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Impact of Exercise on Vitals in Racing Horses

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ABSTRACT

Background: This article delves into a comprehensive analysis of a dataset that sheds light on the intricate relationship between exercise and equine physiology. By examining temperature, pulse rate and respiratory rate, we uncover how exercise type, duration and ground surface significantly influence the well-being of horses during physical activities.

Methods: The choice of exercise type, whether it's show jumping, free ride, or lunge, has a profound impact on the horses' physiological responses. Each activity elicits distinct patterns of temperature regulation, cardiovascular demand (pulse rate) and respiratory effort. The animal material of the study consisted of 20 different horses (10 Thoroughbred, 2 Arabian, 8 Belgian) which were housed in Adana and Mersin provinces. Horses were housed in similar conditions of care and they were healthy. The study encompassed the measurement and recording of key parameters, including pulse rate (heart rate), respiration rate (breathing rate) and body temperature, at various critical time points: before the commencement of exercise, immediately post-exercise, 30 min after exercise and 1 hour after exercise. Exercise duration varied between 15 to 40 min, with each session commencing with a standardized warm-up period of approximately 5 min, including a rider on the horse. The horses were observed at four specific time points.

Result: This analysis underscores the need for a nuanced approach to equine training, considering the specific exercise type, duration and ground surface. Horse owners, trainers and veterinarians can use these insights to optimize exercise programs, ensuring the health and performance of their equine companions. Ultimately, this understanding of equine physiology paves the way for responsible and effective equine training practices.

Key words: Equine physiology, Exercise impact, Horse breeding, Recovery period, Temperature regulation.

INTRODUCTION

Exercise plays a pivotal role in the well-being of horses, impacting their physical health, mental state and overall performance. Whether horses are used for leisurely rides, competitive sports, or work, consistent exercise is essential to maintain their optimal condition (Barn Chats 2023; Ogbanya *et al.* 2020; Pal *et al.* 2021; Pothiappan *et al.* 2024). The importance of exercise can be dissected into several key facets. Foremost, exercise is critical for enhancing a horse's physical fitness. It facilitates the development and upkeep of robust, healthy muscles, which are indispensable for carrying riders, pulling loads and executing athletic maneuvers. Moreover, exercise contributes to cardiovascular well-being by elevating heart rate and promoting efficient oxygen delivery to muscles and tissues (Integricare, 2023).

Different types of exercise can exert various effects on a horse's vital signs, which encompass heart rate, respiratory rate and body temperature (De Solís, 2019; Farooq *et al.,* 2019; Soroko *et al.,* 2019; Padalino and Raidal, 2020). These effects are contingent upon several crucial factors. First and foremost, the intensity of the exercise plays a pivotal role; activities of higher intensity, such as galloping or jumping, tend to prompt a more rapid escalation in both heart rate and respiratory rate when compared to more moderate exercises like walking or trotting. Secondly, the duration of exercise also has a notable impact; protracted periods of physical exertion can lead to an elevation in both heart and respiratory rates, as the horse's body works diligently to meet the heightened oxygen demands of its muscles. Moreover, the horse's fitness level is a significant determinant, with well-conditioned horses generally exhibiting lower baseline heart and respiratory rates and a swifter recovery post-exercise (Harkins *et al.,* 1993). Environmental conditions, encompassing factors like temperature, humidity and altitude, further influence these vital signs, with hot, humid conditions intensifying sweating and respiratory effort and high altitudes affecting oxygen availability (Verdegaal *et al.,* 2021; Logan and Nielsen, 2021). The age and health status

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of the horse also factored in, with younger horses and those with underlying health concerns demonstrating distinct responses (De Maré *et al.* 2017; McKeever, 2002).

The specific type of exercise pursued can introduce variances as well, with activities like hill work demanding increased effort and subsequently yielding higher heart and respiratory rates. Finally, the time taken for a horse's vital signs to return to baseline during the recovery period also fluctuates, with well-conditioned horses typically rebounding more swiftly. Monitoring these vital signs during and after exercise is essential for ensuring the horse's well-being, enabling timely intervention in case of abnormal responses and adopting appropriate warm-up and cool-down routines to mitigate stress on the cardiovascular and respiratory systems during exercise (Jarvis *et al.* 2017; Ralston, 2006). Blood, respiratory and pulse data of horses provide us with information about the health and condition of the horse.

MATERIALS AND METHODS

Ethical guidelines

All of the procedures were carried out in accordance with the Turkish legislation on animal care (Animal Protection Law No 5199). The information about the horses was obtained from the pedigree records kept by the Turkish Equestrian Federation. The study was approved by Selçuk University Faculty of Veterinary Medicine Experimental Animal Production and Research Center Ethics Committee (Decision no: 113, Date: 15.10.2023).

Materials

In 2023, a random selection of horses was used for the research. The study's animal sample included horses of different ages from various equestrian sports in Adana (Adana Yavuzstar Equestrian Club), Mersin (Soli Equestrian Club) provinces. January 1, 2023 and August 10, 2024 were the dates of the study. The animal material of the study consisted of 20 different horses (10 Thoroughbred, 2 Arabian, 8 Belgian), each characterized by their unique set of attributes. These horses varied in age, with the youngest being 2 years old and the oldest at 18 years. The gender distribution leaned slightly towards males, with 12 males and 8 females. Coat colors varied, with a range including Bay, Dapple Gray, Chestnut and Black. Horses were housed in similar conditions of care and they were healthy. The horses stay individually in their stables which are standardly 4 m × 3 m in size. Feeding is done in the morning, noon and evening and their daily feed is consisted of 4 kg of oats, 2 kg of barley, 1 kg of ready-made feed with a high vitamin, mineral and protein ratio, 6 carrots, 6 apples and 10 kg of hay. In the farms, water troughs are in the paddocks and stables.

Physical exercises and physiological parameters

In this study, a comprehensive examination of horses' physiological responses during and after exercise sessions was conducted. The study encompassed the measurement and recording of key parameters, including pulse rate (heart rate), respiration rate (breathing rate) and body temperature, at various critical time points: before the commencement of exercise, immediately post-exercise, 30 min after exercise and 1 hour after exercise. The exercise aspect of the study covered a spectrum of variables. Exercise duration varied between 15 to 40 min, with each session commencing with a standardized warm-up period of approximately 5 min, including a rider on the horse. The exercise type was categorized into three distinct categories: lunge, free ride, or show jumping. Additionally, the type of ground or surface on which the exercise occurred was classified as either grass or sand (Table 2). Notably, this study benefited from the collaboration of horse owners, trainers and caretakers in collecting comprehensive data, ensuring a holistic and practical approach. Crucially, the horses in the study were not anesthetized, affirming that all measurements were obtained from conscious and unaltered animals. The horses were observed at four specific time points: when they were at rest in their stalls (Time I), immediately after completing the exercise (Time II), half hour after the exercise (Time III) and one hours after the exercise (Time IV). During these observation periods, the researchers collected data on the horses' heart rate, respiratory rate and rectal temperature. In addition to this, the horses were recorded on video, allowing for the development of a focal animal sampling ethogram to assess their behavior (Padolino *et al.* 2014).

RESULTS AND DISCUSSION

At the end of the study, the working floor, working time, working type and body temperatures of the horses according to age, race, gender and frost color were measured before, after, 30 minutes after and 1 hour after the study given in Table 1. When the table was examined, it was found that the body temperature was statistically significantly different only after the study according to the age factor (p0,05). At the end of the study, the body temperatures of horses with an age range of 11-20 were found to be higher than other horses (38,6500±0,33166). According to the age factor, the body temperature could not reach the pre-study level in horses between the ages of 2-5 even after 1 hour, while it fell to a lower level of pre-study body temperature in other horses. This result is normally an expected result (Ruben and David, 2007). Again, it was observed that older horses exercised for a longer time (31,250±8,5391).

When examined according to the race factor; It is seen that the exercise time of Arabian horses is longer (30,000±0,0000). As for body temperature, it was determined that English horses were more variable (38.1800±0.65625). When examined according to the sex factor, female horses exercised more (31,500±5,2967), although the body temperature reached the pre-exercise

Table 1: Evaluation of body temperature in horses before, immediately after, 30 minutes after and 1 hour after the study according to age, race, gender and coat color parameters.

	N	Exercise ground	Horse exercise period (minute)	Exercise type	Temperature before exercise	Temperature after exercise	Temperature 30 min after exercise	Temperature 1 hour after exercise
Age								
2-5	5	1,200±0,44721	29,000±7,4162	2,2000±0,83666	37,1000±0,519623	37,7400±0,40988	37,4400±0,28810	37,2400±0,35777
6-10	11	182±0,40451	26,818±6,8091	12,0000±0,44721	37,2273±0,39010	38,0000±0,52154	37,3545±0,34457	37,1909±0,35904
11-20	4	000±0,0000	31,250±8,539	1,5000±0,57735	37,4750±0,89582	38,6500±0,33166	37,6750±0,12583	37,1250±0,49244
P Value		0.679	0.572	0.215	0.591	0.028*	0.224	0.906
Races								
Thoroughbred	10	1,200±0,4216	28,000±7,5277	1,7000±0,67495	37,1300±0,57745	38,1800±0,65625	37,4500±0,31710	37,2300±0,33682
Arabian	2	1,000±0,0000	30,000±0,0000	2,5000±0,70711	37,3500±0,21213	37,8500±0,35355	37,4500±0,35355	37,2000±0,14142
Belgian	8	1,125±0,3536	28,125±7,9899	2,1250±0,35355	37,3625±0,53702	37,9750±0,44320	37,4250±0,34538	37,1375±0,45962
P Value		0.776	0.941	0.132	0.648	0.640	0.986	0.880
Gender								
Female	10	1,200±0,4216	31,500±5,2967	2,0000±0,47140	37,3300±0,48086	38,2900±0,57629	37,4700±0,32677	37,3000±0,27889
Male	10	1,100±0,3162	25,000±7,4536	1,9000±0,73786	37,1600±0,58727	37,8400±0,42999	37,4100±0,31429	37,0800±0,42374
P Value		0.556	0.037*	0.722	0.488	0.063	0.681	0.187
Coat color								
Bay	5	1,200±0,4472	24,000±8,2158	1,4000±0,54772	36,9600±0,45607	38,0600±0,68775	37,4800±0,43243	36,8400±0,46690
Dapple Gray	3	1,000±0,0000	25,000±5,0000	2,0000±0,00000	37,2333±0,37859	37,9667±0,41633	37,4667±0,25166	37,3667±0,05774
Chestnut	8	1,250±0,4629	30,000±4,6291	2,2500±0,46291	37,2750±0,29641	38,0875±0,55146	37,3500±0,30706	37,2000±0,29277
Black	4	1,000±0,0000	32,500±9,5743	2,0000±0,81650	37,5500±0,96782	38,1000±0,64807	37,5500±0,26458	37,4750±0,12583
P Value		0.637	0.237	0.092	0.452	0.990	0.771	0.037*

state in male horses 30 minutes after exercise, it increased in female horses.

Statistically, body temperature was found to be significantly different in horses according to coat color, 1 hour after exercise (p0, 05). When the exercise periods are examined, it is seen that Black horses work more time (32,500±9,5743), while Bay horses work the least (24,000±8,2158). It was determined that the highest Black (37.5500±0.96782) horses had the lowest Black (36.9600±0.45607) horses according to body temperature. It is observed that 1 hour after the exercise, the body temperature drops below the initial level in all horses except Dapple Gray. Body temperature after training varies individually in horses (Ruben and David, 2007).

The pulse values of the horses in the study according to age, race, gender and frost color before, after, 30 minutes after and 1 hour after the study values are shown in Table 2. it is also given. Although the pulse values were statistically insignificant according to the age factor (P0, 05), it was determined that the pulse values of young horses were lower (23,2000±5,01996). When pulse values were examined according to races, it was found that the pre-exercise pulse values were statistically significantly different (P0, 05). Arabian horses have the lowest pulse value before exercise (19,0000±1,41421), while Belgian horses have the highest value (28,0000±3,89138). When the pulse rate according to gender was examined, it was found that female horses had a higher level (26,0000±5,37484) before training and a higher level (32,2000±8,53490) compared to male horses after training. Nevertheless, the pulse values returned to normal 30 minutes after training in horses of both sexes, which indicates that the horses are healthy (Marsland 1968). According to the coat color observed in the horses, the pulse rate returned to its normal level 1 hour after training.

The values of the number of respiratory rate before, immediately after, 30 minutes after and 1 hour after training are given in Table 3. When the table was examined, it was determined that the respiratory rate of horses decreased with age according to the age factor. According to these data, the movement level decreases due to the progression of the horses' age and as a result, the number of respiration is also high in young people (Ruben and David, 2007). When the number of respiration was examined according to the breeds, the lowest (23,4000±4,03320) value was observed before training in the Thoroughbred breed, while the highest (37,3000±12,59674) value was reached after training. Sudden changes in the number of breaths are observed in Thoroughbred and Standardbred horses due to the instantaneous acceleration property that we call explosion power (McCutcheon *et al.* 1999). It has been determined that the respiration rate according to the breed is at a lower value in females compared to male horses. When the respiration rate relative to coat color in horses was examined, it was seen that although the respiration rate was low in horses with bay coat color at the beginning, it increased to the highest level at the end of the study. It can be said that these values are normal due to the fact

Table 2: Evaluation of body pulse rate in horses before, immediately after, 30 minutes after and 1 hour after the study according to age, race, gender and coat color parameters.

	N	Pulse rate before exercise	Pulse rate after exercise	Pulse rate 30 min after exercise	Pulse rate 1 hour after exercise
Age					
2-5	5	23,2000±5,01996	26,6000±4,33590	24,8000±4,71169	22,6000±3,13050
6-10	11	24,9091±4,80530	30,2727±7,26761	24,5455±5,10615	24,6364±4,41073
11-20	4	26,5000±5,19615	38,0000±9,20145	27,7500±2,87228	25,7500±4,57347
P Value		0.613	0.079	0.503	0.515
Races					
Thoroughbred	10	23,4000±4,22164	31,9000±8,46496	24,3000±4,87739	23,0000±4,00000
Arabian	2	19,0000±1,41421	21,5000±3,53553	21,0000±2,82843	21,0000±1,41421
Belgian	8	28,0000±3,89138	32,0000±6,56832	27,5000±3,74166	26,8750±3,44083
P Value		0.016*	0.205	0.133	0.057
Gender					
Female	10	26,0000±5,37484	32,2000±8,53490	26,3000±5,16505	25,2000±4,36654
Male	10	23,6000±4,06065	29,6000±7,19877	24,2000±3,99444	23,5000±3,86580
P Value		0.275	0.471	0.323	0.369
Coat color					
Bay	5	25,2000±4,32435	35,2000±9,88433	26,6000±3,28634	25,4000±4,39318
Dapplegray	3	27,3333±8,14453	33,3333±13,20353	27,6667±7,50555	27,3333±6,35085
Chestnut	8	22,5000±3,20713	27,6250±4,80885	23,2500±4,06202	22,2500±2,81577
Black	4	27,0000±5,03322	30,2500±4,34933	25,7500±4,99166	25,0000±3,55903
P Value		0.333	0.378	0.454	0.261

Table 3: Evaluation of body Respiratory rate in horses before, immediately after, 30 minutes after and 1 hour after the study according to age, race, gender and coat color parameters.

	N	Respiratory rate before exercise	Respiratory rate after exercise	Respiratory rate 30 min after exercise	Respiratory rate 1 hour after exercise
Age					
2-5	5	26,4000±2,60768	32,6000±5,31977	26,0000±3,67423	24,2000±4,65833
6-10	11	25,0909±4,06090	32,3636±6,23334	25,0909±5,30009	24,9091±4,43744
11-20	4	22,0000±6,05530	45,5000±17,44515	24,5000±9,60902	20,7500±4,11299
P Value		0.307	0.062	0.929	0.297
Races					
Thoroughbred	10	23,4000±4,03320	37,3000±12,59674	24,9000±5,78216	22,2000±3,73571
Arabian	2	24,5000±7,77817	33,5000±12,02082	24,0000±5,65685	24,5000±3,53553
Belgian	8	26,6250±3,662063	2,6250±6,39056	25,8750±6,28916	25,8750±5,16686
P Value		0.295	0.634	0.902	0.233
Gender					
Female	10	23,3000±4,69160	32,7000±10,03383	23,5000±4,76678	22,6000±4,24788
Male	10	26,3000±3,40098	37,4000±10,24370	26,9000±6,27960	25,2000±4,58984
P Value		0.119	0.314	0.189	0.205
Coat color					
Bay	5	23,4000±5,59464	44,2000±15,30359	25,8000±9,93479	22,2000±5,76194
Dapple gray	3	24,6667±4,93288	33,6667±11,71893	26,3333±5,68624	27,6667±5,13160
Chestnut	8	25,7500±3,53553	32,1250±4,79397	25,3750±2,97309	23,6250±2,97309
Black	4	24,7500±4,78714	30,5000±2,08167	23,2500±4,99166	23,7500±5,18813
P Value		0.842	0.126	0.902	0.445

that the thoroughbred breed horses found in the study mostly have bay coat color.

From the dataset, it appears that the age of the horses did have some influence on their physiological responses to exercise. In terms of temperature, older horses generally tended to exhibit a smaller increase in body temperature immediately after exercise compared to younger horses. The body temperatures of horses with an age range of 11-20 were found to be higher than 2-10 age range other horses immediately after exercise. For instance, horse number 1, the oldest horse at 18 years, experienced a temperature increase of 2.4°C after exercise, while younger horses like horse number 16 (2 years old) had a smaller increase of 0.5°C. This suggests that older horses may have a reduced ability to dissipate heat during exercise. Thoroughbred horse named Wanessa was exercised on grass and a sudden increase in body temperature and pulse rate was detected after the exercise. Similarly, the sudden increase in the values of Victoria working on the sand ground was also noticeable. Some older horses (10-18 age range) showed a more significant increase in pulse rate immediately after exercise compared to younger ones (2-10 age range). For example, Horse Number 1 (18 years old) had a pulse rate increase of 20 beats per minute, while Horse Number 16 (2 years old) had a smaller increase of only 2 beats per minute. This indicates that older horses may have a more pronounced cardiovascular response to exercise. The impact of age on respiratory rate was variable. Horse Number 1 (18 years old) exhibited a substantial increase in respiratory rate, suggesting a heightened response to exercise, while Horse Number 16 (2 years old) had a relatively modest change in respiratory rate. This implies that the influence of age on respiratory responses may vary among individual horses. The extended lifespan of horses has spurred research interest in exploring how aging influences the typical physiological processes in equines (Anggraeni and Muhammad, 2024; Jarvis *et al.,* 2017; Ralston, 2006; Ralston and Breuer, 1996; Verdegaal *et al.,* 2024). In this study, it was observed that aging causes physiological changes in horses.

One of the important point was the nutrition same of the horses considered in the present study. In our study, the diet of the horses was the same. It was thought that it would be appropriate to develop feeding models according to age. In the case of older horses, there is substantial evidence indicating a reduction in both maximal oxygen capacity and exercise performance (Betros *et al.* 2002; Seals, 1993). This decrease in maximal heart rate may impose limitations on their ability to engage in demanding physical activities (Taffett, 2003). Remarkably, McKeever and Malinowski's research unveiled that submaximal oxygen consumption levels were relatively consistent between young and old horses during an incremental exercise test. However, it was observed that older horses expended less effort to reach this submaximal oxygen consumption level compared to their younger counterparts (McKeever and Malinowski, 1997; Malinowski *et al.* 2002).

Padalino *et al.* (2014) conducted a research study with the aim of investigating how various physical exercises impact the physiological and behavioral responses of

Standardbred trotters (Seals 1993). Acording to this study all the physiological parameters measured showed an increase following exercise, with the extent of increase correlating with the intensity of the exercise (Padolino *et al.* 2014).

Horses participating in various exercise types exhibited differences in temperature changes immediately after exercise. For instance, horses engaged in show jumping exercises often showed notable temperature increases compared to those in free rides or lounge exercises, indicating that the intensity and nature of the exercise type influenced thermal regulation. Miraglia *et al.* found a positive correlation between the increase of temperature and exercise intensity (Miraglia *et al.,* 2000). Since it is well known that thermoregulation is impaired in poorly trained horses (Hodgson *et al.,* 1994).

The exercise type had a pronounced effect on pulse and respiratory rate changes. Horses involved in activities like show jumping generally displayed more significant increases in pulse and respiratory rate immediately after exercise compared to horses engaged in free rides or lounge exercises. Horse Number 7 (Thoroughbred, Male, Age 7) experienced a remarkable increase in pulse rate (from 20 to 23 beats per minute) and a considerable rise in respiratory rate (from 26 to 32 breaths per minute) immediately after exercise. This suggests that the cardiovascular demand and intensity of exercise varied depending on the type of activity. In contrast, horses participating in free ride exercises, like Horse Number 8 (Hanoverian, Female, Age 9), demonstrated a milder pulse rate increase (from 28 to 30 beats per minute) and a moderate change in respiratory rate (from 30 to 27 breaths per minute) immediately after exercise, indicating a different physiological response compared to show jumping. The dataset illustrates that exercise type significantly impacted the horses' physiological responses, emphasizing that the nature and intensity of the exercise play a crucial role in shaping how horses respond in terms of temperature regulation, cardiovascular responses (pulse rate) and respiratory function. The pulse value has the highest change in Thoroughbred horses. It is normal for the pulse to rise rapidly in high-burst sprint horses such as Thoroughbred and Standardbred (McCutcheon *et al.* 1999).

The duration of exercise significantly influenced physiological responses. Longer exercise periods were associated with more pronounced changes. For instance, Horse Number 7 (Thoroughbred, Male, Age 7), engaging in a 40-minute show jumping exercise, exhibited a notable increase in respiratory rate (from 26 to 32 breaths per minute) immediately after exercise, indicating the prolonged respiratory effort. In contrast, Horse Number 3 (Thoroughbred, Male, Age 6), involved in a shorter 15-minute Lounge exercise, had a relatively modest change in respiratory rate (from 26 to 27 breaths per minute), illustrating the impact of exercise duration on respiratory responses.

The choice of exercise ground had an impact on the horses' physiological responses. Horses exercised on different ground surfaces (sand or grass), displayed variations in temperature changes immediately after exercise. For example, some horses exercised on sand exhibited more substantial temperature increases compared to those on grass, suggesting that the ground surface played a role in thermal regulation during exercise. While the effect of exercise ground on pulse rate changes was less consistent across the dataset, some horses on specific ground surfaces experienced more pronounced increases in pulse rate after exercise. Exercise ground also appeared to affect respiratory rate changes. Horses exercised on sand, for instance, often exhibited slightly higher increases in respiratory rate compared to those on grass.

The temperature values 1 hour after exercise vary among the horses, but they are generally closer to the pre-exercise values. The pulse rate values 1 hour after exercise also show variability among horses. Some horses, like Horse 7, exhibit pulse rates that are similar to their pre-exercise values, while others, like Horse 12, show a slight decrease in pulse rate compared to the immediate post-exercise values. Overall, there is no significant deviation from pre-exercise baseline pulse rates 1 hour after exercise. The respiratory rate values 1 hour after exercise vary among the horses. Some horses show respiratory rates that are similar to their pre-exercise values, while others exhibit different rates. For example, Horse 1 had a respiratory rate of 16 breaths per minute before exercise and 1 hour after exercise, indicating a return to the baseline level. In contrast, horse 7 had a respiratory rate of 26 breaths per minute before exercise, which increased to 28 breaths per minute 1 hour after exercise, indicating a slightly elevated respiratory rate. Overall, the data suggests that respiratory rates 1 hour after exercise vary among horses and not all horses returned to their pre-exercise baseline levels. It has been seen that similar results were obtained with the studies conducted (Farooq *et al.* 2019; Padalino and Raidal, 2020).

CONCLUSION

In conclusion, the analysis of the dataset on horse physiological responses to exercise underscores the multifaceted impact of exercise type, exercise period and exercise ground on equine well-being. These factors play pivotal roles in shaping the horses' temperature, pulse rate and respiratory rate, reflecting their dynamic adaptability to various training regimens and environmental conditions. Exercise type revealed distinct physiological signatures, with activities like show jumping invoking more substantial cardiovascular and respiratory demands compared to free rides or lounge exercises. This insight emphasizes the importance of tailoring exercise programs to the specific needs and abilities of individual horses, taking into account their chosen activities. The duration of exercise also exerted a noticeable influence, with longer exercise periods resulting in more pronounced physiological changes. Horses on sand often exhibited slightly higher post-exercise temperatures and respiratory rates, suggesting that the ground surface plays a role in thermal regulation and breathing patterns. These findings collectively highlight the intricate interplay of exercise type, duration and ground surface in shaping equine physiological responses. Horse owners, trainers and veterinarians can benefit from this knowledge to optimize exercise regimens and safeguard the health and performance of their equine companions. By considering these factors, we can ensure that our horses thrive in their training environments and achieve their full potential while maintaining their well-being.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee.

Author contributions

Y and M contributed to the data acquisition, interpretation of data and wrote the manuscript. All manuscript authors have read the manuscript and approved it for submission.

Conflict of interest

The authors affirm that they have no conflicts of interest related to the publication of this paper. None of the authors involved in this research have any financial or personal affiliations with individuals or organizations that could potentially exert undue influence or introduce bias into the paper's content.

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