REBUILDING AND INSTALLATION OF THE SENSOR HEART RATE MONITOR GARMIN FORERUNNER 305 IN THE HORSE'S SADDLE HARNESS

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Abstract: *For the research the heart rate monitor for humans "Garmin Forerunner 305" was modified to measure the heart rate frequency of a 12-year old stallion during training. In our experience the incorporation of Garmin Forerunner 305 into the saddle harness is much cheaper and equally applicable as the original Polar horse heart rate monitor. Throughout one month's training by the help of the integrated sensor four fitness tests were performed on the same path on which four stations had been determined. There, the horse heart rate, respiration rate and body temperature were measured and the horse's physical fitness monitored. Also the environmental influences were monitored and the correlation between variables at rest (ambient temperature, horse's temperature, relative air humidity, air pressure, heart rate, breathing frequency) was established. The applicability of the rebuilt device for heart rate monitoring was confirmed.*

Key words*: measurements, garmin forerunner, heart rate, horses, training*

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1. Introduction

In the past the horse passed from war implement to sports partner in horse-breeding. The endurance riding is one of the fastest growing disciplines in horse breeding in the world. Though the endurance tests were performed already in the U.S.A. in the middle of 1800, the modern sport endurance riding started in 1955, when the endurance test from Squaw Valley to Nevada in California was organized (160 kilometers in one day). The first endurance contest in Europe took place around 1960 with rules changing from country to country (http://www.ushorse.biz/discipline-endurance.htm). The competitions in endurance riding emphasize the relation between rider and horse. They strive to jointly face the difficulty and overcome the obstacles. They stress correct selection of horse’s tempo and burdening (http://endurance-slovenija.com). The disciplines include: speed races, rule races and long distance races ranging from 30 to 160 km.

A prerequisite for any training is the previously warmed up horse with healthy and attended-to hooves. The basic manner of exercise is intensifying horse training up to the level, where our satisfaction and expectations and the horse’s good feeling meet. The training program should be prolongation of the distance covered with the same hearts rate. This program is shortly (http://www.seraonline.org) called the LSD program (long slow distance). It allows the body to work at the same heart rate without oxygen shortage (aerobic exercise). The training progresses and the heart rate at which aerobic breathing is still possible (Evans, 2000; http://www.amazon.com) is increased (e.g. from 120 to 150 beats/min).

The research was focused on the endurance discipline, where riders with their horses strive to cover a certain distance with as little exhausted horse as possible within the shortest possible time. The research was directed towards horse training and continuous monitoring of heart rate during training. The two main aims of the research were the re-building/installation of the heart rate sensor Garmin Forerunner 305 into the saddle harness and monitoring how the heart rate during the horse’s one month training period varies.

Prior to and during training the daily measurements of air temperature, relative air humidity, air pressure, horse’s body temperature, respiration rate and heart rate were performed. Our target was to establish the dependences between the variables studied. Prior to the beginning of the research three hypotheses were put forward. The first hypothesis was that the mean value of heart rate during training would be lower from week to week. The other hypothesis was that the modified heart rate monitoring device would be as usable and precise as the original one. The last hypothesis was based on the loss of the horse’s body mass during training.

2. Materials and Methods

2.1 Measuring of heart rate, respiration and body temperature at rest

Measurements were performed in the morning before feeding and in the evening before feeding in the horse’s box from 29th May to 30th July 2011. When approaching the horse and before measuring we were relaxed, our motions slow and respiration rate low in order not to excite the horse.

Measurements of the heart rate were performed by means of the stethoscope with low blood pressure and mostly by left-hand finger cushions. We were standing by the horse's left side and felt the artery by left fingers between the gullet and the left neck muscle in the middle of the neck length (somewhere at the fifth neck vertebra). The heart beats were measured during one minute – the results of measurement are the heart beats per minute (Rose & Hodgson, 2000).

Measurements of respiration were performed visually during hard breathing and obvious movement of the thorax and abdomen during breathing. During resting we were standing by the horse's left side in the direction of tail. We put the right hand onto the belly and felt the expansion and contraction during one minute. The measurement result is the number of breaths per minute.

Measuring of body temperature was performed by the body temperature meter Thermoval of "classic" type. Measuring was performed in the box. We were standing by the horse's right side turned against tail. With the right hand we gently pushed the meter with slow semi-circular movements about 5 cm into rectum. Measuring was finished, when the temperature did not rise for more than 0.1 °C within 16 seconds. The result of measurements is the horse's body temperature in °C (Vogel, 2007).

Simultaneously with the horse's vital parameters we recorded also the ambient temperature, relative air humidity and air pressure from the local meteorological station. In order to find out the body mass reduction (Sendel, 2010) we measured also the trunk length and the horse's chest circumference in two stages – measuring prior to and after training. For measuring the measuring tape for measuring animals, 250 cm length, was used. The circumference and length of the trunk were measured as shown in Figure 1.

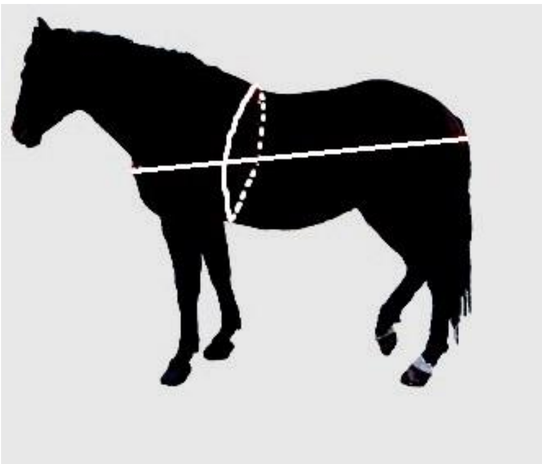

Fig. 1. Illustration of measuring chest girth and hull length

For the determination of the circumference and length of trunk the mean value of six measurements (twice in the morning, at noon and in the evening) before the beginning of training and after completion of training was used for higher accuracy of measured values.

2.2 Measurements during four fitness tests

The horse was trained for one month from 24th June to 22nd July 2011 five to six days a week. The individual training lasted between half an hour to two and a half hours. Because of monotony the training ground and path were changed every day. Once a week the horse's fitness test (in total, four tests) was performed always on the same path with four stations determined, where the horse's vital parameters were measured (HT, HR, RR). The fitness test lasted two hours and a half and was 15 kilometers long. It was always performed in early morning hours because of favourable temperature.

The fitness test started with warming up followed by the first kilometer of relaxed riding. After the first kilometer the horse ran moderately trotting half a kilometer. One-half kilometer trotting was followed by relaxed riding up to the first slope one and a half kilometer long. This was followed by one hundred meters of relaxed walking with rider, then the horse galloped moderately one kilometer long. That was followed by two kilometers of relaxed walking with rider up to the very steep slope, where the horse reached his highest heart rate during training. The slope was five hundred meters long. On the steep part the horse with the rider walked with relaxed steps one kilometer long, then we were riding down for one kilometer. After riding down the rider rode relaxed for one hundred meters, followed by gallop one kilometer long. After galloping the rider rode relaxed in step for one kilometer and a half. The last two kilometers were covered in step without rider.

During the fitness tests also the heart beat, altitude, path length and time from the beginning of the test were measured by means of the modified hand GPS (global position system) receiver (para 3) in automatic intervals of 2 to 18 seconds.

2.3 Description of rebuilding of hand GPS receiver with heart rate sensor Garmin Forerunner 305

The heart rate is most conveniently detected on the horse's right side at 4 cm behind the front right leg. The first electrode is located at 56 cm downward from withers (Janzekovic & Prisenk, 2009a; Janzekovic & Prisenk, 2009b). For measuring the heart rate during training the following equipment was used:

- Saddle harness "sintetic comfort", of 90 cm length and 11 cm width,
- Heart rate sensor in combination with heart rate monitor Forerunner 305, of 34 cm length and 3.5 cm width.

The first band of the saddle harness is sewn-on at 12.5 cm distance from the right side towards center. The other band is 33 cm from the first one. The top and bottom bands have the function of stabilizing the heart rate sensor between the saddle harness and the horse's body. The saddle harness has a cut-out hole of 5 cm radius between both bands to facilitate transmission of data between the clock and the heart rate sensor. Detailed drawing of the heart rate sensor and modified saddle combination is shown in Figure 2.

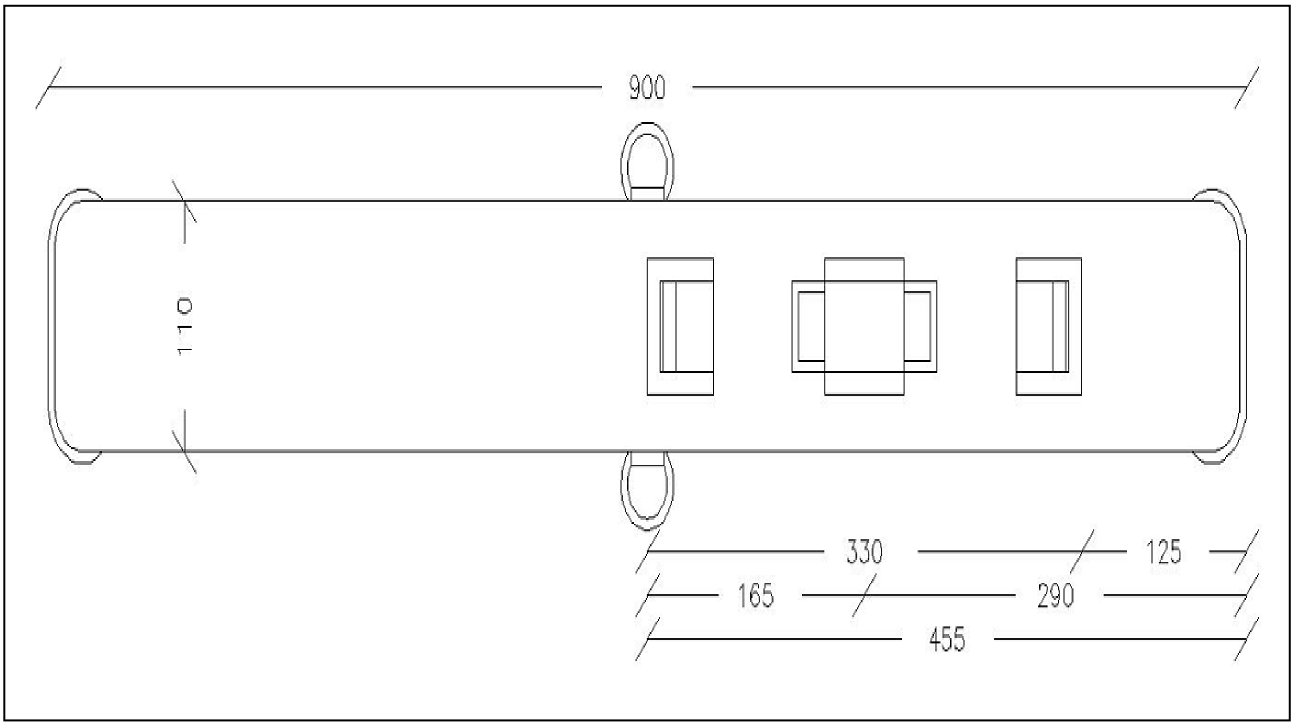

Fig. 2. Plan the installation of the sensor heart rate in the saddle belt

The equipment Garmin Forerunner 305 consists of a heart rate receiver in the form of a clock, heart rate sensor and software Garmin training center. For smooth operation the recommended distance between the sensor and receiver is between half a meter and one meter. During training the meter was fixed to the right of the saddle about half a meter from the heart rate sensor. Before every measurement the skin was moistened with luke-warm water without additives.

2.4 Statistical analysis

For the analysis of data we used statistical software SPSS version 18.0. Correlations of horse's vital parameters at rest and ambient temperature, relative air humidity and air pressure were analysed using Spearman correlation coefficient (r). Changes in values of horse's vital parameters at rest during the one month period were tested by regression analysis.

A repeated measures ANOVA was used to test differences between four fitness tests based on data collected at the four stations.

Heart rate was measured in random intervals during each fitness test. Significant differences in heart rate between fitness tests were detected by One-Way ANOVA and Tukey's post hoc test on $\alpha = 0.05$ significant level.

For the prediction of horse's body temperature as a function of heart rate we used a linear regression model where the coefficients were estimated by the method of least squares.

Correlations between horse's vital parameters during horse's physical activity were studied with the use of Pearson correlation coefficient and partial correlation.

Smoothing of the heart rate curves obtained during fitness tests was achieved with the method of moving averages (Kendall, 1976).

3. Results with discussion

3.1 Results of heart rate, respiration rate and body temperature measurements as a function of relative air humidity, air temperature and atmospheric pressure in the rest period

In environmental parameters the significant negative correlation (in the morning r = –0.4; in the evening r = –0.65) between air temperature and relative air humidity was observed (Table 1). This is in agreement with the study done by Pucnik (1980).

We observed the significant positive correlation in vital parameters of the horse between heart rate and body temperature (r = 0.29) and also between heart rate and respiration rate (r = 0.44), but only in the evening.

Some vital parameters of the horse are correlated to environmental parameters. Significant positive correlation can be observed between respiration rate (RR) and air temperature (AT). This correlation is larger in the evening (r = 0.62) than in the morning (r = 0.27). This is probably due to the greater exhaustion of the horse in the evening.

At the higher atmospheric pressure (AP) value we notice that the horse's morning temperature (HT) is significantly lower (r = –0.40), on the other hand there is a significant increase in the respiration rate (RR) (r = 0.31).

Table 1 shows that the correlation coefficient between RAH and RR is statistically significant in the evening, but we have to stress that there is no relevant direct connection between these two variables. The reason for the significant correlation coefficient lies in strong correlation between both RAH and RR with variable AT.

		AT	HT	RAH	AP	HR
HT	M	0.002				
	E	–0.129				
RAH	M	−0.400**	−0.181			
	E	−0.649**	0.036			
AP	M	0.002	−0.402**	−0.010		
	E	−0.076	−0.068	−0.072		
HR	M	0.114	0.162	−0.239	−0.114	
	E	0.063	0.293*	−0.171	0.252	
RR	M	0.269*	−0.007	−0.221	0.306*	0.085
	E	0.616**	−0.026	−0.536**	0.382**	0.444**

M – morning, E – evening

** = The correlation is statistically significant at 0.01 significance level

* = The correlation is statistically significant at 0.05 significance level

Tab. 1. Spearman correlation coefficient of investigated variables in the morning (M) and in the evening (E)

In one month's training period the respiration rate at rest significantly dropped from mean value of 13 to 9 breaths per minute (Figure 3), while differences at others horse's vital parameters at rest are not significant.

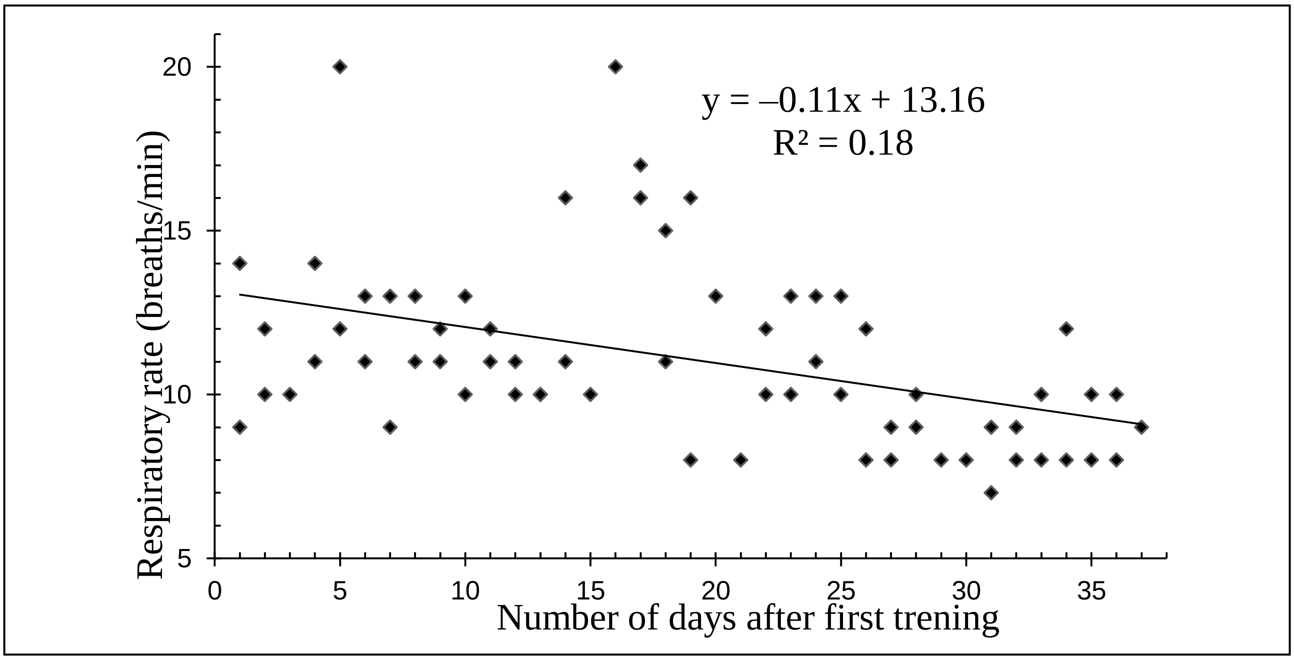

Fig. 3: Respiratory rate in days after first trening

3.2 Heart rate, body temperature and respiration rate comparison during the fitness tests

Figure 4 shows means and standard deviations of variables HR, RR and HT by endurance tests. Analysis of variance results show the influence of horse's physical fitness on the heart rate ($p = 0.000$). In our study the mean heart rate dropped significantly when compared between the first and second endurance test. Drop in heart rate was 7.2 beats per minute in this first case. The drop in heart rate between second and third endurance test was 8.1 beats per minute, after that it increased between third and fourth test by 1.5 beats per minute (difference is not significant). We were surprised by the increase of the heart rate mean from third to the fourth training session as we anticipated by the previously set hypothesis that the heart rate should drop to a reasonable limit, which by the expert's opinions and experiences (Trapecar, 1999) shouldn't be reached before months or even years of training. In our study we interpreted this result as a consequence of hormonal changes of the horse. Between third and fourth physical test we let the horse for 6 consecutive days into vicinity of a mare. In the mating period many of the hormonal changes take place in the stallion. In our opinion these hormonal changes caused a reduced focus in the horse and consequently its greater energy consumption during the whole training session. Figure 5 shows curve changes in heart rate during individual fitness tests.

When looking at the consecutive fitness tests we observe a decrease in mean frequency of inhalations per minute. The drop between first and second test was by 6.50 inhalations per minute, between second and third test the drop was by 8.50 and between third and fourth test the observed drop was by 5.75 inhalations per minute. Total decrease in respiration rate was from the value of 51.25 inhalations per minute, which is the mean of first measurement to the mean value of 30.50 inhalations per minute in the last measurement (Figure 4). With repeated measures ANOVA we established that differences were not statistically significant because of large variability presumably due to the method chosen for measuring the respiration rate (visual method).

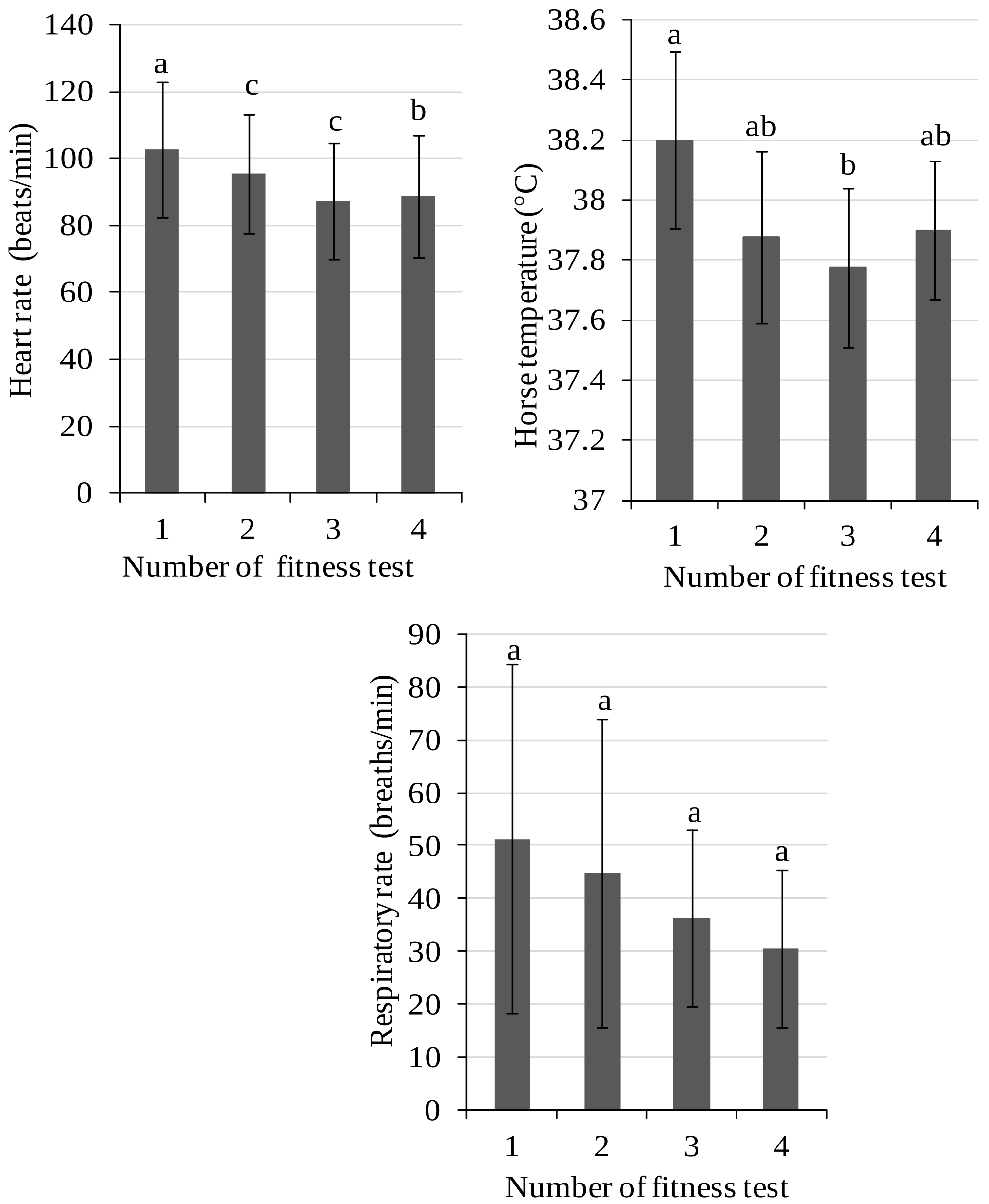

Fig. 4. Means and standard deviations of HR, RH and RR by condition tests. Means labeled with the same letter are not signifficantly different (Tukey, $\alpha = 0.05$)

Repeated measures ANOVA results showed horse's body temperature to be significantly dependent on its physical fitness ($p = 0.017$). Mean body temperature value was highest at the first fitness test, 38.2°C and lowest at the third fitness test, 37.8°C. We found this difference to be statistically significant.

Relations between variables HT, HR and RR during horse's physical activity are shown in Table 2. Even though we found the correlation coefficient between respiration rate (RR) and horse's body temperature (HT) to be statistically significant, partial correlation analysis shows this to be due to strong correlation between both body temperature and respiration rate with heart rate. This means that when the heart rate increases, horse's body temperature and respiration rate also increase. Similar conclusions were made in the study done by Prisenk (2010). In the next step we plan to collect data of horse's vital parameters for different races.

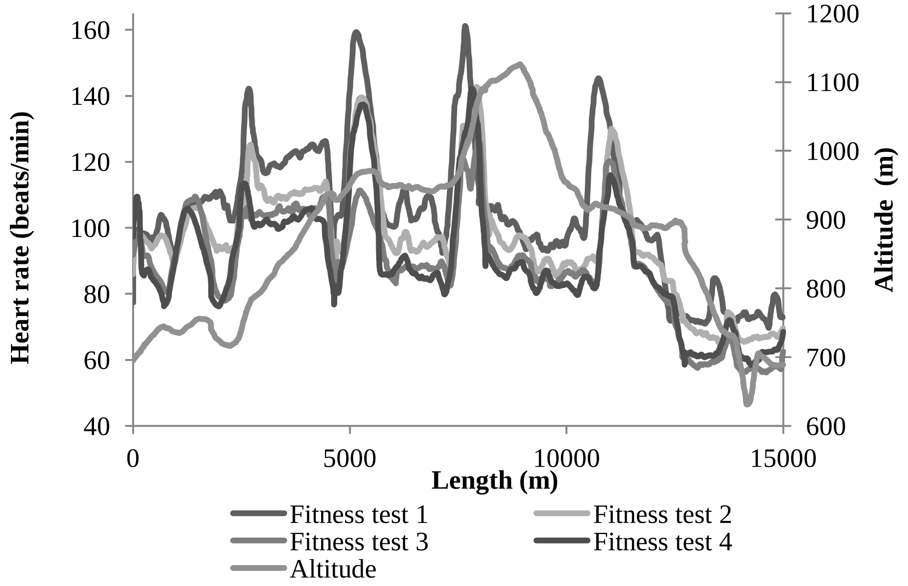

Fig. 5. Comparison of the curve changes in heart rate during the Fitness test

3.3 Change in body mass after one month of training

Mean values of horse's body parameter measurements were 187.7 cm for chest circumference and 155.2 cm for trunk length. After one month of training there was no change in trunk length, measured value was 154.7 cm (5 mm deviation due to measurement errors). There was a reduction in chest circumference by 7.3 cm and had a value of 180.3 cm after the end of training. With the use of Carroll and Huntington's equation (1988) we calculated horse's body mass to be 460.1 kg before the beginning of training sessions and 423.5 kg after one month of training. Horse lost 36.6 kg of body mass during the period of one month.

4. Conclusion

Because results of invasive methods for measuring horse's vital parameters during training are not always reliable, we tested Garmin Forerunner 305 as noninvasive device. Simultaneously body mass reduction during the period of training was investigated.

We found statistically significant drop in heart rate by 18.32 heartbeats per minute on average from first to third physical test. Increase of mean heart rate by 1.5 heartbeats per minute between third and last physical testing was a surprise. The difference was not statistically significant. We believe that this observation was due to hormonal changes in the stallion as it was brought to the mare on six consecutive days. We found that the mean respiration rate value at rest decreased on average by 4 inhalations per minute in one month training period. Spearman correlation test showed an interesting statistically significant correlation between number of inhalations per minute measured both before and after noon with atmospheric pressure.

The results of research confirmed our hypothesis on measuring horse's vital parameters and also on horse's body mass reduction during the period of training. Horse had lost 36.6 kg of body mass after one month of training.

In the future we will expand investigation of stress parameters with other noninvasive methods.

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