

Analysis of work intensity in draft horses based on the heart rate recovery index

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Summary

So far, no tests have been developed for draft horses to measure their exertion rate. In our study, the heart rate regeneration index was used for the first time to assess the exertion and fatigue of draft horses. A pair of horses was pulling a cart with 12 tourists + a coachman with a total weight of about 1580 kg. The 7-kilometre part the road is uphill in 82%, with an average slope of 4.6%. The control examination of heart rate was performed on horses before transporting tourists, immediately after work and after 10 minutes of rest. The analysis of the horses' exertion was calculated on the basis of the recovery index, according to the formula $(t_2 - t_3/t_2 - t_1) \times 100\%$, where t_1 denotes the initial heart rate (before exercise), t_2 – heart rate immediately after exercise, t_3 – after 10 minutes of rest. The following scale of exertion assessment was adopted: group I recovery index < 20% – very heavy exertion (long regeneration), group II – recovery index 20.1-50% – heavy exertion, group III – recovery index 50.1-80% – moderate exertion, group IV – recovery index > 80.1% light exertion. Based on the analysis, it was found that the horses' exertion was: very heavy for 3.3% of horses, heavy for 50%, moderate for 44.8% and light for 1.9% of horses. For about 58% of the horses pulling the carts with full load, this work was a much greater effort compared to the control trials, when the horses pulled „empty” carts without passengers in 2019 ($P < 0.001$). The degree of exertion (fatigue) was the same for horses with a slow pace (76.1 min) and for horses that covered the route at a faster pace (67.6 minutes). The heart rate recovery index is a simple and non-invasive measure of exertion (fatigue) of horses and their adaptation to the work performed and can be used both to assess the preparation of horses for work and their welfare.

Keywords: draft horses, work intensity, recovery index, heart rate

Lake Morskie Oko, located in the Tatra mountains in Poland at the altitude of 1400 m above sea level, is one of the most beautiful mountain lakes in Europe and is surrounded by unique scenery. Unsurprisingly, it attracts crowds of tourists, with about 10 thousand people visiting this magical spot on days with favourable weather. For environmental reasons, the last 8 kilometres of the route must be covered on foot or by a horse-drawn carriage. Out of this stretch of winding asphalt road, 82% has an average slope of 4.6%, while the steepest slope reaches 9.3%. On foot, this distance requires about 2 h 20 minutes. By horse-drawn carriage it takes about one hour. The ride in a carriage pulled by a pair of horses is a huge treat that attracts not only families with children and one-day hikers, but also seasoned tourists, who want to save some energy for a further trek that will take them to some of the surrounding peaks (Fig. 1).

With the welfare of the horses in mind, horse transport on this route is closely supervised by the Tatra National Park. Before each summer season, the horses working



Fig. 1. Horse transport to Lake Morskie Oko in the Tatra mountains in Poland

here undergo obligatory medical checks conducted by experienced equine veterinarians. The owners and carriage drivers have to obey regulations, including the following rules:

- on the way up the slope, a pair of horses can pull a carriage with no more than 12 passengers, and a horse belonging to one owner can work only 15 days per month,

- horses over 4 but less than 5 years old can only work on one full ride (up and down) per day,
- after finishing a ride horses get unlimited access to water and if necessary are allowed to drink also at a horse drinker on the route,
- carriage drivers are not allowed to speed up the horses, horses pull the carriage only at a walk, trotting is possible only on a short section of the route; moreover, the trot must not result from rushing the horses,
- after each ride uphill the horses must be allowed to rest for at least 20 minutes, after a full “up and down” course they must rest for 2 hours,
- carriage drivers are obliged to participate in annual training sessions in horse management and husbandry, conducted by specialists.

Despite these regulations and health checks, allegations have been made that carrying tourists to Morskie Oko exceeds effort capacities of the horses. In equestrian sports, depending on the discipline, horses are professionally selected and prepared for the competition. The assessment of their physical capacity is checked on artificial treadmills with electronic speed control, and with the help of specialized equipment connected to the animals, their physiological parameters and the level of training are assessed. However, so far no tests have been developed to measure the level of exertion of draft horses and their fatigue is based only on subjective feelings. According to specialists in sports medicine, the most important element of the assessment of intensity of effort and level of physical fitness is registering physiological parameters during and after the effort, as well as measuring the pace of restitution, i.e., returning to the initial values (1, 2, 8, 9).

In our research the recovery index (RI) was used for the first time to assess the post-effort recovery efficiency in horses (5, 6). The recovery index (RI), which is widely used in human exercise physiology, informs about heart rate recovery rate and is presented as the percentage of heart rate recovery in a specific number of minutes after the effort. RI depends on exercise intensity and physical fitness of the subject. Low index heart rate recovery indicates either hard work (poor adaptation to effort) or poor fitness.

The aim of this study is to summarise the research on the use of the heart rate RI to assess the fatigue and welfare of draft horses working on the route to Morskie Oko in the years 2019 and 2021.

Material and methods

Draft horses work intensity analysis. The tests performed on 11-13 June and 7-8 July 2021 and involved 267 horses pulling carts specially adapted for carrying passengers (Fig. 1). During each ride there were 12 passengers in the carriage (6). Moreover, the analysis included tests carried out on 2 June and 6 July 2019, in which 64 horses pulled empty carts (with no passengers) (5).

The horses belonged to 60 owners from nearby villages. Just before going on the route, the horses underwent clinical and orthopedic examination by the first veterinarian. The

second vet took the heart rate. Immediately after the arrival of the cart, another veterinarian checked the post-effort HR and then the HR recovery after a 10-minute rest. The heart rate was measured by auscultation with a stethoscope placed over the heart, for 30 sec for calm and 60 sec for skittish horses where approaching the examiner caused a temporary increase in HR.

In long-distance horse races, it is assumed that in cases where the heart rate does not exceed 150 bpm, the horse's effort is at the aerobic level, and in such cases, 5-10 minutes after the end of the exertion, the heart rate should not exceed 64 bpm (2, 4). In our research, in all horses working on the route to Morskie Oko, the post-exercise (immediately after finishing work) heart rate did not exceed 130 bpm, so it was carried out under aerobic conditions and based on the set numbers for horses competing in long-distance races, the post-exercise measurement of heart rate was set to occur after 10 minutes of restitution for work horses.

The analysis of heart rate recovery was performed on the basis of RI according to the formula $(t_2 - t_3/t_2 - t_1) \times 100\%$, where t_1 – resting (pre-exertion) HR, t_2 – heart rate immediately after exertion, and t_3 – after the 10 minutes of recovery. Taking into consideration body mass and physiological resting heart rate of horses as well as the time of post-exertion HR check (10 min), the following interpretation of the RI was adopted:

- group I – RI < 20% – very heavy exertion (long recovery),
- group II – RI 20.1-50% – heavy exertion,
- group III – RI 50.1-80% – moderate exertion,
- group IV – RI > 80.1% – light exertion.

In 2021 there were 268 draft horses, including 98% geldings and 2% mares, aged 8.9 ± 3.0 year with weight in the range of 560-680 kg. The majority of horses (54%) belonged to the Silesian breed (Polish warmblood), Polish Half-bred constituted a smaller proportion (17%), the remaining horses were heavy type/coldblood horses or crosses of unknown breed.

On the basis of a general examination as well as an orthopedic exam it was decided that all horses met physiological norms and were fit for draft work. However, it was pointed out that several horses were obese and had excessive adipose tissue. During heart activity checks, two horses were eliminated due to excessive nervousness resulting from proximity of other horses, which led to increased heart rate. In the remaining horses no distinct reactions deviating from the norm were observed.

Statistical analysis. The statistical significance of the influence on the horse's heart rate of such factors as: the horse's exertion level (belonging to the exertion group: GI – very heavy exertion, GII – heavy exertion; GIII – moderate exertion; GIV – light exertion), the filling of the cart, and the heart rate in relation to the degree of exercise (T1 – resting heart rate, T2 – exercise and T3 – restitution/recovery after 10 minutes), were studied using a three-way analysis of variance. On the other hand, the statistical significance of the influence on the value of the recovery index (RI) (such as: the degree of horse's exertion (belonging to the G1-G4 exertion group), and the filling of the cart was investigated using a two-way analysis of variance. In both cases, the significance of differences between groups were determined post hoc by Tukey's test (for $P < 0.05$). Analyses were performed using the Sigma Stat 3.5 statistical program (SoftStat).

Results and discussion

Horses' physiological response to exertion. Mean baseline heart rate (pre-exertion) was 40.0 ± 5.0 beats/min, while just after finishing work it was 91.0 ± 7.0 beats/min, with variations from 52 to 128 beats/min. This meant that all horses ended their work at the level of aerobic exertion. Mean post work heart rate measured 10 minutes after finishing the ride was 65.2 ± 8.7 beats/min. The average RI calculated on this basis for all horses was 50.6%, which places it at the lower border of moderate effort/.

On the basis of the accepted scale of effort, the horses were divided into 4 groups: 9 horses (3.3%) were qualified to the first group – very heavy exertion (long recovery). Out of 9 (3.3%), 4 worked in the first season and 2 worked in the same pair. Unfortunately, it was not possible to obtain reliable information about the pre-season preparation of horses for carriage work on the route to Morskie Oko. In 2019, out of 10 (3.4%) horses qualified for group I (5), in 2021, 6 of them were still working on the route to Morskie Oko. In 2000, due to the coronavirus pandemic, horse-drawn tourist transport to Morskie Oko was stopped. It can therefore be assumed that many horses were insufficiently adapted to work in mountainous terrain at the beginning of the tourist season. Such a very low value of RI should raise a red flag, as it shows that the effort was too big for a given horse and the animal should undergo detailed observation and diagnostics. 134 horses (50.0%) were qualified for group II (heavy exertion). Although for these animals the level of tiredness was not alarming, they need more attention and better preparation for work in the mountains, as the RI indicates that their organisms have not been sufficiently prepared for this kind of work. Group III (moderate exertion) consisted of 120 horses (44.8%) and group IV (light exertion) of 5 horses (1.9%), which means that for 46.7% of horses this work constitutes moderate or light exertion (Tab. 1).

Many factors not connected with exertion/effort can affect the level of tiredness of draft horses, e.g.,

badly matched pairs. If a horse with a long stride is put in a pair with a horse with a short stride, both of them will be nervous and will exert too much energy. Another reason for lower exertion capacity (RI) can be asymptomatic illness, pain, incorrect shoeing, badly fitting harness, etc.

A comparison of the exertion of horses pulling a fully loaded carriage as opposed to an empty carriage. The level of fatigue is to a large extent connected with the weight of the pulled carriages. According to Kolstrung's calculations (3) a carriage designed for carrying tourists to Morskie Oko weighs approximately 540 kg, while the driver accounts for about 80 kg, which means that on the way up with an empty carriage, a pair of horses pulls 620 kg, while with the maximum number of passengers the burden amounts to about 1580 kg (carriage + driver + 12 passengers), which is 960 kg more.

A comparison of the level of exertion of horses pulling a carriage without passengers in 2019 (5) and with 12 passengers, which is the maximum number allowed, in 2021 (6), demonstrated that the effort with full load for 3-4% of horses in the analysed years was very intense, regardless of whether they were pulling a carriage with a full load of 12 passengers or one without passengers. Out of 3 horses in this group, pulling an empty cart, 2 of them were still working on the route to Morskie Oko in 2021. On the other hand, in the second category – heavy effort, there were 30% more horses pulling a carriage with full load than ones pulling an empty carriage. In groups III and IV (moderate and light exertion) there were 28% more horses pulling an empty carriage (Tab. 1).

Statistical analysis showed that the value of the RI depended on the degree of effort of the horses ($P < 0.001$), not the load on the cart ($P = 0.527$). However, interactions between these factors were noted ($P < 0.001$). This means the evaluation of the horses' exertion, and thus the classification to particular effort groups, on the basis of the value of the recovery index (RI) is justifiable. The increase in the RI value followed a decrease

Table 1. Values of heart contractions (mean $\pm$ SD) and the recovery index (RI) of work horses transporting tourists in the Tatra National Park depending on the load on the cart and the scale of exertion

Vehicle loading (N horses)	RI (%)	Exertion	Group	N (%)	Heart rate (beats/minute)			Recovery index (RI) % $\pm$ SD
					T1- resting	T2-exertion	T3-restitution, after 10 minutes	
A ride with full load passengers in 2021 (268)	< 20	very heavy	I	9 (3.3)	39.3 ± 3.46^{ab}	85.3 ± 9.22^{gh}	78.2 ± 7.71^g	2.0 ± 15.90^i
	20.1-50.0	heavy	II	134 (50.0)	39.1 ± 4.55^{ab}	90.8 ± 11.88^h	69.3 ± 7.59^f	39.9 ± 7.66^k
	50.1-80.0	moderate	III	120 (44.8)	40.8 ± 5.21^b	92.0 ± 11.05^h	60.1 ± 6.25^d	64.0 ± 8.83^d
	> 80.1	light	IV	5 (1.9)	44.0 ± 0.00^{bc}	84.5 ± 6.19^{gh}	51.0 ± 2.58^{cd}	102.9 ± 16.20^n
A ride without passengers in 2019 (64)	< 20	very heavy	I	3 (4.7)	46.0 ± 8.72^c	79.7 ± 4.51^g	79.3 ± 1.16^g	15.5 ± 5.27^j
	20.1-50.0	heavy	II	13 (20.3)	39.8 ± 3.16^{ab}	77.6 ± 9.71^g	62.0 ± 7.50^e	41.3 ± 7.82^c
	50.1-80.0	moderate	III	36 (54.7)	37.8 ± 4.95^a	80.0 ± 12.05^g	53.2 ± 6.17^d	62.4 ± 8.02^l
	> 80.1	light	IV	13 (20.3)	45.2 ± 6.95^c	73.8 ± 13.95^{gh}	45.3 ± 8.33^c	84.5 ± 4.34^m

Explanations: a, b, c, d, e, f, g, h – heart rate (HR) values marked with different letters differ statistically significantly ($P < 0.05$); i, j, k, l, m, n – values in the Recovery index (RI) column marked with different letters differ statistically significantly ($P < 0.05$)

in the degree of exercise (fatigue) of the animal (from the GI to GIV exercise group), regardless of whether the animals were pulling the cart full or empty. Despite this trend, the degree of vehicle load had an impact on the Recovery index (RI) in the GI and GIV exercise groups. Thus, for an empty car and with a full set of passengers, respectively (Group GI), the value of this coefficient in the case of horses with very strenuous exertion was 2.0 ± 15.90 and $15.5 \pm 5.27\%$ ($P = 0.016$), and with a very light effort (group IV) 102.9 ± 16.20 and $84.5 \pm 4.34\%$ ($P < 0.001$). However, such differences were not found in the case of horses with medium (GII) ($P = 0.612$) and moderate exertion (G3) ($P = 0.318$) (Tab. 1).

Statistical analysis confirmed that the number of heartbeats depends not only on the belonging to the exertion group ($P < 0.001$), the load on the cart ($P < 0.05$) and the heart beat rate associated with the exercise phase ($P < 0.001$), but also showed significant mutual interactions between these factors ($P < 0.001$) (Tab. 1). The exercise heart rate (T2) was on average two times higher than the resting heart rate ($P < 0.001$). Yet, the average value of this parameter for horses towing an empty cart ranged between 73.8 and 80.0 beats a minute ($P = 0.373$), while for horses towing a full cart it ranged between 84.5 and 92.0 beats/minute ($P = 0.576$)., in both cases the extreme values were related to the GIV (low effort/fatigue) and GIII (moderate effort/fatigue) groups, respectively. This means that in individuals towing a full cart, the value of this parameter was higher by about 13% (10.4 beats/minute) compared to those towing empty carts ($P < 0.001$) (Tab. 1). The frequency of heart contractions during restitution/recovery (T3) decreased by about 1/3 compared to the exertion one ($P < 0.001$), and on average in the group of horses towing an empty and full cart it was 60.1 ± 10.09 and 64.7 ± 8.775 beats/minute, respectively ($P = 0.006$). However, in the group of slightly tired horses (GIV), this value decreased to the level of the resting heart rate, both in the case of empty cart pulling (45.3 ± 8.33 beats/minute; $P = 0.994$) and full cart pulling (51.0 ± 2.58 beats a minute; $P = 0.225$). However, in the case of severely tired horses (group GI), it was found that the value of this parameter was still at the level of the exertion heart rate (79.3 ± 1.16 and 78.2 ± 7.71 beats/minute) (Tab. 1).

The presented calculations imply that for about 58% of horses pulling a fully loaded carriage constituted a heavy effort and it was not easy for the cardiovascular system of these animals to return to the pre-exertion state. However, it must be noted that the long break from work caused by the pandemic in 2021 may have affected the level of fitness of the horses and their adaptation for draft physical work.

The effect of travel time on the level of fatigue of draft horses. With animal welfare in mind, horses working on the 7.3 km route to Morskie Oko on the way up can pull the carriage only at a walk. Trotting is allowed only on a short section of the road, with the ca-

veat that trotting cannot result from rushing the horses. The average travel time measured by us for 74 carriages (148 horses) with a full load was 70.7 ± 4.3 min, with the difference between the slowest and the fastest ride amounting to 22 minutes.

In order to compare the tiredness of horses travelling fast and slowly, the horses were divided into two groups. The first group comprised 78 horses which covered the route in the average time of 67.6 ± 2.6 (fast pace) while the second group consisted of 70 horses with the average time of 76.1 ± 3.0 min, that is 10 minutes longer (slow pace). The calculation of the RI demonstrated that the level of tiredness was the same for the two groups. Thus we can assume that the speed with which the horses were travelling on that route was an effect of the horses self-regulating their pace and adjusting it to their capabilities (6).

Conclusions:

1. The exertion of horses working in mountainous terrain, analyzed with the use of the RI index, was very varied. For 3.3% of the horses it was a very high exertion, for 50.0% it was high, for 44.8% moderate and for 1.9% light ($P < 0.001$).

2. The degree of vehicle load had an effect on the Recovery index (RI). In the second category – heavy exertion, there were 30% more horses pulling a carriage with full load than ones pulling an empty carriage. In groups III and IV (moderate and light exertion) there were 28% more horses pulling an empty carriage.

3. The heart rate recovery index (RI) is a simple and sensitive measure of the degree of exertion (fatigue) in horses and can be used in all field conditions. In order to obtain information on the adaptation of horses to the work performed and on their welfare, the RI tests should be repeated periodically.

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