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**Original Paper**

# Physiological Indicators of Workload in Horses: Analysis of Heart Rate and energy expenditure during riding

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Objective monitoring of physiological parameters, such as heart rate (HR), energy metabolism, and the temporal structure of exercise, forms the basis for optimizing the overall training process of sport horses. Determining the threshold between effective stimulation and overloading is crucial for preventing overtraining and performance decline. Training programs based on these indicators take into account the adaptive capacity of the horse, thereby maximizing performance while supporting health and welfare.The aim of this study was to analyze physiological parameters, particularly heart rate and energy expenditure, during riding training and its duration. Sixteen horses of different ages and sexes were included in the study and divided into two groups based on sporting experience. The first group ($n$ = 8) comprised horses in the preparatory phase of their sporting careers with a maximum of one year of competition experience, while the second group ($n$ = 8) consisted of more experienced horses with at least two years of sporting seasons. Horses were housed in two riding centers and fed high-quality meadow hay (10–12 kg depending on body weight), supplemented with a complete feed mixture (2–5 kg depending on workload), with *ad libitum* access to water. All horses were stabled in individual boxes. Heart rate and energy expenditure were measured using the CEEFIT Pulse & ECG system by Seaver. Analysis revealed a statistically significant difference ($p$ <0.01) in HR between groups: less experienced horses had an average HR of 93.92 beats.min$^{-1}$, whereas experienced horses exhibited values approximately 9.81 beats.min$^{-1}$ higher. This difference may be attributed to more intense interaction between rider and horse in the experienced group, while the lower HR in less experienced horses likely reflects reduced exercise intensity. Significant correlations were observed between exercise duration and HR ($p$ <0.001), as well as between exercise duration and energy expenditure ($p$ <0.001). In less experienced horses, a strong correlation between HR and energy expenditure was also detected ($p$ <0.0005), whereas in experienced horses, only a correlation between HR and energy expenditure was confirmed ($p$ <0.0001). The results confirm substantial differences in physiological parameters between groups and highlight the impact of training intensity on the horse's organism. These findings emphasize the necessity of a differentiated approach to training program design to optimize the overall training process.

**Keywords:** heart rate, energy, workload, performance, horse

## 1 Introduction

At present, the main selection criteria include the horse's origin, body conformation, and locomotor biomechanics. For a more accurate estimation of the horse's future performance, it is necessary to focus more closely on understanding its exterior and skeletal characteristics and their relationships to functional performance (Sánchez-Guerrero, 2016). Physiological adaptation of horses to training represents a complex process involving progressive changes across multiple organ systems, which enable more efficient handling of workload and improvement of performance. Horses are inherently athletic animals, predisposed to physical performance by their natural lifestyle. From a breeding perspective, understanding the effects of training and workload on the horse's organism – not only in terms of overall conformation but also from physiological and biochemical standpoints – is essential. Training

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influences multiple organ systems, inducing changes in energy metabolism, respiratory and cardiovascular function, and muscle morphology, which collectively affect overall performance and fitness. However, it is crucial to recognize individual limits and tailor training programs accordingly (Hinchcliff et al., 2008). Horses are among the most physically capable animals in sport, primarily due to their high aerobic capacity, substantial intramuscular energy stores, efficient oxygen transport, and effective thermoregulation. Training requires the optimal functioning of all physiological systems to coordinate muscle contractions while maintaining internal homeostasis (Piccione et al., 2013). Inadequate preparation and insufficient warm-up with proper muscle relaxation pose a significant risk of injury and compromise the horse's welfare (Bennet, Cameron-Whytock, Parkin, 2023). For training to be effective, it must elicit a certain level of physiological overload, with sufficient intensity and duration to challenge the organism and homeostasis. Without such stimulus, the desired conditioning effect cannot be achieved. When workload is appropriately applied, the organism adapts, improving performance capacity (Hinchcliff et al., 2008). Conditioning can be characterized as a specific metabolic state induced by training that facilitates optimal athletic performance.

Training has positive effects on cardiac function, including increased heart mass and capillarization, enhancing oxygen delivery to cardiac tissue (Tyler et al., 1996). Neuromotor control – the coordinated interaction between the muscular and nervous systems – plays a crucial role in injury prevention and physiological adaptation of muscles. It encompasses learned and trained movements, including precise timing of muscle contractions. Targeted training improves muscle strength and endurance, increases muscle volume, and can induce changes in muscle fiber type (McGowan, Hyytiäinen, 2017). It is essential to identify the optimal level of overload, as exceeding the horse's capacity can lead to injury, fatigue, or overtraining.

Overtraining represents an imbalance between workload, recovery, and stress, causing muscle damage, hormonal disruption, and altered anabolic-catabolic processes (Hinchcliff et al., 2008). Athletic performance depends on the horse's ability to perform muscular work. During muscle activity, energy requirements rise to sustain contractions, with substrate utilization adapting accordingly. Two metabolic pathways are engaged: anaerobic metabolism supplies ATP and phosphocreatine during short or intense exercise, transitioning to aerobic metabolism after approximately 30 seconds, relying on muscle glycogen. Low glycogen reserves limit performance (Lacombe et al., 2003). Although aerobic metabolism accounts for the majority of energy supply during moderate to high-intensity exercise, it contributes to energy production during all activity, with contribution increasing as workload intensifies (Hinchcliff et al., 2002). Glycogen replenishment in horses is slower than in humans, taking 48–72 hours, partly due to gastrointestinal limitations in starch digestion. Horses, as herbivores with small stomachs, require frequent ingestion of high-quality feed. Muscle glycogen content depends on fiber type; fast-twitch fibers contain higher glycogen levels (Jose-Cunilleras, Hinchcliff, 2004). Increases in muscle volume vary by discipline: approximately 10–15% in dressage and 23% in show jumping, with strength improvements typically observable after 12–16 weeks. Early gains in performance are rapid, slowing as the horse approaches its physiological limits (McGowan, Hyytiäinen, 2017). Proper muscling is crucial for performance, and breed differences exist, e.g., Thoroughbreds possess greater muscle mass in specific regions, facilitating faster contractions and speed (Kearns, 2002). Longer muscle fascicles and fiber bundles can be brought into contraction more rapidly, which contributes to faster movements and the overall speed of the horse (Dyson, 2002). Movement is generated by coordinated contraction and relaxation of opposing muscle groups acting on the skeletal system. Bones remodel under load, and appropriate training can optimize conditioning, morphology, and performance. Improper training or insufficiently conditioned bones, particularly in young horses, can lead to structural damage, inflammation, or overload (Higginsová, Martinová, 2013). Muscle mass as a percentage of body weight is <52% in Thoroughbreds and <42% in standard breeds, with mitochondrial density ranging 6–8.5%, depending on muscle group and fiber type (Jose-Cunilleras, Hinchcliff, 2004). High aerobic activity depends on capillary density, facilitating oxygen transport, enzyme activity, and energy utilization. Mitochondria provide energy for muscle contraction, with horses having twice the mitochondrial content compared to other species. Energy expenditure at maximal speed is approximately 0.5–0.6 $kcal.kg^{-1}.min^{-1}$, sourced from phosphates, glycogen, and glucose. Adequate mitochondrial energy reserves are essential for intensive training. Glycogen is initially utilized from muscle, then blood, and finally fat stores when depleted. Hormonal regulation – including reductions in insulin and elevations in catecholamines, cortisol, and glucagon – coordinates energy mobilization at exercise onset, initiating increased cardiovascular and respiratory activity (Hinchcliff et al., 2008). Heart rate data reflect workload impact on homeostasis and allow monitoring of conditioning, supporting training program design (Davies, 2005).

HR is influenced not only by biomechanical load, intensity, and fitness, but also by environmental factors such as temperature and humidity (Evans, Rose, 1987). Resting HR ranges 36–42 bpm, rising to 240 bpm under intense exercise (Davies, 2005). Blood composition also varies with sampling time; post-exercise erythrocyte levels increase due to splenic mobilization, with recovery taking approximately one hour (Adamu et al., 2013). Heart rate is a readily accessible indicator of aerobic energy expenditure, reflecting cardiovascular response to oxygen demand (Liedtke et al., 2025). According to Eaton et al. (1999) plasma volume increases by approximately 21–29% with increasing the growth of red blood cells. Aerobic and anaerobic metabolism produce by-products such as carbon dioxide and lactate (Hinchcliff et al., 2008). Lactate accumulation occurs when production exceeds oxidative clearance (Pösö, 2002), triggering transcription of specific enzymes for metabolite removal. Muscle contractions also generate heat, increasing body temperature by 3–5 °C, with rectal temperature reaching up to 42 °C, potentially causing heat stress. Physiological responses – including sweating, respiration, excretion, and evaporation – regulate thermoregulation. During adequate training, these physiological adaptations positively influence health, fitness, and mental well-being. Exercise induces coordinated changes in energy metabolism, cardiovascular and respiratory systems, intramuscular biochemical processes, muscle morphology and strength, which in turn affect conformation and performance. Athletic horses undergo rigorous preparation, which significantly impacts mental state, necessitating individualized training plans (Hinchcliff et al., 2008). Williams et al. (2019) describes the possibility of using commercial HR measurements as an advantage for monitoring within the framework of adequate preparation for a sports career. Proper riding technique and equine movement mechanics are also critical for performance maintenance. Modern measurement technologies provide valuable data for improving breeding knowledge and welfare. Wireless sensor systems are increasingly used to collect, analyze, and evaluate movement data (Wang et al., 2018).

The aim of this study is to analyze physiological indicators of workload in horses, focusing on changes in heart rate and estimated energy expenditure during riding. The study seeks to determine how different levels of riding intensity affect the physiological response of horses, thereby contributing to a better understanding of optimal training load and improving their performance and welfare.

## 2 Material and Methods

### *2.1 Characteristics of Biological Material*

Sixteen warmblood horses were included in our study and divided into two categories. The first group ($n$ = 8) comprised inexperienced horses in preparation for a sporting career, participating in their first competitive season. The second group ($n$ = 8) consisted of experienced horses with at least two years of participation in sporting seasons. The horses were housed in two riding centers and fed high-quality meadow hay at 10–12 kg depending on body weight, supplemented with a complete feed mixture of 2–5 kg according to workload. Water was provided *ad libitum*.

### *2.2 Data Collection*

Horses included in the study were assigned individualized training programs, taking into account their temperament, fitness level, and performance capacity. Heart rate and energy expenditure data were collected using the CEEFIT Pulse & ECG system (Seaver, Paris, France). The CEEFIT Pulse & ECG consists of breathable fabric and electrodes that enable heart rate measurement. It was positioned within a girth, on the ventral side between the horse's forelimbs, with one electrode on the inner side and the second electrode attached to the left side near the withers. To initiate heart rate measurement, a contact, hypoallergenic ECG neutral gel (Asept InMed SAS, Toulouse, France) was applied. Data were precisely evaluated using the Seaver mobile application (Seaver, Paris, France). Statistical analysis was performed using SAS Enterprise Guide software.

## 3 Results and Discussion

Our study revealed a statistically significant difference ($p$ <0.01**) between experienced and inexperienced horses. Experienced horses exhibited a higher average

**Table 1** Comparison of average values for exercise duration (min), HR (bpm), and energy expenditure during exercise (kcal.min$^{-1}$)

| Parameter | Inexperience horses (mean ±SD) | Experience horses (mean ±SD) | Statistical significance |
|---|---|---|---|
| Exercise duration | 0.79 ±0.34 | 0.78 ±0.20 | $p$ >0.05 |
| HR | 93.92 ±20.02 | 103.73 ±16.62 | $p$ <0.01** |
| Energy | 117.81 ±56.87 | 120.77 ±36.14 | $p$ >0.05 |

heart rate by 9.81 bpm, suggesting a distinct physiological response to exercise (Table 1).

These results can also be explained by the higher reactivity or greater work engagement of sport-experienced horses. According to Szabó, Vizesi, and Vincze (2021), higher reactivity in horses is responsible for elevated HR values. Conversely, Gregic et al. (2020) reported lower HR values in younger horses. Vincent et al. (2006) demonstrated that HR decreases on average by 0.86 bpm with each additional year of age. An older horse aged 22 years exhibits an HR approximately 17 bpm lower than that of a two-year-old horse. Interestingly, a Thoroughbred horse that does not participate in competitions shows HR values roughly 7 bpm lower than a competing horse. Their study also indicates that horses in better physical condition tend to have higher HR, which aligns with our findings. Additionally, experienced horses generally have better fitness and greater muscular development compared to horses in the preparatory phase, which may contribute to higher HR due to increased oxygen demand by working muscles. Standard deviations of HR values were also more stable in experienced horses, suggesting a more consistent cardiovascular system and improved response to training. Monitored parameters such as exercise duration and energy expenditure were not statistically significant ($p$ >0.05) and were approximately equal between groups. Heart rate is also significantly influenced by the type of training session. Ebert, Moore-Colyer (2020) evaluated dressage, show jumping, and eventing, reporting the lowest HR during show jumping (92 bpm), followed by eventing (93 bpm) and dressage (96 bpm). Interestingly, eventing and show jumping are expected to be more energetically demanding, with higher oxygen requirements, whereas dressage emphasizes reactivity and concentration. As equestrian sport relies on horse-rider cooperation, the rider can influence the horse's physiological responses (Gregic et al., 2020). In horses of the same skill level performing jumps of identical heights, HR changes were observed in relation to the rapid execution of the jump. Transitioning from a 100 cm to a 125 cm jump caused a sharp increase in HR, driven by sudden increases in physical activity and concentration. Mean HR was approximately 102.6 bpm at 100 cm, 110.8 bpm at 120 cm, and 107.9 bpm at 130 cm (Bazzano et al., 2016). Jansen et al. (2009) noted that increased HR during jumping is also influenced by the technical difficulty of the jump and the horse's reactivity. Overall, HR elevation plays a critical role in assessing the physical fitness of sport horses (Szabó, Vizesi, Vincze, 2021).

In inexperienced horses, a strong correlation ($R^2$ = 0.8455) was observed between energy expenditure and HR during exercise. The high $R^2$ value indicates

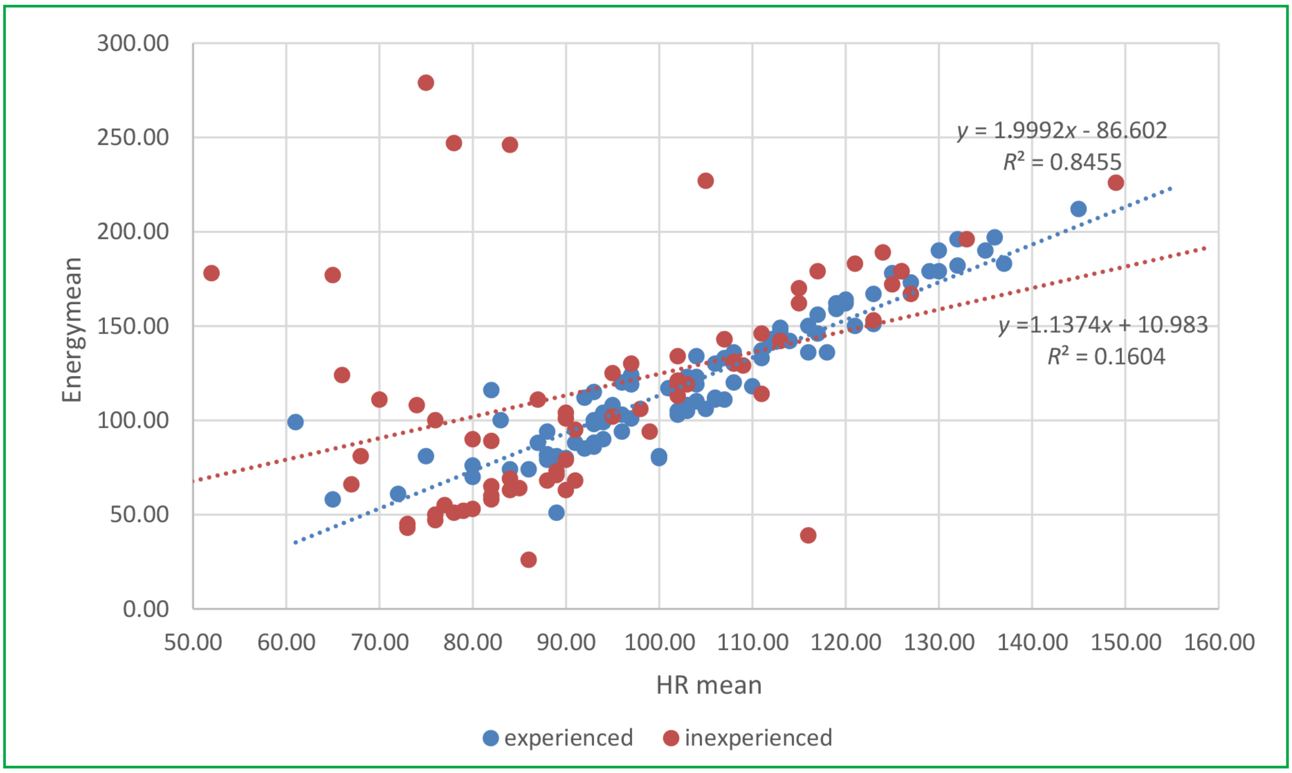


**Figure 1** Relationship between average HR and energy expenditure during exercise
$x$ = mean HR bpm.min$^{-1}$, $y$ = kcal.min$^{-1}$

**Table 2** Statistical significance in the monitored category of inexperienced horses was observed as follows: exercise duration and HR ($p$ <0.01), exercise duration and energy expenditure ($p$ <0.001), and HR and energy expenditure ($p$ <0.001)

| Inexperienced horses | |
|---|---|
| Exercise duration + HR | 0.0023 |
| Exercise duration + energy | $p$ <0.0001 |
| HR + energy | 0.0005 |

that HR measurement is a reliable indicator of exercise intensity and energy consumption. Horses in the preparatory phase for sport showed a more pronounced increase in HR in response to elevated workload compared to experienced sport horses. In experienced horses, a weaker correlation ($R^2$ = 0.1604) was observed, suggesting a more efficient cardiovascular response, resulting in lower energy expenditure at the same HR. In inexperienced horses, an increase of 1 bpm corresponds to an energy expenditure of approximately 2 kcal. The average energy expenditure for horses during light exercise was 0.023 MJ ME.kg$^{-1}$, which translates to approximately 3.298 kcal for a horse weighing 600 kg (Ebert & Moore-Colyer, 2020). Our results indicate higher energy expenditure and, consequently, greater workload, with inexperienced horses expending approximately 7,020 kcal per hour of riding and experienced horses around 7,200 kcal. Dekker et al. (2007) categorized horses based on workload intensity and reported daily energy expenditure: horses in light work expended approximately 0.2189 MJ.day$^{-1}$ for a 500 kg horse, in moderate work 0.2624 MJ.day$^{-1}$, and in heavy work 0.3495 MJ.day$^{-1}$.

Comparing lunging, dressage, and show jumping, differences in energy expenditure were observed. Lunging exhibited the highest values at approximately 609 J.kg$^{-1}$.min$^{-1}$, equivalent to 84 kcal.min$^{-1}$ for a 600 kg horse; dressage averaged 457 J.kg$^{-1}$.min$^{-1}$ (63 kcal.min$^{-1}$), and show jumping 442 J.kg$^{-1}$.min$^{-1}$ (60 kcal.min$^{-1}$). For a 30-minute training session, a horse would expend approximately 2,520 kcal during lunging, 1,890 kcal during dressage, and 1,800 kcal during jumping (Ebert, Moore-Colyer, 2020). Energy requirements for maintaining fitness and performance in training or competition can be predicted relatively accurately if adapted to the discipline, training type, and individual horse. Thoroughbreds require more energy per kg of body weight compared to warmbloods due to involvement in more demanding training regimens (Pagan, 2009). Furthermore, energy expenditure is influenced by temperament: more reactive horses have approximately 18.6% higher energy requirements than calmer horses (McBride et al., 2017). According to NRC (2007), nutritional demands are approximately 9% higher in reactive horses compared to phlegmatic or calm individuals.

From the presented table, it is evident that the most statistically significant factors in inexperienced horses are exercise duration and the energy expended during the workload. Exercise duration and HR showed a significant correlation, indicating that longer training sessions result in higher HR values in sport-inexperienced horses.

## 4 Conclusions

Workload affects the horse's organism as an integrated system. It influences not only performance but also induces morphological, biochemical, hormonal, respiratory, and cardiovascular changes. In our study, we focused on assessing energy expenditure and heart rate during exercise, with horses divided into two categories based on sporting experience. Clear differences in HR were observed between the groups: sport-experienced horses exhibited higher HR values, while energy expenditure was lower at the same heart rate. This can be attributed to better cardiovascular conditioning and greater focus during the riding session. Inexperienced horses showed lower HR values but higher energy consumption at the same HR. Statistical analysis revealed significant correlations between exercise duration and energy expenditure ($p$ <0.001), training duration and HR ($p$ = 0.0023), and HR and energy expenditure ($p$ = 0.0005). In the experienced horse group, statistical significance was found only between HR and energy expenditure ($p$ <0.001**). The results reveal significant variations in physiological parameters between the groups, underscoring the influence of training intensity on the equine organism. These outcomes highlight the importance of adopting a tailored approach to training program design in order to optimize the overall effectiveness of the training process.

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### Conflict of Interest

The authors declare that there is no conflict of interest.

### Author Contributions

All authors contributed to the design and implementation of the study. Data collection and preparation for statistical tests were performed by Monika Šmondrková under the guidance and supervision of Marko Halo. Statistical tests and interpretation of results were performed jointly by Monika Šmondrková and Stanislav Zaťko under the guidance of Marko Halo. The entire team of authors participated in the preparation and editing of the final version of the manuscript.

### AI and AI-assisted technologies use declaration

No generative AI tools/AI-assisted technologies were used during the preparation of the manuscript.

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