values of the average displacement in the frontal plane, the values of average radial displacement in both groups after the end of equestrian training prove their considerable statistic improvement. The parameter tested in the sagittal plane and its statistically significant strong changes have a strong influence on the radial displacement within both planes of sways. In the case of healthy children, changes in the distribution of values refer to the range 0.2-0.4 cm from 4% to 15% and 0.4-0.6 cm from 0% to 19%, simultaneously, there decreased the percentage of ranges with higher values 1.0-1.2 cm from 23 % to 8% and 1.2-1.4 cm from 19% to 4%. After the end of the training we did not notice any values of this parameter in the range 1.4-1.8 cm (Fig.5).

A similar positive tendency of changes in the average radial displacement was noticed in the group of children with mild mental disability. Before the training the values were oscillating within 0.4 – 2.4 cm, and after the end of the training within 0.0 – 1.6 cm (Fig.6).

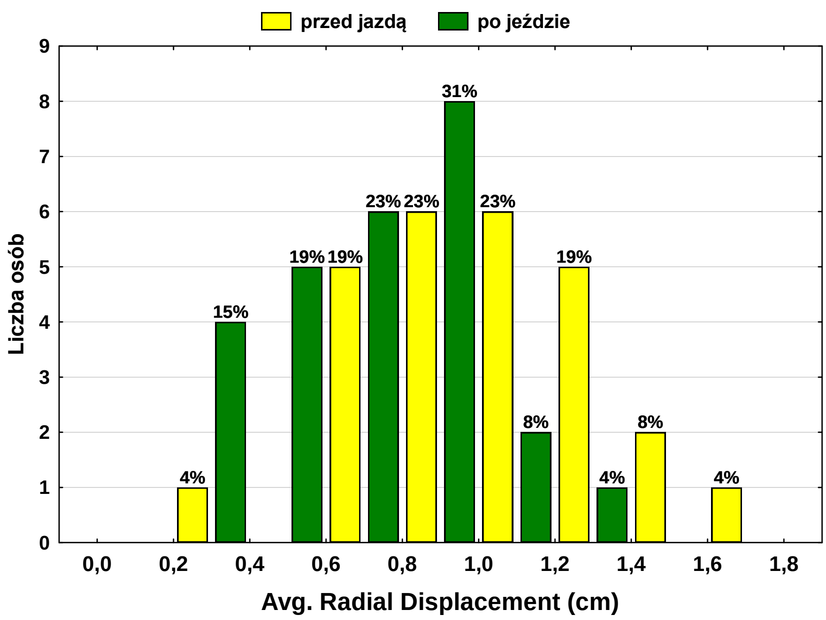

Fig. 5. Distribution of values Avg. Radial Displacement before and after equestrian training in the healthy children group.

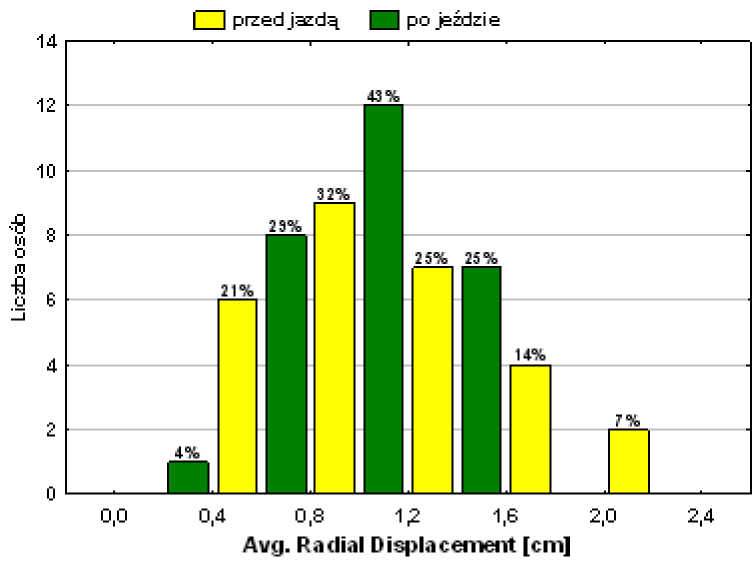

Fig. 6. Distribution of values Avg. Radial Displacement before and after equestrian training in the mildly mentally disabled children group.

SUMMARY AND CONCLUSIONS

A human keeping balance in the upright position is permanently losing and then regaining it. Hence, it's a constant process of making correction movements recovering the proper position of COG with reference to the support surface. The morphological basis for this regulation is the locomotor system, and the nervous system controls the process (Golema 2002). The main task of the posture stability control system is keeping the optimal distance between the COG and limit of stability. Anatomical asymmetry of the body in frontal and sagittal planes, distribution of sensors, as well as different biomechanical properties of the body, result in placing the projection of COG on the support surface away from the center of this area (Błaszczyk, Czerwosz 2005).

The form of movement applied in the experiment to shape the balance reactions due to its specific impact of the natural horse movements onto the rider, proper way of conducting the training and selection of the exercises, enables a multi-area correction of human functioning. In both groups, the healthy children and children with a mild mental disability, participating in equestrian training, showed a statistically significant reduction of the average radial displacement, as well as the average displacement in the sagittal plane which decisively influenced the improvement of radial displacement despite the lack of changes of this parameter in the frontal plane.

The positive changes were proved by the distribution of parameters in both groups. The percentage distribution of average displacement of COG in the frontal plane in both groups does not indicate a statistically relevant improvement. The sways of COG in this plane are controlled by the hip-joint, which, due to its structure, stabilizes the body posture. Positive and statistically significant changes were seen in the displacement of COG in the sagittal plane. In both groups the increase in smaller values in the ranges and lack of extremely maximal values of the parameters led to the improvement in the distribution of the average radial displacement, which is an average displacement of COG in the frontal and sagittal planes.

All the movements made in the sagittal plane possess a higher ability to move in all the joints of the lower limb. Hence, to keep the balance we should engage other groups of muscles different in number and quality which will enable the stabilization of the ankle, knee and hip joints. The central nervous system regulates the position of COG through applying the relevant muscle tension and stabilization of joints. A torso balanced with its COG placed on the ninth thoracic vertebra in the sitting position and aligned with the axis of COG of the horse, transfers the waving movements onto the limbs. The feet pick up the waves with the metatarsus in the spurs and the foot absorbing the shocks in the ankle causes pressure on the spur. The loosely lowered heel indicates the properly positioned lower limbs, physiological health of the hip-joint, flexibility of the pelvis and free transition of its movements to the body (Strauß 1996, Heine1998, Von Dietze 2004, Mazur-Rylska, Ambroży 2010, 2011). It reveals in smaller average radial displacement of COG, which is the result of a noticeable influence of the improvement of average displacement in the sagittal plane after the end of equestrian training in both groups.

The heuristic model of controlling the balance divides the support surface into a few areas having a different influence on the balance control. The real (subjective) limit of posture stability is divided from the mechanical limit of stability, i.e. the envelope of the feet, by the area called the margin of safety. The width of this margin changes with age and depends on the efficiency of the balance system and its controller, that is, the central nervous system (Błaszczyk, Czerwosz 2005). It can be considered that the margin of safety is lower in the people with mild mental disability, since their balance parameters differ against their healthy peers (Mazur-Rylska, Ambroży 2010, 2011). The reduction in the value of average displacement resulting from participation in the equestrian training can play an important role in improving this component of the balance pattern.

The horse movement develops the balance reactions in children aged 15-17 showing statistically relevant positive changes. Horse riding is a physical activity appearing as a result of harmonically coordinated duet in which motor perception and reactions on the stimuli are of prior importance for the joint movements. The scale of improvement in the balance reactions measured by the size of average displacements in the planes of movement and the radial average is of such a significance that horse riding can be treated as an attractive for many reasons way of improving the body balance, which is inevitable for the quality of human physical activity in any age.

BIBLIOGRAPHY

1. Błaszczyk J.W. 1993: *Kontrola stabilności postawy ciała*. Kosmos, 42,2,473-486.
2. Błaszczyk J.W., Lowe D.L., Hansen P.D.1993: *Ranges of Postural Stability and Their Changes in the Elderly*, Gait&Posture,1,4,161-164.
3. Błaszczyk J., Czerwosz L. 2005: *Stabilność posturalna w procesie starzenia*. Gerontologia Polska, 13,1,25-36.
4. Golema M: 2002: *Charakterystyka procesu utrymywania równowagi ciała człowieka w obrazie stabilograficznym*. AWF Wrocław, 10-129.
5. Heine B. Hipoterapia – wielosystemowe podejście do leczenia zaburzeń nerwowo-mięśniowych. *Rehab Med*, 1998; 2: 104–107.
6. Janota M. 2004: *Rok 2004- wychowanie przez sport. Znaczenie ruchu w życiu człowieka niepełnosprawnego*. Lider. 12, 3-6.
7. Lee W.A., Deming L., 1987: *Correlation Between Age and the Size of Normalized Static Support Base While Standing*. Proceedings of the Annual Meeting of the North American Society of the Psychology of Sport and Psychical Activity (abstract), 41.
8. Kwolek A, Drużbicki M.1999: *Wykorzystanie platformy do ćwiczeń równowagi z zastosowaniem biologicznego sprzężenia zwrotnego u chorych po udarze mózgu.* Fizjoterapia. 7,3, 3-6.
9. Kwolek A, Drużbicki M.1999: *Wykorzystanie platformy do ćwiczeń równowagi z zastosowaniem biologicznego sprzężenia zwrotnego u chorych po udarze mózgu.* Fizjoterapia. 7,3, 3-6.
10. Mazur-Rylska A, Ambroży T, Ambroży D. The effect of horse-riding on stabilogrphic parameters in teenage children with mild mental retardation. *Acta Facultatis Educations Physicae Universitatis Comenianae. Publicatio LI/I. Univerzita Komenskeho, Bratislva*, 2011; 51–6.
11. Mazur-Rylska A, Ambroży T, Ambroży D. Możliwość wykorzystania gimnastycznych ćwiczeń na koniu w stymulacji systemu propriocepcji w usprawnianiu psychomotorycznego rozwoju dziecka niepełnosprawnego umysłowo. [w:] T. Ambroży, D. Ambroży (red.) Tradycyjne i nowoczesne formy gimnastyki i tańca w perspektywie kultury fizycznej. *EAS Kraków,* 2010; 389–414.
12. Mraz M., Pietrak P. 1995: *Porównanie częstotliwości zmian stabilogramów osób zdrowych oraz ze schorzeniami ośrodkowego układu nerwowego*. Fizjoterapia.3,1,18-20.
13. Mraz M., Dzius J., Mlądzka I., Mraz M. 2001: *Ocena sposobu utrzymania równowagi w pozycji stojącej u chorych po udarze naczyniowym mózgu na podstawie Testań stabilograficznych.* Fizjoterapia. 9,2, 8-11.
14. Pilecka W. 2001: *Psychoruchowy rozwój dzieci o obniżonej sprawności umysłowej.* [w:] Pilecka W., Pilecki J. (red.). Stymulacja psychoruchowego rozwoju dzieci o obniżonej sprawności umysłowej. Wyd. Naukowe Akadamii Pedagogicznej, Kraków, 9-34.
15. Riach C, Starkes J. 1993: *Stability Limit sof Quiet Standing Postura Control in Children and Adults*. Gait & Posture,1: 105-112.
16. Strauß I. 1996: Neurofizjologiczna gimnastyka na koniu. *Fundacja Hipoterapia, Kraków.*
17. Ślężyński J. 1991: *Rozwój fizyczny i sprawność ruchowa dzieci i młodzieży niepełnosprawnej i społecznie niedostosowanej*. Kultura Fizyczna. 9-10, 30.
18. Ślężyński J.1994: *Rozwój fizyczny i motoryczny dzieci i młodzieży niepełnosprawnej.* [w:] Kasperczyk T. (red.) Rehabilitacja medyczna i społeczna. Kraków, PSON ZG, Ostoja. Materiały I Europejskiego Kongresu „Niepełnosprawni Bliżej Europy”,t.1.
19. Von Dietze S. 2007:Równowaga w ruchu. *Galaktyka, Łódź.*

20. Wilczyński J. 2005: *Postawa ciała a stopień upośledzenia intelektualnego.* Wychowanie Fizyczne i Zdrowotne, 1,16-19.
21. Zosgórnik E. 1989: *Zróżnicowanie rozwoju somatycznego i motorycznego uczniów szkół normalnych i specjalnych dla umysłowo upośledzonych*. Wychowanie Fizyczne i Sport. 41, 41-62.