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Assessment of core stability in equestrian riders

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Abstract: Background: Core stability allows to control and properly perform movements of all body. Optimal core stability level depends on deep muscles capacity and neuromuscular control. Poor core stability is a risk factor for injury, especially during physical activity.
Objective: The purpose of this study was to examine the differences in core stability between sport and recreational horse riders and people, who don't do any sports. We hypothesized that horse riders demonstrate better core stability performance.
Methods: 75 people aged 15–30 (20 recreational horse riders, 20 sport horse riders and 35 non-horse riders) was examined in 4 core stability tests. Individuals were assigned to each group based on authors questionnaire. Differences between groups were assessed by analysis of variance (ANOVA).
Results: The study showed that sport horse riders have the best core stability. Recreational riders, who trained for shorter periods of time obtained much lower results in each test. The non-horse rider group demonstrated the worst results. There was no statistically significant relationship between the frequency of equestrian training and tests results.
Conclusions: Horse riding increases core stability and has a positive effect on all its parameters. The longer the equestrian training, the better core stability.

Keywords: core stability, equestrian, horse riding, stability training.

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Introduction

Recreational and sport horse riding is becoming more and more popular in Poland. It is classified as a high-risk sport and learning its basics takes many years. Despite this, more and more people decide to learn horse riding. The ability to control a horse and the possibility of communing with unpredictable nature is a source of strong emotions what makes horse riding an addiction for many people [1]. Equestrian training differs from other sports disciplines and activities. Success and results depend on both the skills and well-being of the rider, as well as the current mental and physical condition of the horse [2].

An important role in horse riding plays the control of the rider's trunk and posture, which is the responsibility of core stability (CS) [3]. CS is defined in many ways and basically refers to the capacity of the deep muscles of the torso, whose task is to control the center (core) of our body located in the pelvic-lumbar region. A strong core is the basis of any physical activity, both during static and dynamic exercises, especially at the sports level [4–6]. The variety of CS definitions does not allow for an unambiguous determination of what constitutes the core anatomically and physiologically, and therefore the physical assessment of stabilization is difficult to examine. However, many sources indicate that CS plays a very large role in the most important motor functions of the body [7, 8].

According to Hibbs *et al.* [9]. CS is the ability to hold the position of the torso above the pelvis. It is important both in static and dynamic conditions, during daily and sports activities [9]. Thus, CS is crucial for biomechanical functions, maximizing the ergonomic use of force and minimizing the strain on the locomotor system [10, 11]. In turn, according to Kibler *et al.* [12]. CS is the ability to control the position and movement of the trunk relative to the pelvis, ensuring optimal production and transfer of force and power to the appropriate body segments (proximal stability provides distal mobility). Hodges and Richardson [13]. described the core as a box with abdominal muscles at the front, the lumbar spine and buttocks at the back, the diaphragm as a lid, and the pelvic floor at the bottom. Although the static elements, i.e., bones and soft tissue, contribute to maintaining stability, the greatest importance is referred to the dynamic part — actively working muscles [5, 14]. It was proven that the muscles responsible for CS activated before each movement of the limbs. It can therefore be concluded that the core is the center of the functional movement chain [13].

The CS is formed by the muscles that are located in the lumbar region of the spine, simultaneously being responsible for its protection during everyday activities and during heavy physical activity [15]. The deep muscles responsible for CS are: transversus abdominis, multifidus, pelvic floor muscles and the diaphragm — in CS they are activated independently of our will [16].

Because of its complexity, CS is hard to evaluate with one specific test. No examination simultaneously measures all the factors that contributes to CS. Probably the best method to measure core muscle activity is EMG, which shows the electrical activity of muscles. Due to the cost and time-consuming nature of EMG, some tests have been developed that are easy and quick to perform without the need of specialized equipment. They evaluate e.g., the efficiency of muscles related to positioning the body in space [5, 17, 18].

The appropriate level of CS in equestrian is extremely important. Riders, to communicate with the horse, use primarily the trunk, and — to a lesser extent — the limbs. The rider is, in some way, the initiator of the horse's movement. He must be aware of how to be the part of the movement that the horse will perform [19]. With a good CS the movements of the upper and lower limbs can be controlled separately, while maintaining proper balance. A good rider while riding a horse moves freely, somehow blending into the movement of the horse. Stabilization provides the possibility of relaxation, which is crucial for harmony during changes in the horse's gait, and even when the horse is spooked [20]. The rider-horse relationship in terms of CS is not unilateral. The horse's movement stimulates the body to physical reactions, including static and dynamic movements of the trunk and pelvis, rotational movements and changes in the position of the center of gravity.

Research by Kim *et al.* [8] shows that the horse-riding program, compared to the program of core stability exercises, conducted in the same period of time with the same frequency, is more effective and better improves CS.

The aim of the study was to assess the level of core stability in people who regularly practice horse riding at a competitive and recreational level and to compare its level to people who do not practice this sport.

Material and Methods

The study covered a total of 75 people, from whom two groups practicing horse riding were distinguished: recreational (A), sports (B) and a control group (C). Participants engaged in horse riding were recruited in equestrian clubs from the city of Cracow and Cracow County. Group A (recreational) consisted of 20 people (17 women and 3 men) aged 15 to 30, who regularly rode horses at a recreational level for at least two years, and the training frequency was no more and no less than 2 or 3 hours a week. Group B (sports) consisted of 20 people (13 women and 7 men) aged 15 to 30, who regularly rode horses at a sport level for at least five years, and the frequency of training was not less than 3 hours a week. In groups A and B, apart from horse riding, the subjects did not practice any other physical activity for at least 3 hours a week. Group C (control) consisted of 35 people (20 women and 15 men) who did not regularly practice horse riding or any other high-intensity sport, 3 hours a week or more. Recruitment to the control group was carried out personally and pupils, students and graduates of Cracow schools aged 15 to 29 were included in the study.

The classification of participants into recreational (A) and sport groups (B) was based on reported training experience, frequency of training sessions, and participation in organized competitions. For all study groups, the criterion for inclusion in the study was good general health. Additional exclusion criteria were undergoing procedures in the abdominal cavity or spine, musculoskeletal disorders, pain of unknown origin, neurological disorders — in particular problems with the labyrinth, cardiovascular and digestive system diseases. All persons participating in the study were informed about its purpose and course, as well as the possibility of resigning from participation in the study at any stage. Subsequently, all participants agreed to participate in the study — in the case of minors, parental consent was obtained. The permission was obtained from the participants for the publication of photographs.

The research was conducted as part of a research project carried out for the purposes of a master's thesis. Due to the non-invasive nature of the research and the fact that it did not qualify as a medical experiment or clinical trial, the approval of the Bioethics Committee was not required during the project.

All research procedures were designed to ensure the safety and well-being of the participants, as well as to guarantee anonymity, confidentiality, and voluntary participation. The study was conducted in accordance with the principles of research ethics and the guidelines of the Declaration of Helsinki. The participants were informed about the purpose of the study, its course, and the possibility of withdrawing at any stage without giving a reason and without incurring any consequences. They were assured of anonymity, confidentiality of the collected data, and respect for their well-being.

Details of the characteristics of the basic somatic features of all three groups are presented in Table 1. Comparative analysis showed statistically significant differences in body weight, and thus BMI of the examined persons, however, due to the fact that in all groups the BMI index was within the norm — these differences were considered clinically insignificant.

Table 1. Descriptive characteristics of the basic somatic features of the studied groups.

Parameter	Recreational group (A) n = 20				Sport group (B) n = 20				Control group (C) n = 35				p
	Mean	Sd	Min	Max	Mean	Sd	Min	Max	Mean	Sd	Min	Max	
Age [yrs]	20^{C}	5.10	15	30	21.1	3.82	16	29	23.5^{A}	2.89	16	28	0.0035
Height [m]	1.69	0.10	1.50	1.85	1.72	0.08	1.56	1.86	1.73	0.10	1.55	1.92	0.3291
Body mass [kg]	61.8^{C}	15.37	38	100	63.7	9.22	52	80	70.86^{A}	12.17	50	98	0.0206
BMI [kg/m²]	21.5^{C}	3.83	16.71	30.52	21.5^{C}	1.65	17.99	24.69	23.64^{AB}	2.85	17.93	31.25	0.0080

Legend: Sd — standard deviation, Min — minimum value, Max — maximum value, $^{A/B/C}$ — group with statistically significant difference in Kruskal-Wallis test.

In order to assess the level of central stabilization in all groups, the following tests were performed once, in the order of performance: modified Trunk Stability Test (TST) [21], Unilateral Hip Bridge Test (UHBE) [17], Rotatory Stability (RS) and Trunk Stability Push Up (TSP) [18]. To perform them, a non-slip gymnastic mat, a gymnastic ball and a stopwatch were used. The tests were performed in rooms with constant temperature and similar size. The subjects wore clothes that did not restrict movement and were tested not earlier than 2 hours after a meal.

Modified Trunk Stability Test

Before the test, the subject sat upright on the ball, feet on the ground, upper limbs crossed over the chest (Fig. 1). Before starting the test, the subject made pelvic movements from side to side and from front to back in order to "feel" the position of the pelvis on the ball. Subsequently, the subject was tested for a maximum of 30 seconds. The modification of the test consisted in lifting both feet simultaneously instead of each foot separately.

The main part of the test consisted in the subject sitting on a Swiss ball with a diameter of 65 cm, resting his feet on the ground and maintaining a right angle in the knee joints. The subject sat straight, crossed his upper limbs on his chest and lifted both feet so that they did not touch the ground (Fig. 2). The subject's task was to maintain balance as long as possible. The heels and calves were to remain in contact with the front of the ball. The test was performed twice, with a minute break in between. When the subject stopped holding the upper limbs on the chest, touched the floor with his feet or the ball touched the wall, the test ended. The average time of two trials, counted in seconds, was considered for the analysis.

The modification of the TST applied in this study (lifting both feet simultaneously) aimed to increase the test's difficulty in athletic populations.

Fig. 1. TST — starting position.

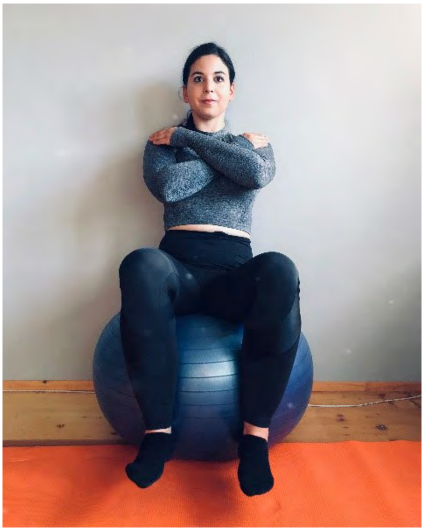

Fig. 2. TST — test execution.

Unilateral Hip Bridge Endurance Test (UHBE)

Initially, the subject was lying on his back with his upper limbs crossed over his chest with bent knees and feet flat on the ground (Fig. 3). The subject lifted the hips, then, keeping the spine and pelvis in a neutral position, straightened one leg at the knee, maintaining this position for as long as possible (Fig. 4). The test was stopped when the participant was unable to maintain a neutral pelvic position. The subjects always lifted the right leg first, and after a 30-second break, they repeated the test lifting the left leg. The result of the test was the time of keeping the lower limb up with the same pelvic position, measured in seconds.

Fig. 3. UHBE test — starting position.

Fig. 4. UHBE — test execution.

Rotatory Stability (RS)

At the beginning of the test, the subject was asked to simultaneously straighten the upper limb in the shoulder joint and the lower limb in the hip joint in such a way that the body remained in a straight line (Fig. 5). Then he was supposed to bend both limbs and at the same time bring the elbow and knee together (Fig. 6). The test was performed bilaterally — the average of measurements for both sides was included in the analysis. Three points were scored for one correct execution of the test, keeping the body line parallel to the ground, knee and elbow of the same side of the body touching the ground line. Two points were scored for making one attempt but the movement of the elbow touching the knee was with the opposite limbs (diagonal plane); one point — when the subject was unable to complete the pattern; no points were scored when pain ailments occurred during the execution of the pattern.

Fig. 5. RS — starting position.

Fig. 6. RS — test execution.

Trunk Stability Push up test (TSP)

Before the test, a provocative test was performed consisting in extending the spine in the lumbar section from the prone position. Pain during the provocation test meant 0 points in the test and failure to start the main part of the test.

The subject's task was to move from the prone position to the push-up position (Fig. 7, 8). Women started in a front-facing position with their hands at jaw height, and men with their hands above their eyebrows. In a situation where the tested person was unable to perform the pattern,

Fig. 7. TSP — starting position.

Fig. 8. TSP — final position.

the point of support for the hand was changed to facilitate the movement — in women to the level of the collarbone, in men — to the level of the jaw. Three points were scored if: the man made one attempt with his thumbs placed at the level of his eyebrows; the woman made one attempt with her thumbs placed at the level of her jaw; 2 points were scored if: the man made one attempt with his thumbs at the level of his jaw; the woman made one attempt with her thumbs placed at the level of her collarbone; 1 point when the subject was unable to complete the pattern and 0 points when pain occurred during the challenge test or pattern execution.

Statistical analysis

Statistical analyses were made using the program STATISTICA PL (13.3). Descriptive statistics of the assessed parameters in individual groups were used. The relationship between the frequency of training and central stabilization was checked using the Spearman correlation coefficient. The Kruskal-Wallis ANOVA test was used to check the differences for independent variables between the study groups. Post-hoc tests were calculated in case the statistically significant differences between the groups. The results were considered significant with $p < 0.05$.

Results

The results of the tests performed, divided into individual groups, are presented in Table 2. In the TST test, the average holding time on the ball was the longest in the sports group and statistically significantly different from the results of the recreational and control groups. In the UHBE test, the average holding time of the lower limb (right and left) in the sports group was almost twice as long as the results obtained in the recreational group. In the control group, the average score was the lowest among the results of the other groups and almost identical in both lower limbs. The differences between the groups (A, B, C) reached statistical significance. The mean results of the rotational test (RS) did not differ significantly between the groups. The best result in the TSP test, which is also significantly different from the results of the other groups, was achieved by the sports group — the results of the recreation group and the control group were similar.

Table 2. Comparison of test results for all examined groups.

Test	Recreational group (A)				Sport group (B)				Control group (C)				p
	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD	Min	Max	<0.0001
TST [s]	14.6^{B}	12.5	2.0	42.5	51.3^{AC}	34.7	13.0	156.5	13.6^{B}	8.8	3.0	40.0	<0.0001
UHBE R [s]	41.0^{BC}	13.1	17.0	72.0	82.8^{AC}	24.1	35.0	124.0	23.3^{AB}	15.4	5.0	80.0	
UHBE L [s]	49.5^{C}	22.9	19.0	110.0	73.0^{C}	25.9	38.0	130.0	22.9^{AB}	13.4	8.0	60.0	<0.0001
RS [pkt]	2.9	0.4	2.0	3.0	2.9	0.2	2.0	3.0	2.6	0.5	2.0	3.0	0.0040
TSP [pkt]	1.8^{B}	0.8	3.0	2.8^{AC}	2.8^{AC}	0.6	1.0	3.0	1.8^{B}	0.9	0	3.0	0.0002

Legend: SD — standard deviation, Min — minimum value, Max — maximum value, A/B/C — group with a significant statistical difference in the Kruskal-Wallis test, TST –Trunk Stability Test, UHBE — Unilateral Hip Bridge Endurance Test, RS — Rotary Stability Test, TSP — Trunk Stability Push Up Test, R — right, L — left.

Table 3 presents the results of the correlation between the weekly frequency of training and the results of core stability tests. In the recreational group, there was a statistically significant correlation between the weekly training frequency and the result in only one of the tests performed — TST. The value of the correlation coefficient was 0.49, which is an average correlation according to the Guilford classification. Other correlations in this group were not statistically significant. In the sports group, the correlation coefficients indicated no linear relationship between the frequency of training and the results of individual tests — none of them was statistically significant.

Table 3. Correlations between the weekly training frequency and the results of individual tests in recreational and sport group.

Variables	Recreational group (n = 20)		Sport group (n = 20)	
	r	p	r	p
x/week & TST [sec]	**0.49**	**0.0291**	−0.06	0.8125
x/week & UHBE R [sec]	0.20	0.4092	0.03	0.9147
x/week & UHBE L [sec]	−0.02	0.9262	−0.07	0.7835
x/week & RS	0.10	0.6610	−0.02	0.9317
x/week & TSP	−0.03	0.9150	0.34	0.1372

Legend: x/week — the weekly training frequency, r — correlation coefficient, TST — Trunk Stability Test, UHBE — Unilateral Hip Bridge Endurance Test, RS — Rotary Stability Test, TSP — Trunk Stability Push Up Test, R — right, L — left.

Discussion

The findings of this study reveal notable differences in core stability performance across the analyzed groups, with the most favorable outcomes observed among individuals engaged in regular sports training. The significantly longer holding times recorded in the TST and UHBE tests within the sports group suggest that systematic, structured athletic training is associated with improved neuromuscular control.

We acknowledge that some of the assessment tools used in this study—particularly the modified TST and components of the FMS — have limited validation against laboratory-based gold-standard measures such as electromyography (EMG) or force platform analysis. However, these tools were selected for their practicality and ecological validity in sport-specific, field-based contexts.

In the conducted study, we found a significant effect of horse riding on the assessed parameters of core stability. These results are consistent with other authors' reports. MacPhail *et al.* [22] studied the control reactions of the trunk in children with cerebral palsy riding horses — they proved that a horse in the slowest gait, automatically causes pelvic sway similar to that which a human performs while walking, stimulating to maintain correct posture and balance [22] Research conducted by Encheff *et al.* [23] showed that horse riding improves proximal stability and balance, which improves the functional movements of the limbs, making it an effective method of exercise used in people with neurological disorders. In turn, according to Szczygieł *et al.* [24] properly conducted CS training improves respiratory parameters. This is primarily influenced by the posture and the appropriate, most ergonomic position of the chest [24]. Sekendiz *et al.* [25] examined the effect of CS training on a Swiss ball on the strength and flexibility of trunk extensors (abdominal muscles), trunk flexors (lower back) and extensors and flexors of the lower limbs, as well as dynamic balance. Eight weeks of Swiss ball training has been shown to significantly improve both endurance and muscle strength [25].

In our study, the TST used to assess neuromuscular control was also performed on a Swiss ball. In the study of Noehren *et al.* [21], from which the methodology was taken, the subjects lifted each lower limb separately from the ground. When conducting research in an equestrian group, this test turned out to be too simple. This resulted in the decision to use a modification by lifting both legs at the same time, which made it much more difficult. The obtained results of the modified TST test were satisfactory. The control and recreation groups had almost the same results. The obtained result of this test (about 14 seconds in both groups) was still higher than in the studies of Noehren *et al.* [21], where the subjects obtained a time of up to 10 seconds using the standard TST test. The high average result of the sports group (51 seconds) was caused by the achievement of an above-average holding time on the ball by several subjects. The minimum time of the sports group (13 seconds) compared to the recreational and control groups (3 s) indicates that subjects from this group have better central stabilization than people who ride less intensively or do not ride at all [21].

Another test used to assess central stabilization in the study participants was the UHBE test. Performance of this test requires significant activation of the multifidus and lumbar spinal extensor muscles thus it provides a good basis for assessing muscle capacity and neuromuscular control of core stability [17]. In a study by Pollen *et al.* [26] in 15 adults, the average time to keep the lower limb up in UHBE test was on average 24 to 27 seconds. A similar time during the UHBE test was presented by the control group of people not riding horses in our study. The result of the recreational group was almost twice as long, and the sports group almost three times longer. This suggests a potentially beneficial effect of horse riding on endurance and neuromuscular control of the lumbar-pelvic complex [17]. In a study by Pollen *et al.* [26] it was not specified whether people performing this test were physically active. However, we found that the somatic characteristics and results of non-equestrians in our study and those in the study of Pollena *et al.* [26] were similar — it can therefore be assumed that they did not practice any sport intensively. In our study we noticed the difference in the results between the average times obtained for the maintenance of the right and left limbs. It was interesting that the time of keeping the leg up was higher in the sports group (82 seconds for the right leg and 73 for the left leg) compared to the recreational group (41 seconds for the right leg and 49 for the left leg). It is possible that the differences between the limbs depend only on individual conditions and the intensity of training does not matter. It would be worth to examine examining these groups in more detail using a dynamometer, considering the lateralization and dominance of the lower limbs [17, 26]. Also Alexander *et al.* [27] draw attention to the asymmetry in the posture of horse riders. They indicate that the rotation of the trunk to the right side is frequent while it depends mainly on the right-handedness of the majority of respondents. As a result, rotation causes asymmetry and uneven loading of the pelvis. This may be due to limited mobility in the hip joints, shortening of the adductors or abductors, or weakness of the muscles of thoracolumbar spine. Also, Hobbs *et al.* [28] pointed out that the height of the right iliac crest is greater the longer the duration of horse riding. This causes weakness of the lower left limb. The authors suggested that this may be due to greater muscle development and tone on the right side of the body, which limits flexion and rotation of the body to the left [28]. These studies confirm previous assumptions about lateralization. Referring to the results of the UHBE test, where the left leg was stronger in the recreational group and the right leg was stronger in the sports group, they agree with Hobbs' statement — it also indicates a good clinical value of these tests [27, 28].

The FMS system, created over 27 years ago by Gray Cook and Lee Burton, is used to assess functional movement patterns, including body stability and coordination [18]. In our study, in order to assess the core stability features, two motor tasks were selected from the FMS test: Rotatory Stability test (RS) and Trunk Stability Push Up (TSP). RS assesses multiplanar stability during combined, ipsilateral movement of the limbs and neuromuscular coordination and control of proper energy transfer through the trunk to the upper and lower limbs. In a study by Linek *et al.* [29] 14 young volleyball players underwent an 8-week training using the Neurac method. Before and after training, the entire FMS assessment was performed, including RS. Half of the subjects before the training program scored 1 point, which means that they were unable to perform the pattern while the other participants scored 2 points. The score of each participant improved by one unit after the end of the training [29]. In turn, in the study by Mitchell *et al.* [30], in which 97 people (53 men and 44 women) aged about 60 took part, the average result of the RS test was 1.7 points. A study by Lewis *et al.* [31], conducted on people similar in terms of somatic parameters, showed that the results of horse riding and non-riding people in the RS test were similar. These results are consistent with the results of our study and confirm the relevance of RS test in assessment of core stability.

In turn, TSP is a test set in a closed kinematic chain, assessing the stability of the trunk during symmetrical work of the arms and the stability of the anterior-posterior part of the spine in the sagittal plane. It assesses the strength of the upper body, but also the efficiency of the trunk muscles, whose task is to maintain a symmetrical position of the hips relative to the shoulders while lifting the body up [18] what may be confirmed by Youdas *et al.* [32] confirmed that push-ups are important to enhance torso muscle training. Schwartzkopf-Phifer *et al.* [33] observed that TSP improved in almost 50% of young women after a six-week program of multiplane trunk stabilization exercises. Other authors point out that also single-plane and static exercises, such as the plank, improve the results obtained in TSP [34, 35]. Frost *et al.* [36] noted that, depending on the degree and type of strength training, firefighters have variable FMS scores, including the push up test. Our own research confirmed the higher difficulty of performing TSP in the control group. This may be due to the fact that during everyday activities the upper limbs do not take too many loads, and the muscles work in the same, developed patterns. Persons who do not practice any sports, as well as those with a short training experience, were unable to lift themselves on their hands, and even if they did, they lifted the upper body first, and then the lower. To our knowledge, similar studies evaluating TSP in horse riders are lacking in the current literature, which indicates the need for further research in this area.

One of the limitations of this study may be the size of the groups, which were relatively small. This affected the difference in somatic parameters between the groups: height, weight and BMI. Due to these facts as well as the subjects were healthy people and the study period was relatively short, the results cannot be generalized to any populations. Another limitation is the lack of normalization of performance metrics to individual anthropometric variables, such as body mass. In tests like the TST or UHBE, this could bias the results in favor of lighter individuals. Additionally, test-retest reliability of the modified TST was not assessed in this study, which may limit its repeatability. This study did not include electromyographic recordings or dynamometric measurements of muscle strength, which limits insight into the neuromuscular mechanisms.

Nevertheless, it seems that the quantifiable ability of trunk stability and balance in healthy people can be used as reliable data and appropriate reference for patient studies. The above studies indicate that horse riding improves trunk stability, especially when practice intensively. However, the asymmetry between the limbs stated in our study as well as by other authors suggest that CS training in horse riders, should be carefully, individually planned [4, 32]. These facts clearly indicate the need of further research in this field, especially considering the use of specialized equipment such as dynamometers or balance platforms to evaluate CS parameters objectively. Future studies should include larger participant groups to ensure sufficient statistical power.

Conclusions

The results of this study indicate that horse riding has a positive effect on trunk stability, but additional factors, such as the level of physical activity, should be taken into account. Longer riding experience improves central stabilization, but the duration of training and its frequency did not affect its parameters. It seems that horse riding can be an additional, multifactorial tool for trunk stability training in people with impaired or low level of central stabilization.

Conflict of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Author's contribution

All authors have participated in drafting the manuscript and revised it critically. All authors read and approved the final version of the manuscript.

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