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Electronic rider's seat control system: pilot studies

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Summary

The aim of the study was to determine the effectiveness of the sensors, determined on the basis of pressure changes in airbags of our own design, placed between the saddle and the horse's back. This would allow for the assessment of the flexibility and correctness of the rider's seat, as well as the strength of its influence on individual parts of the horse's back. The research included 10 Polish warm blood horses aged 7-12 years (5 mares, 5 geldings). Before the test, each horse was examined by a veterinarian who did not find any body asymmetries and they did not show any abnormalities in the musculoskeletal system. All of the horses were clinically healthy. The horse was subjected to regular training 5 times a week, of which 3 days consisted of dressage work, 1 day of pole and cavaletti work, and 1 day of jumping training and was ridden by a woman, aged 28 and weighing 65 kg, who was at the second sports class level according to the Polish Equestrian Association in dressage and show jumping. The task of the rider's seat control system was to determine its correctness. For this purpose, airbags were placed between the saddle and the horse's back. There were four airbags placed in the pad, two of which worked independently and two were connected in a pair (both airbags had the same pressure). The pair of airbags was placed under the front of the saddle, which enabled the analysis of changes in the impact of the rider's seat on the front pommel. Separated airbags were placed under the back of the saddle, which made it possible to test the impact of the rider's seat on the pommel with additional separation into the left and right sides, which enabled, for example, the detection of balance problems or asymmetries resulting from defects in the horse's structure. The results of preliminary research have shown that it is possible to control the quality of the rider's seat and determine its parameters based on measurements carried out using the proposed system. The analysis of the presented sample time series shows that the rider does not sit symmetrically in the saddle, putting more strain on the left side of the body.

Keywords: pressure sensors, rider's seat, load on the horse's back

Perfect cooperation between rider and horse requires great skill on the part of the rider and a high degree of training on the part of the horse.

The rider's seat is considered the most important equestrian aid, and its effective influence allows full control of the horse and full use of its physical and mental capabilities. A technically correct and balanced seat allows for maximum harmony between the horse and the rider, which in turn translates into lightness and smooth movement of the horse in full balance (13, 15). The rider's seat should be balanced, straight but not stiff, which allows for an even load on the horse's back. It has been proven many times that seat incorectness and loss of balance of the rider adversely affect the horse's back, which in turn leads to back pain, disturbances in the functioning of the thoracic and pelvic limbs, loss of rhythm during movement and mental discomfort (2, 14). Symptoms of back pain may come and go, making it difficult to diagnose the problem, so the horse's reactions and behavior should carefully observed and, if necessary, veterinary diagnosis carried out and appropriate treatment applied. For preventive purposes and to ensure the well-being of horses, the use of broadly understood physiotherapy is becoming more and more common, as it not only has a therapeutic effect but also allows for faster regeneration after intense physical exercise. For the back, manual massage, chiropractic care, solarium, water treadmill and LED light therapy work best (1, 7, 8, 10). In turn, riders who have problems maintaining proper posture and balance in the saddle should undergo exercises with a professional personal trainer who, by selecting appropriate exercises, will make specific muscle groups more flexible and stronger (3, 4, 9). It can therefore be assumed that the accumulation of the above-mentioned activities will improve the welfare of horses and extend their period of use. The aim of the study was to determine the effectiveness of the sensors, determined on the basis of pressure changes in airbags of our own design, placed between the saddle and the horse's back, which would allow for the assessment of the flexibility and correctness of the rider's seat, as well as the load on the certain parts of the horse's back.

Material and methods

The research included 10 Polish warm blood horses aged 7-12 years (5 mares, 5 geldings). Before the test, each horse was examined by a veterinarian who did not find any body asymmetries and showing no abnormalities in the musculoskeletal system, all of them were clinically healthy. The horse was subjected to regular training 5 times a week, of which 3 days consisted of dressage work, 1 day of pole and cavaletti work, and 1 day of jumping training and was ridden by a woman, aged 28 and weighing 65 kg, who was at the level of the second sports class according to the Polish Equestrian Association in dressage and show jumping.

The training schedule was as follows: 5 minutes walk to the left and 5 minutes walk to the right, 3 minutes rising trot to the right, then 3 circles with a diameter of 20 meters, 1 minute walk (change of direction), 3 minutes rising trot to the left, then 3 circles with a diameter of 20 meters, 1 minute walk (change of direction), 3 minutes canter to the right, then 3 circles with a diameter of 20 meters, 1 minute walk (change of direction), 3 minutes canter to the left, then 3 circles with a diameter of 20 meters, 1 minute walk (change of direction), 3 minutes sitting trot to the right, then 3 circles with a diameter of 20 meters, 1 minute walk (change of direction), 3 minutes sitting trot to the left, then 3 circles with a diameter of 20 meters, 5 minutes walk to the left, 5 minutes walk to the right. The rider performed all figures in the same place.

During training, a special pad containing pressure sensors was placed under the rider's saddle. The sensors recorded pressure changes continuously. Five-second recordings of the horse-rider pair moving at a trot and canter in various directions and in various seating positions of the rider were qualified for the initial analysis. During one second of recording, 20 pressure measurements were obtained in the posted airbags.

The research was carried out with the consent of the Animal Welfare Team operating at the Local Ethics Committee, according to which, in accordance with the Act on the protection of animals used for scientific purposes (Journal of Laws of 2015, item 465) and Directive 2010/63/EU of the European Parliament and of the Council of 22 September 2010 on the protection of animals for scientific purposes (OJ EU L 276/33), all methods used in the study will be non-invasive, which means that within the meaning of the Directive they will not cause pain, suffering, distress or lasting damage equal to or more severe than a needle prick.

The structure and principle of operation of the system. The task of the rider's seat control system was to determine its correctness. For this purpose, airbags were placed between the saddle and the horse's back. For research purposes, a Winderen corrective saddle pad was used, the design of which allowed for easy placement of airbags inside.

The introduction of airbags between the inner layers of the pad means that the horse taking part in the study did not feel any difference between everyday work and work while conducting the experiment. Four airbags were placed in the pad, two of which worked independently and two were connected in a pair (both airbags had the same pressure). A pair of airbags was placed under the front of the saddle, which enabled the analysis of changes in the impact of the rider's seat on the front pommel. Separated airbags were placed under the back of the saddle, which made it possible to test the impact of the rider's seat on the pommel with additional separation into the left and right sides, which enabled, for example, the detection of balance problems or asymmetries resulting from defects in the horse's structure. The arrangement of the airbags is shown in Figure 1.

In the process of preparing the system for testing, the airbags were placed in a 20 mm high pocket, and then all

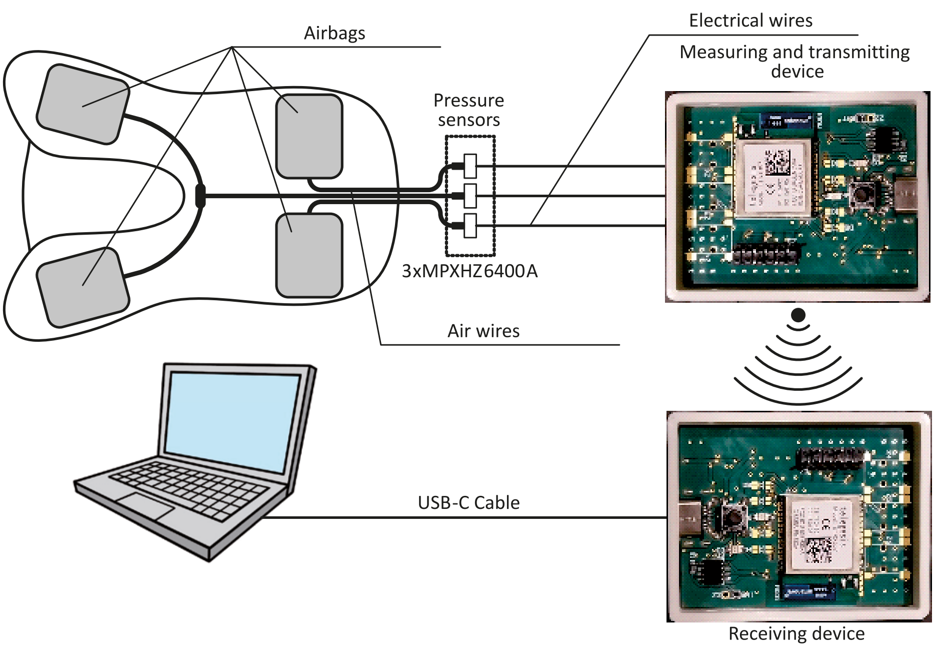

Fig. 1. The structure of the electronic rider's seat control system

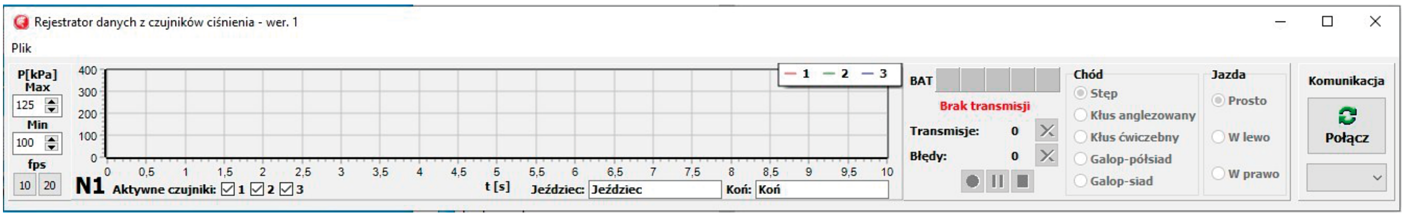

Fig. 2. Computer application window for receiving and acquiring data

airbags were filled with air to obtain the same initial pressure (100 kPa), which ensured repeatability of measurements during the tests.

The consequence of the impact of the rider's seat were changes in the air pressure in the airbags. The air from the airbag was led outside the saddle using thin pneumatic tubes and then introduced to micromechanical, piezoresistive semiconductor pressure sensors type MPXHZ6400A from Freescale Semiconductor. The above pressure sensors were in the system a converter of a physical quantity, which was pressure, into an electrical value in the form of output voltage. Voltage signals from three pressure sensors (one for the front airbag and two for the rear airbags) were fed through wires to the measurement and transmission system, where they were converted into digital form and sent via radio link to the receiving system connected to the computer. The structure of the system is presented in Figure 1.

The measuring and transmitting system was built using an MSP430F5529 microcontroller manufactured by Texas Instruments. Such a microcontroller was used due to its high performance to power consumption ratio (high efficiency/low power consumption). Additionally, the above microcontroller is equipped with two UART interfaces, one of which was used for direct connection to the computer to configure the unit and the other for transmission via the wireless transmission module. The microcontroller also had a built-in 12-bit analog-to-digital converter enabling measurement of voltages from pressure sensors.

Wireless transmission was carried out using the ETRX357 module manufactured by Silicon Labs. This module enabled transmission in the ZigBee system. The use of this transmission system allowed the creation of a wireless network, thanks to which it was possible to record data from many measuring and transmitting devices at the same time. The range of wireless transmission between two points was not less than 100 m. In the ZigBee network, it was possible to extend the range by transmitting between modules through other modules (e.g. the transmission was carried out when the distance between the transmitter and the receiver was too large but there was an additional transmitter, which was then a retransmitting element).

The measuring and transmitting system is equipped with a lithium-ion battery with a capacity of 2000 mAh and a charging management system. This battery capacity allowed for continuous operation for approximately 10 hours. The battery was charged from any charger equipped with a USB output.

Due to cost optimization, the receiving system had a hardware structure identical to the measuring and transmitting system. It did not use voltage signal measurement inputs and was deprived of a battery and a charging management system. The main difference between these systems was the software of the control microcontroller. The task of the receiving system was to receive data sent wirelessly from the measurement and transmitting systems and send them via a USB connection to a computer, where, using a dedicated application, it was possible to continuously preview the transmitted data and acquire it. The application window is shown in Figure 2.

In order to verify the correct operation of the system, preliminary tests were carried out consisting of recording time series illustrating changes in pressure in the airbags. Measurements were carried out at a frequency of 20 Hz. The tests were carried out at the following gaits: rising and sitting trot, and canter. Figures 3-11 show the recorded time series for individual gaits. Registrations were made for straight traffic and for left and right turns.

Statistical methods. Basic statistical parameters were calculated for the recorded data: mean (M), median (Me), standard deviation (σ), minimum (Min), maximum (Max) and peak-to-peak value (A). Statistical parameters were determined separately for the pressure courses in the left, right and front airbags. The above statistical parameters enable the analysis of the strength and dynamics of the rider's influence on individual parts of the horse's back, including the detection of seat asymmetry or balance irregularities. In further research, it is planned to extend statistical analyzes aimed at comparing changes in the quality of the rider's seat at the beginning of the research work and after conducting a series of exercises with the rider. The exercises will aim to make the rider's seat more flexible and balanced.

Results of preliminary tests

The results obtained regarding the analysis of the tested rider's seat indicate a stronger load on the left side of the body (Tab. 1). When analyzing both mean and amplitude for each of the 10 horses tested, mean pressure values were higher on the left side.

Table 2 contains a numerical summary of the recorded parameters. When analyzing different gaits and different seating positions of the tested rider, a tendency to put more strain on the left side of the body is once again visible. This is especially noticeable in the case of the average pressure between the right and left sides.

The data in Figure 3 show the course of pressure changes in the airbags while riding straight in an rising trot. The load on the front, while the rider was floating in the saddle, was at a similar, although not equal, level (above 112 kPa, not exceeding 115 kPa), which also indicates a clear relief of the rear load every second step. When sitting in the saddle, the pressure on the front was correspondingly greater, although the differences in pressure were slightly smaller than when the

Tab. 1. Statistical parameters of recorded time series for different horses in sitting trot

Horse	Airbag	*M (kPa)	Me (kPa)	σ	Min (kPa)	Max (kPa)	A (kPa)
1	Left	113.37	113.70	3.64	106.3	120.9	14.6
	Front	112.28	111.90	2.62	108.4	119.8	11.4
	Right	112.61	112.90	2.90	107.6	117.5	9.9
2	Left	113.92	113.63	3.22	109.1	120.3	11.2
	Front	110.55	110.20	2.63	106.3	115.9	9.6
	Right	110.58	110.30	3.08	105.6	116.3	10.7
3	Left	113.88	113.50	3.81	107.9	121.2	13.3
	Front	112.09	112.20	2.82	107.4	117.3	9.9
	Right	111.26	111.30	3.48	104.7	117.7	13.0
4	Left	115.00	114.80	5.28	106.6	124.5	17.9
	Front	109.70	109.00	3.18	105.8	115.5	9.7
	Right	112.27	112.30	4.65	105.1	121.4	16.3
5	Left	115.06	115.29	4.11	108.6	123.4	14.8
	Front	112.30	111.90	2.79	108.3	117.8	9.5
	Right	112.01	112.00	4.10	105.9	120.5	14.6
6	Left	116.50	115.70	6.31	108.0	128.5	20.5
	Front	112.33	111.50	3.47	107.6	120.0	12.4
	Right	112.86	112.60	5.21	105.8	123.5	17.7
7	Left	116.73	116.60	4.27	109.7	124.3	14.6
	Front	111.99	111.80	2.28	108.1	115.8	7.7
	Right	115.43	115.50	3.95	108.7	122.6	13.9
8	Left	116.93	116.60	4.52	109.7	128.7	19.0
	Front	111.93	111.80	2.26	108.1	115.8	7.7
	Right	115.50	115.50	4.04	108.2	123.0	14.8
9	Left	115.63	115.32	5.41	107.2	124.9	17.8
	Front	112.07	111.40	2.61	108.5	117.2	8.7
	Right	112.35	111.90	4.87	105.3	122.4	17.1
10	Left	115.66	115.20	5.50	106.6	128.2	21.6
	Front	109.40	108.10	2.94	105.6	115.3	9.7
	Right	112.48	112.10	4.61	105.1	123.8	18.7

Explanations: *M – average value; Me – median; σ – standard deviation; Min – minimum value; Max – maximum value; A – amplitude (difference between values, A = Max – Min)

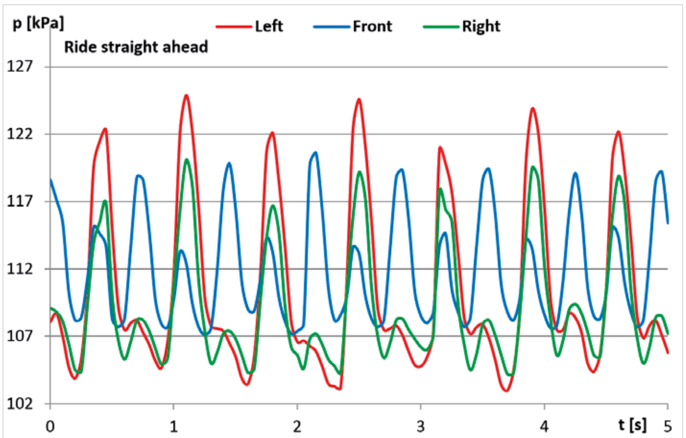

Fig. 3. The course of pressure changes in the pads in rising trot (ride straight ahead)

Tab. 2. Statistical parameters of recorded time series in different gait of horses and different position of the rider

Gait	Direction	Airbag	*M (kPa)	Me (kPa)	σ	Min (kPa)	Max (kPa)	A (kPa)
Rising trot	Straight ahead	Left	110.44	107.80	6.3	103.0	124.9	21.9
		Front	111.98	110.60	3.9	107.1	120.6	13.5
		Right	109.13	107.40	4.4	104.2	120.1	15.9
	Left turn	Left	111.69	109.20	5.5	106.1	128.0	21.9
		Front	111.73	111.20	3.3	107.5	119.7	12.2
		Right	109.44	107.80	4.8	102.7	121.5	18.8
	Right turn	Left	111.58	109.40	5.7	104.5	125.2	20.7
		Front	111.19	110.60	3.0	107.3	117.7	10.4
		Right	110.73	109.30	4.7	105.2	122.7	17.5
Sitting trot	Straight ahead	Left	115.00	114.80	5.3	106.6	124.5	17.9
		Front	109.70	109.00	3.2	105.8	115.5	9.7
		Right	112.27	112.30	4.7	105.1	121.4	16.3
	Left turn	Left	115.92	115.10	5.5	107.0	125.7	18.7
		Front	109.89	108.80	3.0	106.0	115.8	9.8
		Right	112.08	111.70	4.5	105.2	121.0	15.8
	Right turn	Left	114.91	115.10	4.8	107.5	124.8	17.3
		Front	110.04	109.00	3.1	105.8	115.7	9.9
		Right	112.46	112.30	4.2	105.0	121.6	16.6
Canter	Straight ahead	Left	115.49	116.10	6.2	106.0	127.0	21.0
		Front	108.13	108.40	1.9	104.6	111.8	7.2
		Right	112.94	112.90	4.9	105.8	122.0	16.2
	Left turn	Left	115.22	115.30	5.8	106.6	125.4	18.8
		Front	108.28	108.70	1.9	104.6	112.8	8.2
		Right	112.29	112.40	5.4	104.6	121.6	17.0
	Right turn	Left	116.63	117.00	6.3	107.2	128.8	21.6
		Front	108.35	108.80	1.9	105.3	111.7	6.4
		Right	111.89	111.90	3.9	105.6	119.7	14.1

Explanations: *M – average value; Me – median; σ – standard deviation; Min – minimum value; Max – maximum value; A – amplitude (difference between values, A = Max – Min)

rider was floating in the saddle. However, there were noticeable differences between the load on the left and right sides of the horse's back, which indicates that the rider was sitting asymmetrically. When returning to the saddle, a significantly stronger load was found on the left side, which amounted to 122 kPa and above, while on the right side, during each recorded step, it was below 118 kPa. Smaller differences were noted when the rider was floating in the saddle, but also in this case the data on the chart indicate uneven loads on both sides of the saddle.

While riding in a left turn, the front load turned out to be uneven when the rider sat in the saddle. Quite large pressure differences were found between individual steps. When the rider was floating in the saddle, the differences were small, which may indicate that the rider maintains better balance while performing this movement. There were large discrepancies between the load on the left and right sides of the body. When riding to the left, the rider clearly put more strain on the left part of the horse's back and this was done very unevenly. The load on the right side was slightly smaller but also uneven. Similarly, when the rider was floating in the saddle, the pressure in the cushions on the left side was greater than on the right side – Figure 4.

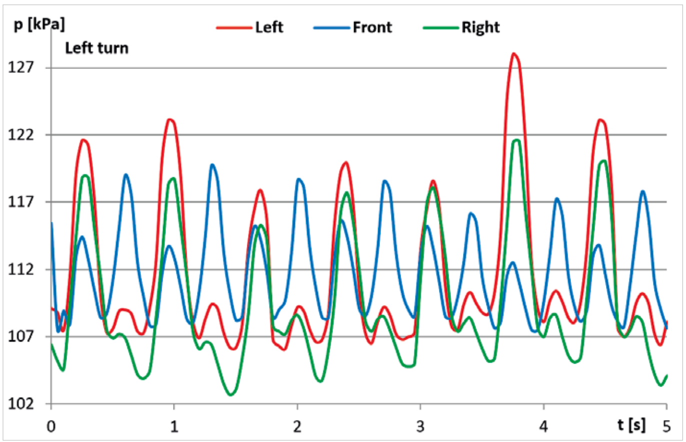

Fig. 4. The course of pressure changes in the pads in rising trot (left turn)

The front load when driving to the right turned out to be equal, both when loading and unloading the saddle. Smaller differences were also recorded in the pressure value between the left and right sides of the back, although in this case the data also indicate slightly stronger pressure on the left side. A similar tendency was observed when unloading the saddle, where the pressure oscillated around similar values – Figure 5.

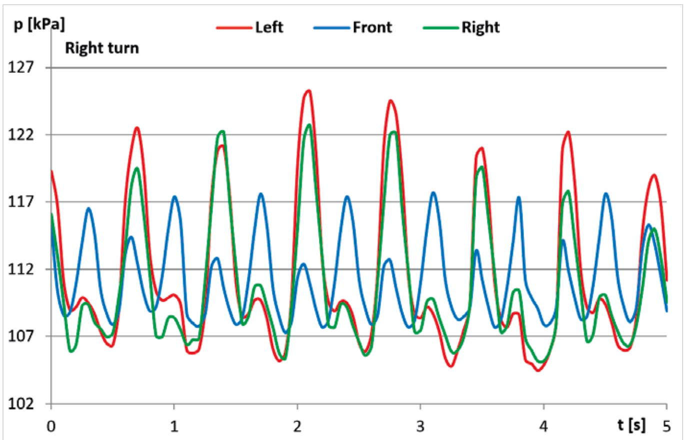

Fig. 5. The course of pressure changes in the pads in rising trot (right turn)

When riding straight in a sitting trot, the load on the front was the least varied. The pressure in the airbags, although not maintained at the same level, did not exceed 117 kPa, and when the saddle was unloaded it dropped below 107 kPa. The load on the right side turned out to be uneven during individual steps, which indicates the rider's balance disorders in this gait. This is confirmed by the significantly greater and irregular pressure on the left side of the horse's back – Figure 6.

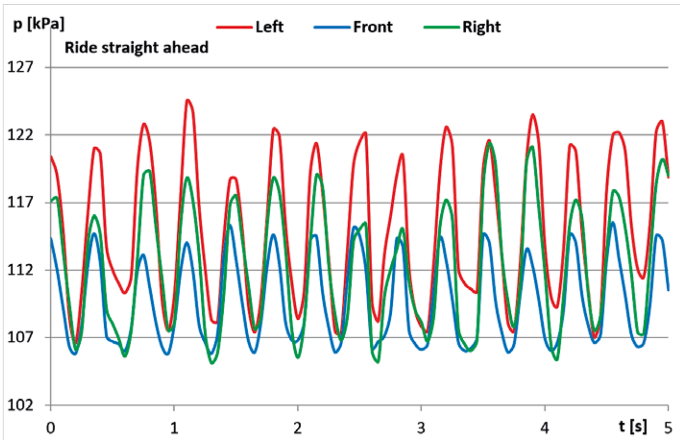

Fig. 6. The course of pressure changes in the pads in sitting trot (ride straight ahead)

The load during sitting trot to the left turned out to be even more asymmetric than when riding straight. Quite a large irregularity of the pressure on the front part of the horse's back was found. The pressure on the left side of the horse's back, in the case of most of the recorded steps, was significantly stronger and exceeded 122 kPa. The load on the right side was also very diverse, and large discrepancies in pressure were found between individual steps – Figure 7.

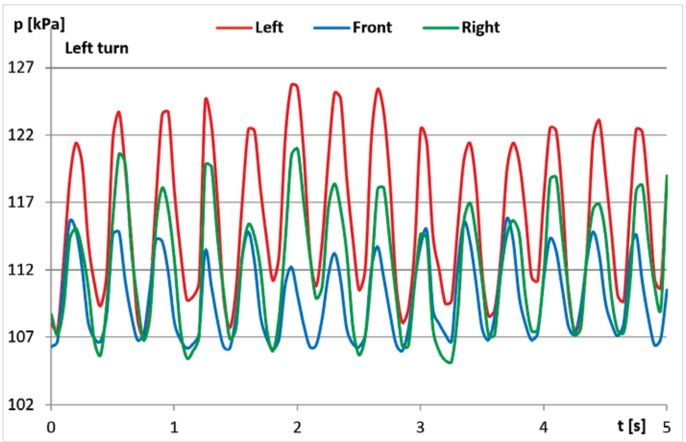

Fig. 7. The course of pressure changes in the pads in sitting trot (left turn)

A similar tendency was noted when the horse moved to the right, although in this case the differences between the pressure values in the pads on the left and right side of the horse's back were not as large as when moving to the left. The graph shows that when riding to the right, the rider also put a little more weight on the right side of the back, which reduced the difference in the load on both sides. The pressure values reflecting the pressure on the front part of the saddle were similar to those recorded when driving to the left – Figure 8.

The front load when riding straight was relatively regular and did not exceed 112 kPa. However, during this gait differences in pressure on the left and right sides of the horse's back were also noted. On the left side, during each foul, the pressure was above 122 kPa,

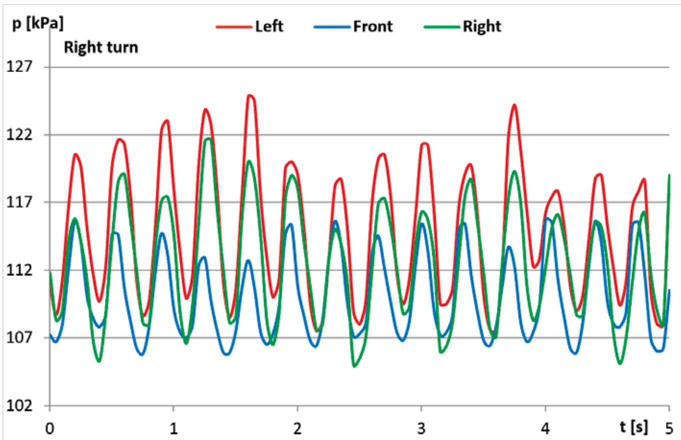

Fig. 8. The course of pressure changes in the pads in sitting trot (right turn)

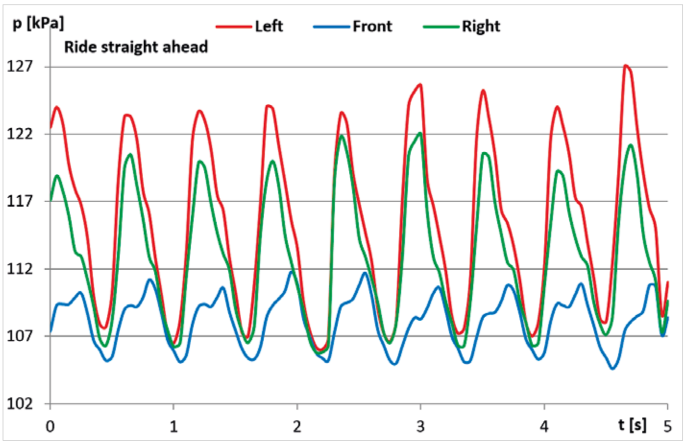

Fig. 9. The course of pressure changes in the pads in canter (ride straight ahead)

while on the right side, in only two cases it reached the level of 122 kPa, and in the remaining cases it was below this value – Figure 9.

Cantering to the left was also characterized by a greater load on the left side of the back, at a level exceeding 122 kPa. The pressure recorded on the right side, as in the case of riding straight, did not exceed this level. The pressure values on the front part of the back were also not even and at some steps they approached the level of 112 kPa – Figure 10.

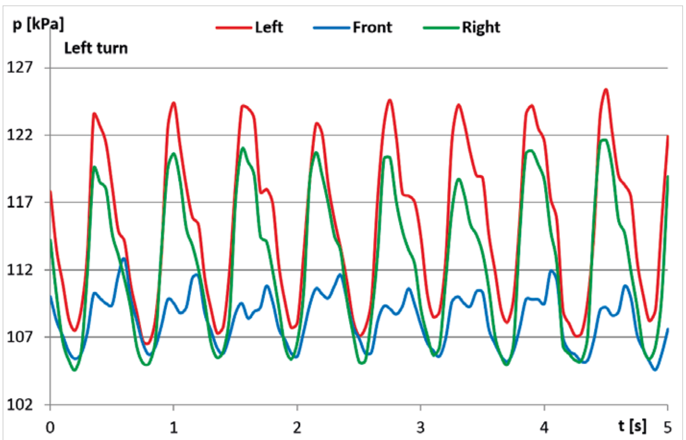

Fig. 10. The course of pressure changes in the pads in canter (left turn)

The greatest pressure differences between the pressure on the left and right sides of the back were recorded when galloping to the right. The graph shows that the rider put more strain on the left side of the body than in turns to the left, and the pressure values reached even 127 kPa and above. In turn, on the right side of the back, the pressure was visibly weaker (Fig. 11) than that observed in the gallop to the left. The front load was below 112 kPa and was more or less even.

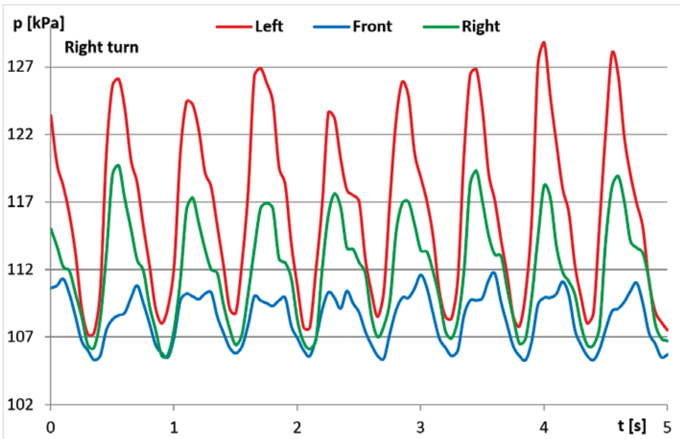

Fig. 11. The course of pressure changes in the pads in canter (right turn)

The results of preliminary research have shown that it is possible to control the quality of the rider's seat and determine its parameters based on measurements carried out using the proposed system. The analysis of the presented sample time series shows that the rider does not sit symmetrically in the saddle, putting more strain on the left side of the body. We can also notice (as expected) that there is a change in the distribution of the rider's body weight when riding in corners – in this particular case, there is a noticeable change in the load on the right side of the body with simultaneous slight changes in the load on the left side, which confirms the asymmetry observed when riding straight. There is also a noticeable change in the weight distribution between the front and back depending on the type of gait and seat. In the case of trotting, a much greater load on the front of the saddle can be observed than in canter. Additionally, in rising trot there is a clear relief of the rear end every second step.

Due to the innovative nature of the test performed, there are no studies on the discussed issue in the available literature. Research on the load on the horse's back and the stability of the rider's seat, conducted by Peham et al. (11), on a treadmill simulator, concerned only trotting, where the horse only moved straight ahead. Therefore, it is impossible to compare the obtained results with those obtained by the cited authors. In another study, Peham et al. (12) reported, however, that horse riding skills influence the stability of movement of the horse and rider, and their improvement is the subject of the presented research, which will be continued on a broader scale.

Based on the results obtained, it seems reasonable to introduce physical exercises with a personal trainer aimed at improving the flexibility of the rider's seat (5). It is common knowledge that work on strengthening specific muscle groups, stretching exercises and appropriate physiotherapy significantly contribute to improving relaxation and balance in the saddle, which in turn translates into increasing the physical and mental comfort of the mounted horse (6).

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