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Connections between the heart rate and selected motor and biometric parameters in young half-bred stallions

Powiązania między tętnem a wybranymi parametrami ruchowymi
i biometrycznymi młodych ogierów półkrwi

Summary. The study concerned 345 half-breed stallions maintained at Training Centres in 2001–2003. The study was performed three times, and it consisted in heart rate recording and stallion's pace length measurements. Riders passed a determined distance nine times (three replications of walk, trot, and gallop). In addition, 114 biometric measurements were made, the results from which were listed in complex indices referring to: body, chest, front, and rear legs. Significant connections between the heart rate and body dimensions as well as pace length in trot and gallop occurred at the end of the training cycle. Inter-relations in the heart rate in particular paces were also recorded: between walk and trot (whole training cycle), walk and gallop, trot and gallop (2^{nd} and 3^{rd} phases), as well as between studies: in walk (within 2^{nd} and 3^{rd} phases), as well as trot and gallop (all phases). Basing on the correlations, six ways of comparative estimation of half-bred stallion's heart rate were established taking into account: a single phase of training cycle – on the basis of the heart rate in all paces, or the whole training cycle – on the basis of the heart rate in a single pace.

Key words: half-bred stallions, training centers, heart rate

INTRODUCTION

Assessment which the half-bred stallions are subjected to during the 100-day test, should be maximally detailed and objective [Kownacki *et al*. 1993, Chrzanowski and Łojek 2001, Kaproń *et al*. 2003a, 2003b, 2003c]. It should be focused upon the analysis of the performance predispositions and on the other hand, upon more „general" features associated, among others, with character [Budzyński and Sołtys 1989], fodder utilization and health [Szarska 1990, Barrey *et al*. 1993, Szarska 1994]. They are all extremely important in professional and reproductive exploitation of stallions [Kownacki *et al*. 1993].

The heart rate analysis is a reliable and one of the simplest tests that allows collecting information on the horse's health and evaluating the level of its physical efficiency and reaction towards training [Czajkowski 1961, Novikov 1994, Kaproń *et al*. 2000]. However, the heart rate greatly depends on a spectrum of outer factors, which was confirmed in earlier studies [Kaproń *et al*. 1996a, 1996b, Kaproń *et al*. 1997]. A possibility to eliminate or take into account those factors along with optimum simplification and reduction to a strictly necessary and reliable heart rate analysis should contribute to use that method in all forms of horse utility.

The present study is a continuation of earlier publication cycle concerning the parameters of half-bred stallions' training progress [Kaproń *et al*. 2003b, 2003c, Kaproń *et al*. 2004]. The study aimed at evaluating the dependence between exercise heart rate (measured during three basic pace types) vs. biometric parameters and motor efficiency, as well as elaborating methods of comparative assessment of stallions on the bases of their heart rate in consecutive 100-day test stages.

MATERIAL AND METHODS

The study concerned 345 half-bred stallions maintained at Training Centres in 2001–2003. Studies during the riding trainings were carried out in three replications system. Their terms fell on the end of the first (stage I), second (stage II) and third (stage III) month of training prior to the performance tests. During each observation, riders passed 30 m way marked out along the longer wall of manege nine times. The way was passed three times in walk, three times in trot and three times in gallop. Every pace rate was increased in consecutive phases: walk 1 – 120 m/min, walk 2 – 130 m/min, walk 3 – 140 m/min, trot 1 – 200 m/min, trot 2 – 220 m/min, trot 3 – 230 m/min, gallop 1 – 300 m/min, gallop 2 – 320 m/min, gallop 3 – 350 m/min. During the training, the stallion's heart rate was measured using telemetric devices (type – S610, POLAR). Synchronizing the heart-rate-meter receivers with manual timers allowed monitoring the stallion's heart rate during the effort (computer analysis applying Polar Precision Performance software). Taking into account three replications for every pace, the heart rate was presented as mean value for walk, trot, and gallop. In addition, the measurements of 5-steps length for each pace were made (using measuring tape), which enabled presenting a mean value of that parameter (mean walk, trot, and gallop lengths).

Biometric assessment consisted of the following measurements [Kaproń *et al*. 2004]:

– upper body section – height at withers (1), height at back (2), height at croup (3), and dock (4) – defining the „upper body parts" indicator aiming at summarized estimating the body upper line, namely „whitering" as:

WGPK = 1 + [(1 – 2) + (1 – 3) + (1 - 4)],

– chest – chest depth (1), chest circumference (2) – defining the „chest" indicator giving additional information on chest volume as:

WKLP = 1 + 2,

– front leg – shoulder length (1), arm length (2), forearm length (3), front cannon length (4) – defining „front leg" indicator as:

WKP = 1 + 2+ 3 + 4,

– rear leg – croup length (1), distance between hip-joint and knee-joint (2), distance between knee-joint and ankle-joint (3), length of rear cannon (4) – defining „rear leg" indicator as:

WKT = 1 + 2 + 3 + 4.

The data were statistically processed (mean, min., max., standard deviation – SD, variability coefficient – V). The significance of differences between mean values was calculated using t-Student test and the dependencies were evaluated by means of simple correlation coefficients.

RESULTS

As an introduction, general information on statistical characterization of analyzed parameters, detailed values of which were discussed in earlier publication, was given [Kaproń *et al*. 2004].

The stallions' heart rate analysis during particular paces (Tab. 1) revealed that for walk, the lowest value was recorded after the first training month. In its second and third stage, the heart rate exceeded 80 beats per minute. Statistically significant differences between subsequent examinations were found.

Table 1. Statistical characteristics of studied stallion's heart – rate during walk. trot. and gallop
Tabela 1. Statystyczna charakterystyka tętna badanych ogierów w trakcie stępa. kłusa i galopu

Statistical measures Miary staty-styczne	Test 1 Badanie 1			Test 2 Badanie 2			Test 3 Badanie 3		
	walk stęp	trot kłus	gallop galop	walk stęp	trot kłus	gallop galop	walk stęp	trot kłus	gallop galop
Mean Średnia	76.59 **AB**	113.85 **A**	145.00 **aB**	84.50 **Ac**	113.81 **B**	143.16 **aC**	82.51 **Bc**	111.31 **AB**	140.22 **BC**
Min.	67.67	66.67	108.00	78.88	72.33	112.33	58.33	87.33	105.33
Max.	130.33	148.00	184.67	129.67	153.67	179.00	129.00	147.00	193.00
SD	14.91	14.99	17.52	12.40	11.34	15.60	11.28	10.30	13.96
V	19.47	13.16	12.09	14.67	9.96	10.90	13.67	9.26	9.95

Means (at walk, trot, gallop) marked with the same letter differ: at $P \leq 0.05$ small letters, $P \leq 0.01$ capital letters (at tab. 1–2)
Średnie w obrębie danego chodu oznaczone tymi samymi literami różnią się istotnie przy: $P \leq 0{,}05$ małe litery; $P \leq 0{,}01$ duże litery (dotyczy tab. 1–2)

In the case of trot, the value was from 113.85 (stage I) to 111.31 beats per minute (stage III), with gradual decreasing during the training cycle. Similar situation was observed in gallop: the difference between mean values recorded at the first and third observations was almost 5 beats per minute. The variability coefficient (V) was at its average level that did not exceed 20%. Decrease of the heart rate during subsequent measurements might indicate some stabilization of stallion's physiological efficiency in Training Centres [Czajkowski 1961, Kaproń *et al*. 2004].

Table 2. Statistical characteristics of analyzed biometric indices and motor parameters of studied stallions
Tabela 2. Statystyczna charakterystyka analizowanych wskaźników biometrycznych i parametrów ruchu badanych ogierów

Statistical measures Miary statystyczne	Biometric measurements Wskaźniki biometryczne				Test 1 (step length) Badanie 1 (długość kroku)			Test 2 (step length) Badanie 2 (długość kroku)			Test 3 (step length) Badanie 3 (długość kroku)		
	WGPK	WKLP	WKP	WKT	stęp walk	kłus trot	galop gallop	stęp walk	kłus trot	galop gallop	stęp walk	kłus trot	galop gallop
Mean Średnia	187.66	260.04	171.16	219.15	192	288	333	190	290	327	190	297	312
Min	168.00	229.00	159.00	169.00	152	210	259	153	192	186	103	193	185
Max	282.50	284.00	189.00	258.00	271	356	439	227	564	418	248	428	476
SD	9.20	16.20	9.29	14.50	0.15	0.24	0.26	0.13	0.30	0.29	0.16	0.32	0.51
V	4.90	6.23	5.43	6.62	7.86	8.29	7.68	6.91	10.38	8.78	8.46	10.64	16.38

Table 3. Straight correlation coefficients between heart – rate and biometric indices of studied stallions

Tabela 3. Zestawienie współczynników korelacji prostych między tętnem a wskaźnikami biometrycznymi badanych ogierów

Biometric indices Wskaźniki biometryczne	Test 1 Badanie 1			Test 2 Badanie 2			Test 3 Badanie 3		
	walk stęp	trot kłus	gallop galop	walk stęp	trot kłus	gallop galop	walk stęp	trot kłus	gallop galop
WGPK	0.089	-0.034	-0.020	-0.097	-0.020	-0.069	0.013	-0.019	-0.057
WKLP	-0.011	-0.036	-0.027	-0.016	0.042	0.010	-0.053	-0.012	-0.113 *
WKP	-0.006	0.007	0.004	-0.062	0.073	0.024	-0.114 *	-0.002	-0.066
WKT	0.074	0.039	0.031	-0.001	0.080	0.022	-0.040	-0.076	-0.173 *

Correlation coefficient significant at: * $P \leq 0.05$; ** $P \leq 0.01$ – (at tab. 3–6)
Współczynniki korelacji istotne przy: * $P \leq 0{,}05$; ** $P \leq 0{,}01$ – (dotyczy tab. 3–6)

Table 4. Straight correlation coefficients between heart – rate and motor parameters of studied stallions

Tabela 4. Zestawienie współczynników korelacji prostych między tętnem a parametrami ruchu badanych ogierów

Step length Długość kroku		Test 1 Badanie 1		
		walk stęp	trot kłus	gallop galop
Test 1 Badanie 1	walk stęp	-0.097	-	-
	trot kłus	-	-0.057	-
	gallop galop	-	-	-0.010
Step length Długość kroku		Test 2 Badanie 2		
		walk stęp	trot kłus	gallop galop
Test 2 Badanie 2	walk stęp	-0.120	-	-
	trot kłus	-	0.002	-
	gallop galop	-	-	0.020
Step length Długość kroku		Test 3 Badanie 3		
		walk stęp	trot kłus	gallop galop
Test 3 Badanie 3	walk stęp	-0.024	-	-
	trot kłus	-	0.138 *	-
	gallop galop	-	-	0.245 **

Table 5. Straight correlation coefficients between stallion's heart – rate during particular pace of a given test
Tabela 5. Zestawienie współczynników korelacji prostych między tętnem ogierów w poszczególnych chodach danego badania

Pace Chód	Test 1 Badanie 1		Test 2 Badanie 2		Test 3 Badanie 3	
	trot kłus	gallop galop	trot kłus	gallop galop	trot kłus	gallop galop
Walk Stęp	0.247 *	-0.055	0.495 **	0.494 **	0.564 **	0.464 **
Trot Kłus	-	-0.055	-	0.647 **	-	0.542 **

Table 6. Straight correlation coefficients between stallion's heart – rate at a given pace during subsequent studies
Tabela 6. Zestawienie współczynników korelacji prostych między tętnem ogierów w danym chodzie podczas kolejnych badań

Test Badanie	Walk Stęp		Trot Kłus		Gallop Galop	
	test 2 badanie 2	test 3 badanie 3	test 2 badanie 2	test 3 bada- nie 3	test 2 badanie 2	test 3 badanie 3
Test 1 Badanie 1	0.128	-0.048	0.279 **	0.252 **	0.433 **	0.307 **
Test 2 Badanie 2	-	0.562 **	-	0.521 **	-	0.557 **

Referring to motor efficiency, the steps in walk and trot remained at similar lengths (Table 2). Changes were observed only in *foulee* length, that decreased during subsequent examinations. The V indicator was low exceeding 15% only in gallop *foulee* length at the end of training. No statistically significant differences between mean values within particular pace types were recorded.

Table 2 also contains statistical characterization of the proposed biometric indicators. A low variability within the results is worth underlining. It probably resulted from the requirements for stallions at qualifying to the training centre [Warunki kwalifikacji... 2008]. At the same time, apparent differences between extreme values of particular dimensions indicate the presence of considerable distinctions in their body conformation.

The correlation analysis showed that in the case of heart rate relationship to biometric indices (Tab. 3), statistically significant coefficients were present at the end of the training cycle (stage III). They concerned the negative interaction between heart rate at walk and „front leg" indicator, as well as heart rate at gallop and „chest" and „rear leg" indicators.

A similar tendency was observed in dependencies between the heart rate and pace length (Tab. 4). Statistically significant interactions were recorded also during the last

examination. which included positive correlations between the heart rate and pace length at trot and gallop.

Correlations found in the heart rate at different pace types during particular examinations indicated significant positive dependencies between walk and trot (all stages), walk and gallop (stages II and III) and trot and gallop (stage II and III) (Tab. 5).

The occurrence of positive dependencies within the heart rate recorded at walk in stages II and III, as well as trot and gallop in every stage, was also found (Tab. 6).

The results (Tables 3–6) made possible to determine the way of comparative heart rate assessment in half-bred stallions:

1. During a given stage of the training cycle – considering the heart rate at all three pace types:

X_1 = (heart rate at walk + heart rate at trot + heart rate at gallop).

2. Considering the whole training cycle – on a base of heart rate at one selected pace:

X_2 = (heart rate in stage I + heart rate in stage II + heart rate in stage III).

The following way of the selection of parameters was proposed:

a) if statistically significant positive dependencies between mean values occur – heart rate recorded during one chosen pace is sufficient.

b) in case of dependencies between heart rate at a given pace and biometric indicators and motor efficiency indicators:

– positive dependence – heart rate to the indicator ratio (or indicators sum);

– negative dependence – product of heart rate and the indicator (or indicators sum).

In every case, low value of the heart rate indicator should show a higher advancing level of trained stallion.

On the basis of the presented rules, formulae of comparative indicators for half-bred stallion's heart rate were defined:

Ad. 1:

– stage I

X_1 = (heart rate at walk or heart rate at trot) + heart rate at gallop

– stage II

X_1 = heart rate at walk or heart rate at trot or heart rate at gallop

– stage III

X_1 = (heart rate at walk × WKP) or (heart rate at trot / pace length) or [heart rate at gallop × (WKLP + WKT) / pace length].

Ad. 2:

– on the basis of heart rate at walk:

X_2 = (heart rate in stage I + heart rate in stage II) or [heart rate in stage I + (heart rate in stage II × WKP)]

– on the basis of heart rate at trot:

X_2 = heart rate in stage I or heart rate in stage II or (heart rate in stage III / pace length)

– on the basis of heart rate at gallop:

X_2 = heart rate in stage I or heart rate in stage II or heart rate in stage III × [(WKLP + WKT) / pace length].

DISCUSSION

Problem of the heart rate is the most often analyzed in combination with very intensive exercise. Studies carried out by Barrey *et al*. [1993], Novikov [1994], Szarska [1994], and Kaproń *et al*. [1996b, 1997] provide the results of heart rate at different efficiency tests and during participation at competitions. The studies by Kaproń having been published since 2000, discuss the issue of stallion's efficiency assessments at training centres on the basis of the heart rate [Kaproń *et al*. 2004], as well as analysis of connections among quantitative evaluation features [Kaproń *et al*. 2003c]. However, data contained in these publications are very detailed, thus they can be difficult to analyze, namely by average horse users. They focus on the heart work assessment at each pace and different stages of the training cycle. Instead, there is no studies on stallion's heart rate analyzed on the basis of a selected parameter that should be determined only once. The simplicity of determination should be also taken into account. Wide availability of a method is possible only when it is safe and not invasive. Studies by Szarska [1990] and Kędzierski *et al*. [2007] based on the blood analysis were performed with the use of specialized laboratory equipment, which may make their practical application considerably difficult.

The issue of introducing a complex and quantitative assessment of half-bred stallions at training centers was earlier undertaken by Kaproń *et al*. [2003a, 2003b]. The present study is a continuation and partial summarization of earlier considerations.

CONCLUSIONS

1. Significant dependencies between the heart rate at particular paces indicate the possibility to make a comparative assessment of half-bred stallion's efficiency, based on the heart rate analysis at walk, trot or gallop. Such practice should be applied mainly after completing the initial training stage.

2. At the end of the 100-day test, when assessing the heart rate of the stallions, their biometric and motor efficiency parameters should be taken into account, since they show statistically significant relationships with the heart rate at every kind of pace.

3. The study can be considered as pilot and in future, it should be broadened by analysis of dependencies with many other factors (e.g. the rider's effect, weather circumstances, etc.), that the half-bred stallions are exposed to during the performance test.

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Streszczenie. Obserwacjami objęto 345 ogierów półkrwi, utrzymywanych w Zakładach Treningowych w latach 2001–2003. Badania przeprowadzono trzykrotnie. Polegały na rejestracji tętna oraz pomiarach długości kroku ogierów. Jeźdźcy przejeżdżali wytypowany odcinek dziewięciokrotnie (trzy powtórzenia stępa, kłusa i galopu). Dodatkowo dokonano 14 pomiarów biometrycznych, których wyniki zestawiono w kompleksowe wskaźniki dotyczące kłody, klatki piersiowej oraz kończyny przedniej i tylnej. Istotne związki w obrębie częstości pracy serca z wymiarami ciała i długością kroku w kłusie i galopie wystąpiły dopiero w końcowym etapie cyklu treningo-

wego. Odnotowano także wzajemne relacje tętna między chodami w stępie i kłusie (cały cykl treningowy), stępie i galopie oraz kłusie i galopie (II i III faza); między badaniami w stępie (w obrębie II i III fazy), kłusie i galopie (wszystkie fazy). W oparciu o wyniki korelacji ustalono sześć sposobów porównawczej oceny tętna ogierów półkrwi, uwzględniając jedną fazę cyklu treningowego – na podstawie tętna we wszystkich chodach lub cały cykl treningowy – na podstawie tętna w jednym z wybranych chodów.

Słowa kluczowe: ogiery półkrwi, zakłady treningowe, tętno