UNIVERSITI PUTRA MALAYSIA

VARIATION OF PERFORMANCE OF ENDURANCE HORSES WITH THE CHANGE OF ENVIRONMENT TEMPERATURE AND HUMIDITY

AHMAD FAHMI BIN MD YUSUF

VARIATION OF PERFORMANCE OF ENDURANCE HORSES WITH THE CHANGE OF ENVIRONMENT TEMPERATURE AND HUMIDITY

AHMAD FAHMI BIN MD YUSUF

FACULTY OF VETERINARY MEDICINE

UNIVERSITI PUTRA MALAYSIA

SERDANG, SELANGOR

DECEMBER 2020

VARIATION PERFORMANCE OF THE ENDURANCE HORSES WITH THE CHANGE OF TEMPERATURE AND HUMIDITY OF SURROUNDING ENVIRONMENT

AHMAD FAHMI BIN MD YUSUF

A project paper submitted to the

Faculty of Veterinary Medicine

Universiti Putra Malaysia (UPM)

In partial fulfilment of the requirement for the

BACHELOR OF DOCTOR OF VETERINARY MEDICINE

UNIVERSITI PUTRA MALAYSIA

SERDANG, SELANGOR

CERTIFICATION

It is hereby certified that we have read this project entitled "Variation performance of the endurance horses with the change of temperature and humidity of surrounding environment", by Ahmad Fahmi Bin Md Yusuf and in our opinion it is satisfactory in terms of scope, quality and presentation as partial fulfilment of the requirement for the course VPD 4999- Final Year Project.

ASSOCIATE PROFESSOR DATUK DR. BASHIR AHMAD FATEH MOHAMED

DVM (UPM), MVS (MELBOURNE), PhD (UPM)

Equine Medicine and surgery

(Supervisor)

ACKNOWLEDGEMENTS

وَمَن يَتَوَكَّلْ عَلَى اللَّهِ فَهُوَ حَسْبُهُ

All praises to the 99 names, for the countless blessings; health, rizq, ilm and well-being.

Specially dedicating my near-final episode of my undergraduate studies, to everyone who was there from the beginning, for every invaluable guidance, every support given, every faith instilled, and every love shown in my quest for knowledge.

You know who you are.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PERBEZAAN VARIASI PRESTASI KUDA LASAK DIMANA PERUBAHAN SUHU DAN KELEMBAPAN SEKELILING

Oleh

AHMAD FAHMI BIN MD YUSUF

No. Matrik: 189869

Penyelia: Profesor Madya Datuk Dr. Bashir Ahmad Fateh Mohamed

ABSTRAK

Analisis retrospektif bertujuan untuk melihat pengaruh suhu dan kelembapan ke atas prestasi kuda berdasarkan parameter metabolik seperti degupan jantung, warna membran mukus, masa pengisian kapilari, mundur kulit dan bunyi usus. Dengan sistematisasi prosedur dan menganalisis parameter yang dinyatakan di atas untuk 8-12 ekor kuda (setiap acara) dalam 10 acara kuda lasak dari 2018 hingga awal 2020 yang diadakan di Terengganu International Endurance Park (TIEP) berdasarkan data dari buku log. Dalam kajian ini, sampel kumpulan kawalan ditetapkan untuk tempat dan kuda dari Royal Terengganu Endurance Stable (RTES). Suhu persekitaran (Darjah Celsius °C) dan kelembapan relatif (%) dikumpulkan dari laman sesawang The Weather Underground yang dimiliki oleh IBM Cloud spesifik di Marang, Terengganu, Malaysia di mana TIEP berpusat. Parameter yang dipilih dibahagikan kepada dua kategori analitik iaitu degupan jantung dan parameter metabolik yang telah diklasifikasikan secara ideal diperhatikan untuk korelasi yang signifikan terhadap persekitaran suhu dan kelembapan. Data untuk setiap kuda dibandingkan dengan

mengasingkan sampel kepada jarak larian (40km dan 80km). Suhu dan kelembapan persekitaran berkorelasi secara signifikan dengan prestasi keseluruhan kuda dan dapat disimpulkan bahawa penerimaan alternatif di mana suhu dan kelembapan persekitaran mempengaruhi prestasi kuda. Walaupun begitu, terdapat banyak faktor yang boleh mengubah pencapaian kuda sepanjang acara bertahan. Ini menunjukkan bahawa kuda akan berprestasi lebih baik di bawah suhu persekitaran yang sejuk dan kelembapan yang lebih rendah sehingga mampu untuk mengurangkan permasalahan metabolik, tekanan haba dan keperluan rawatan pada acara berdasarkan kategori jarak.

Kata kunci: ambien, kelembapan, suhu, prestasi, daya tahan kuda, metabolik, penghapusan.

VARIATION OF PERFORMANCE OF ENDURANCE HORSES WITH THE CHANGE OF ENVIRONMENT TEMPERATURE AND HUMIDITY

By

AHMAD FAHMI BIN MD YUSUF

Matric No.: 189869

Supervisor: Associate Professor Datuk Dr. Bashir Ahmad Fateh Mohamed

ABSTRACT

A retrospective analysis aimed to determine the influence of surrounding temperatures and humidity on the performance of the horses based on metabolic parameters such as heart rate, colour of mucous membrane, capillary refill time, skin recoil and gut sounds. By systematizing procedure and analysing the parameters stated above for a group of 8-12 horses (per event) in previous 10 events from 2018 to 2020 held in Terengganu International Endurance Park (TIEP) based on their performance data recorded in endurance logbooks. In this study, a control group sample was from horses at Royal Terengganu Endurance Stable (RTES). The ambient temperature (Degree Celsius °C) and relative humidity (%) were obtained from The Weather Underground website powered by the IBM Cloud collected at Marang, Terengganu, Malaysia where TIEP located. The selected parameters were divided into two analytical categories which is the heart rate and all metabolic parameters classified were observed for significant correlation with the surrounding temperature and humidity. Data for each horse were compared by grouping up the sample by event distance (40km and 80km) and their loops. Interestingly, the surrounding temperature and humidity significantly correlated with the overall performance of the horses and can be concluded that ambient temperature and humidity influence the performance of horses. Nevertheless, other factors may affect the performances of the horses during the endurance event. Horses will perform better under cool ambient temperature and lower humidity hence reducing incidence of metabolic condition, heat stress and the need for treatments on event based on their distance category.

Keywords: ambient, humidity, temperature, performance, endurance horse, metabolic, elimination.

1.0 INTRODUCTION

1.1 Background

Having a competition or tournaments in hot humid surroundings will put the animals at uncertaint risk because of its high point metabolic range and also linked with high level of heat production, its high up sweating capacity eventually putting a critical risk of alarming dehydration and little surface area to bodyweight ratio compared to other athletic species (Hodgson DR, Davis RE, McConaghy; 1994).

In previous laboratory experiments, an approximately two-fold increase in post-exercise respiratory rate has been observed in horses under hot, humid environment when compared to cool, dry environmental conditions (Hinchcliff et al., 2014). As in same study show that 20% to 25% increase in the respiratory rate of horses during speed and endurance tests in hot environment compared to cool conditions.

In other study, heart rates, recovery time and percent of completion were compared under both high and low ambient temperature and relative humidity during a submaximal incremental field exercise test in horses tested in summer and in autumn and show that heart rates were significantly greater by a mean of 13 beats per minute during exercise in the hot than cool conditions (Hinchcliff et al., 2008).

It is recommended that human athletes training for tournament in hot environments requires their body heat to acclimatize at least 2 or optimally 3 weeks prior leaving for their events. Physiologic improvements can be induced when humans are barely working under heat for 10 to 14 days, although 3 weeks would be optimal. Similar responses were notified in horses in studies conducted prior to the Olympic Games in

Atlanta. As such, it is now a common practice for horses participating in International Level competitions in regions where hot and humid conditions are to be expected to acclimatize well in advance and to arrive at the venue at least a week prior to competition (Noakes, 2003).

These is because complication issues such as heat stress, loss of stamina, and traumatic injuries are crucial concern among trainers. And many eliminations for metabolic disorders in endurance occurred repeatedly in hot and humid countries (Flaminio & Rush, 1998; Lawan, Noraniza, Rasedee, & Bashir, 2012).

As in our current setting, most of the endurance events in tropical countries are flagged off between 4:30 pm – 6:00 pm to take advantage of more pleasant temperature and humidity during the entire ride. This is based more on experience of organising event where the percentage of completion in the endurance race is lower during day-time races when the environment temperature and humidity are not conducive. The endurance performances of horses were assessed through several parameters including heart rate, capillary refill time, colour of mucous membrane, skin tent and lameness. It has been generally observed that overall performance in term of completion is better when environmental temperature is cooler and humidity is lower. Therefore, the data acquired from this study will help to determine the influence of temperature and humidity to the performance of the horses using indicators including heart rate, colour of mucous membrane, capillary refill time, skin recoil and gut sound that could be an encouragement to the organizers or veterinarians to advice and monitor endurance events in Malaysia and subsequent refinement on the current practices to prevent and avoid risks such as heat stress or metabolic consequences.

1.2 Hypothesis

The hypothesis of the study were:

1. Low surrounding temperature have no influence on performance of endurance horses.
2. Low surrounding temperature improve performance of endurance horses.
3. Low humidity have no influence on the performance of endurance horses.
4. Low humidity results in better performance of endurance horses.

1.3 Objectives

To determine whether environmental temperature and humidity (on-event) will effects the performance of horses during endurance events.

2.0 LITERATURE REVIEW

2.1 Effects of surrounding temperature and humidity.

Increase surrounding temperature, relative humidity and radiant power will interrupt the potentiality of animals to release heat, that result in an increase in body core temperature. This condition will commence a compensatory and adjustable mechanisms to reinitiate the body homeostasis and homeothermy (Stott GH; 1981). Therefore, physiologic reaction of the animal when exposed to environmental stress can be evaluated from the variations in body temperature (commonly measured as rectal temperature, respiratory rate and heart rate (Finch et al., 1982; Ayo Jo et al., 1998; Minka Ns et al., 2007). This supported by the results from Yuji Takahasi, Hajime Ohmura, Kazutaka Mukai, Tomoki Shiose and Toshiyuki Takahashi, 2020; that intrinsic evaporation and convection effect may be restricted in hot and humid surroundings with very narrow heat dissipation process.

In human marathon events, it has been revealed that any increase or decrease of ambient temperatures will result in slow running speed and eventually reduction of performances (Ei Helou N, Tafflet M, Berthelot G, Tolaini J, Marc A, Guillaume M et al., 2012). This is supported by a fact from Carlson GP (1985), Mackay-Smith M, Cohen M (1982) that state most of participants in 1996 Olympic Games in Atlanta are concern for the capability of their competition horse to suit with extreme high temperature, with/out high humidity until the decision was made to hold the competitions (Mackay-Smith M, Cohen M; 1994).

Rise in temperature and humidity could also indicates inducing critical factors for extreme tiredness and reduction in horse's speed through the endurance competition. During the events, when humidity increases, the gradient between ambient dew point and skin were impaired and evaporative heat loss will reduce (Geor RJ et al., 2000).

Consequently, the risk of horses having thermal stress and hyperthermia will increase under high surrounding temperatures and humidity because of inadequate rate of thermolysis to avoid progressive rise in body temperature (Marlin DJ et al., 1996). A. Munoz et al., (2017) also prove that a cumulative of ambient temperature (°C) and humidity (%) higher than 110 is a signal of unsuitable conditions for an events to be held and could cause detrimental impact of exhaustion and recommended that the ride should be discard.

Study show meteorologic stressors that gave a detrimental effect towards livestock performance and health are surrounding temperature, relative humidity, thermal radiation and airspeed (Bianca WK; 1976). The most crucial environmental element influencing the body operation of domestic animals is temperature. The animals in tropical and subtropical countries frequently faces heat stress (Vathana S, Kang K, Loan CP, Thinggaard G, Kabasa JD, ter Meulen U; 2002). When temperature flares outside the comfort zone, other climatic causes will have of worthy attention which is the level of humidity, solar radiation and wind speed (FAO Corporate Document Repository; 2007). The capability of the air to sponge up additional moisture is restricted while insufficient cooling will lead to heat stress in a hot and humid climate (Vathana S, Kang K, Loan CP, Thinggaard G, Kabasa JD, ter Meulen U; 2002).

Physical activity that were perform under hot and humid environments will put a limitation for the horse performances. Increased in packed cell volume, heart rate, respiratory rate, and total protein in mature horses been observed in hot (31.3 ± 0.9°C), humid (67 ± 3%) surroundings in comparison with cool (17.6 ± 0.4°C), dry (47 ± 3%) surroundings. Study in humans on the effects of work out in hot, humid condition has also showed high plasma packed cell volume, body temperature at rest and through physical activities, exercising heart rate, enhanced skin blood flow, high stroke volume and decreased circulation of cardiac output between skin and muscle capillary bed and tone down the threshold for onset of sweating (Art and Lekeux, 1995; Marlin et al., 1999).

As a consequence, big range number of eliminations from the size samples studied could be linked with the horse's age and the environmental surroundings at the time of the endurance events (Lawan Adamu, Noraniza Mohd Adzahan, Abdullah Rasedee, Bashir Ahmad; 2013). This expected outcome was also proven by Whiting J; (2009) which states that eliminations may be due to an outcome of thirst reflex associated with extreme loss of water and electrolytes through sweating during high surrounding temperature and humidity.

2.2 Physical parameters.

Several physical parameters are correlated with high risk of elimination for lameness and metabolic disorders (Nagy A, Dyson Sj, Murray JK; 2012). Endurance horses will be eliminated if there is presence of metabolic disorders such as increase heart rate, status of colour and moisture of mucous membranes, capillary refill time, gut sounds intensity and existence of other alarming clinical signs such as neuromuscular and acid-base disorders (Castejon et al., 2006; Munoz et al., 2010). This is the main rationale for analysing the metabolic parameter such as heart rate, colour of mucous membrane, skin recoil, capillary refill time, and gut sounds to observe if there is significant influence from the ambient temperature and humidity level during an events.

To determine how the heart efficiently send the blood throughout the vessels and periphery capillaries, preliminary examination by veterinarian can assess through the colour of mucous membrane (Prichard JC et al., 2008). A pale mucous membrane suggested a reduction of red blood cells (RBCs) or oxygen circulating the peripheral capillaries. This event will eventually lead to severe or continual blood supply deficit, toxaemia and dehydration (Butudom P, Axiak SM, Nielsen BD, Eberhart SW, Schott II HC; 2003). This also has been strongly supported by Pritchard JC et al., (2008) and Rose RJ et al., (2000) that report dehydration in equine species can be assessed through the examination of heart rate, capillary refill time, colour of mucous membrane and skin recoil. The most important atypical of colour of mucous membrane as a horse dehydrates is reddening of the mucous membranes just high up the tooth root and similar observation to the other parts of the tissue and is identified by a sticky and dry appearance (Butudom P, Axiak SM, Nielsen BD, Eberhart SW, Schott II HC; 2003).

Heart rate is one of the criteria that will be affected by meteorologic stress because when exposed to heat stress, heat-intolerant animals will increase their body temperature in parallel to surrounding temperature, in spite of utmost use of thermoregulatory engine (Bligh J, 1970; Johnson KG, 1971; Ayo JO et al., 1998). In addition, heart rate stays more elevated during the hot season and are closely connected to type of physical activities. This is proven in study by Foreman JH and Lawrence LM (1991) that heart rate monitoring during an events is an absolute way of evaluating metabolic and cardiovascular response towards exercise.

Skin tenting is the straightforward sign of dehydration (Pritchard JC et al., 2006; Ettinger Sj et al., 2000). Also known as skin recoil, it is the capability of the skin to get back to its original structure after being lifted up by using the examiner's thumb and forefinger at the shoulder point area, where skin recoil is time span from raised and return to normal shape (Dorrington KI., 1981; Pritchard JC et al., 2006). However, factors that influence the skin recoil status which varies with age and the pathologic condition of the animals cannot be discriminated (Dorrington KI., 1981). Those are more factors that could influence skin recoil as stated by Dorrington KI, (1981) where skin recoil also can be affected by the neck and head posture, motion, anatomical position of the raised skin and the degree to which the skin is stretch away from its original gridline before the force of the pinch is halted.

Capillary refill time signify the potential of the horse to pump blood through the capillaries bed in the mucous membranes of the mouth and is the duration desired for the discoloration to resurface back in the mucous membranes of the mouth after thumb force is gently applied to the gum (AEC Rider's Handbook; 2006). AEC Rider's

Handbook; (2006) state that physical assessment (capillary refill time) is dependable in considering the interior health status of the equine athlete.

The interruption of blood from visceral to muscle distribution can reduce down intestinal sounds or even causing complete ileus (Lawan Adamu, Noraniza Mohd Adzahan, Abdullah Rasedee, Bashir Ahmad; 2013). When the body core temperature rises, blood circulation towards the skin escalating to reach optimum level for heat dissipation into the environment. These mechanisms will indirectly result in a decrease in blood flow to the intestines and central nervous system (Hodgson DR, 2014; Brownlow MA et al., 2016; Bouchama A, Knochel JP, 2005).

The abnormalities of physical parameters combination prior to veterinarian's check in every loop in endurance event reflects the fitness and performance of the horse and signal that the horse is in difficulty and is a candidate for elimination from an endurance competition. The foremost known abnormalities in endurance horses that develops metabolic complication are continuously increase heart rates, synchronous diaphragmatic flutter, dehydration, shifting of electrolytes and fluid and subclinical state resulting in elimination from the race (Schott II HC et al., 2006; Robert C et al., 2010; Adamu I et al., 2010).

In this study, the data parameters were collected from the endurance personal logbook recorded by authorize veterinarian recognize compromised horses using clinical examinations. All the equine athlete must be precisely monitored prior to the vet gates, where it is decided whether the horses are fit enough to proceed the race (Munoz et al., 2010; 2013).

Metabolic physical parameters were analysed in this study as these parameters will be affected by ambient temperature and humidity during the events. Burger and Dollinger (1998) reported elimination due to metabolic disorder in endurance horse events is 24%. While, FEI (Federation Equestrian International) data from endurance event in European countries and Arabian countries record approximately 8% - 10% elimination from metabolic disorders (Nagy A, Murray JK, Dysson SJ; 2014). It is strongly supported that metabolic diseases are second factor of elimination of endurance horses in competition (Ana Munoz et al., 2016). And so, this study was initiated because issue of elimination rates in endurance events was observed to have increase over the years, which is a concern for the sport's ethics and personality (Marlin DJ, McEwen J, Sluyter F, 2008) and maybe affected directly by environmental factors.

3.0 MATERIALS AND METHODS

A retrospective project was managed based on 10 endurance events from February 2018 to January 2020 which was all held in Terengganu International Endurance Park, Terengganu, Malaysia. Only horses from a single club was selected to ensure minimal variation management such as feed, stable management, training and etc. Cumulative endurance events involved in this project were 10 competitions. Data was also restricted to collection by competition at a single locality to minimise variation in terrain and track design.

3.1 Metabolic parameter variables

All horses selected were mix breed with no preference to age and sexes. Heart rate, colour of mucous membrane, capillary refill time, skin recoil and gut sound were obtained from individual log books recorded for 10 events. The parameters are then categorized into two groups the heart rate which is numerical and other parameter which are subjective and analysed as shown below:

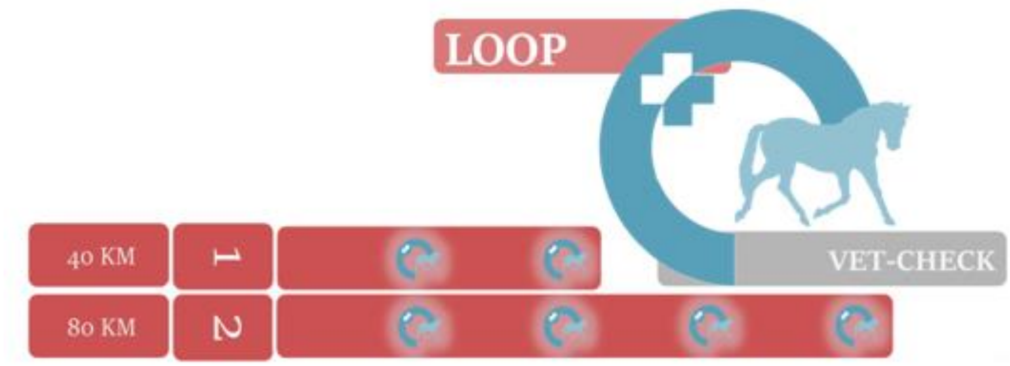
PARAMETER	SECONDS	POINTS
MUCOUS MEMBRANE	A	10
	B	7.5
	C	5
	D	2.5
CAPILLARY REFILL TIME	1-2	10
	2-3	7.5
	3-4	5
	4-5	2.5
SKIN RECOIL	1	10
	2	7.5
	3	5
	4	2.5

GUT SOUNDS	Normal	10
	Mild Decrease	7.5
	Moderate Decrease	5
	Marked Decrease	2.5

Table 1: Analytical score for metabolic parameter based on Federation Equestre International (FEI) Endurance Rules: 10th Edition, effective 2020

All of the data are also categorized into 2 different distance event which is 40km and 80km.

Figure 1: Number of Veterinary Inspection (Loop) in 40km and 80km distance.



As the longer distance the horse is competing, the more loops are covered and each loop with veterinary evaluation (vet-check) will inspect all vital parameters of the horses to ensure their welfare and to acknowledge whether they are fit to proceed to the next loops or been eliminated. The sample size for 40km is 43 horses covering 2 loops while the sample size for 80km is 28 horses with 4 loops in total.

3.2 Environmental Factors variable

Hourly temperature and humidity recorded from The Weather Company website at the competition site which is Terengganu International Endurance Park (TIEP), Jalan Merang, Kuala Terengganu from the start to completion of each race. The data will be analysed using IBM SPSS Statistics software to determine the association between environment temperature and humidity with performance indicators.

Figure 2: Overall Temperature (°C), Humidity (%) and Feels-like temperature (°C) pattern throughout all loops following in 10 endurance events.

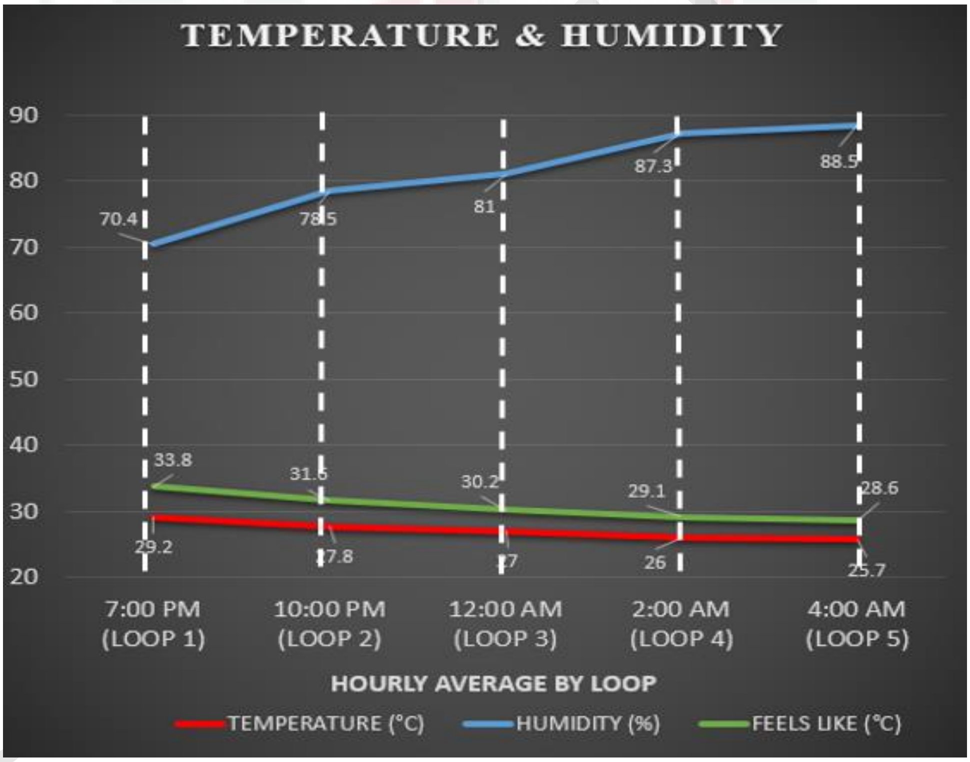


Figure 2 shows the pattern for all the temperature and humidity in this study that were taken hourly by loop as shown in the graph. Temperature will be analysed by degree Celsius, while relative humidity as percentage. "Feels like temperature" was taken into consideration as stated in Met Office News, 2001 that this "Feels like temperature" is mainly to evaluate how a person actually feels the surrounding temperature with influence of humidity.

Thermal stress index is the temperature-humidity index (THI) is also included, which assess the integrate effects of air temperature and humidity. This Equation index for (THI=3.43+1.058xTdb –0.293xRH+0.0164xTdbxRH+35.7) is proved to be the best index having significantly correlated towards respiratory rate, heart rate, rectal temperature and body surface temperature of horses.

Therefore, the dependent variable in this study was heart rate and metabolic rate while the independent variable was the ambient temperature (°C) and relative humidity (%).

Both variables which were performance parameters and ambient factors (ambient temperature, humidity, temperature-humidity index (THI) and feels like temperature are analysed by using IBM SPSS Spearman non-parametric correlation statistics for 2 different distances (40km and 80km) with a total of 75 samples for all the 10 events conducted between 2018 to early 2020. The data were collected from every loops (veterinary check) to assess all the parameters that indicate the horse's performance.

3.3 IBM SPSS statistical analysis

The data was analysed separately by loop and distance to avoid masking of non-significant from different distances and to avoid any overlapping data that will effects the overall results. Distance classification is taken into account to interpret the results.

Therefore, statistical analysis which is Spearman's test were performed for every loop comparing with the respective ambient temperature, humidity and feels like temperature for each distance, to assess if ambient temperature, humidity and feels like temperature has influence on metabolic parameters as well as the overall performance of the horses.

All the horses were classified into distance grouping of 40km and 80km. Appendix 2 to Appendix 6, the mean values for all the variables which is heart rate (HR), metabolic parameter (MP), temperature (T), relative humidity (RH), feels-like temperature (FLT) and Temperature-Humidity Index (THI). These values will be use to analyse the correlation by loop for each group (40km and 80km). All of these values will be in the correlation (Bivariance) data to observe the presence of significant factors.

4.0 RESULTS

4.1 Spearman's Test analytical data result for both 40km and 80km category on the first loop to see significant correlation between variables.

Table 2: Spearman's Test Correlation Statistical Analytical result between variables for each distance on the first loop.

P-values (Loop 1)	**Environ.**	Temperature	Humidity	FL Temp.	THI
Parameter	**Distance (km)**				
Heart Rate	40	.679	.623	.969	.665
	80	.905	.837	.702	.837
Mucous Membrane	40	.206	.680	.658	.707
	80	.612	.670	.741	.707
Capillary Refill Time	40	.657	.693	.672	.639
	80	.634	.397	.512	.526
Skin Recoil	40	.907	1.00	.907	.909
	80	.167	.104	.319	.325
Gut Sound	40	.249	.848	.370	.459
	80	.044	.680	.102	.119

On analysing for both distance category (40km and 80km) for the first loop.

(Table 2) It is obvious that there is no significant difference between heart rate and metabolic parameter towards the ambient temperature and relative humidity. This is mainly seen and simplified by P values which $P>0.05$ that indicate no significant to each other as shown in the results from Loop 1 category.

Therefore, the results for Loop 1 category is accepted null rather than alternative hypothesis which is show that the overall performance is not influenced by the environmental factors.

4.2 Spearman's Test analytical data result for both 40km and 80km category on the second loop to see significant correlation between variables.

Table 3: Spearman's Test Correlation Statistical Analytical result between variables for each distance on the Second loop.

P-values (Loop 2)	**Environ.**	Temperature	Humidity	FL Temp.	THI
Parameter	**Distance (km)**				
Heart Rate	40	.263	.809	.511	.562
	80	.001	.001	.000	.000
Mucous Membrane	40	.493	.874	.798	.546
	80	.628	.314	.436	.484
Capillary Refill Time	40	.608	.140	.434	.798
	80	.054	.246	.093	.056
Skin Recoil	40	.617	.884	.790	.775
	80	.245	.858	.546	.372
Gut Sound	40	.986	.902	.818	.868
	80	.365	.834	.745	.669

Analysing data for the second loop which is the final loop for 40km category.

(Table 3) The heart rate and metabolic parameters for this final loop remaining 20km does not have significant values towards the measured environmental factors (temperature and humidity). This is mainly because 40 km ride is FEI qualification ride and 40km distance is not heavy to affect horse parameter. 40km ride also has control speed and horse is not allowed to exceed 16 km per hour. At this speed level of work, 40 km distance is not stressful enough hence well train fit horses will not be affected by temperature and humidity. Besides, loop distance of 40 km is short compared to 80km category. Therefore, distance covered for each loop of 40 km group of horses is not stressful for a fit horse. In addition, for 80 km category ride, there is no speed limit imposed total and average horse in 80 km ride speed at 15 to 20 km per hour with a first loop for 80 km competition speed average of 20 to 30 km per hour.

Analysis of the second loop 80km category as shown (Table 3), show a significant difference between the heart rate parameter and all of the environmental factors variables. It shows in a blue labelled data which $P<0.05$ that is interpreted as a significant association between both variables.

Referring to the Appendix 2, mean values for heart rate (HR) is 57.14(A), whereas the mean values for ambient temperature, relative humidity, feel-like temperature and THI were 27.98(B), 78.21(C), 32.29(D) and 82.01(E) respectively. All the significant values ($P<0.05$) are positively correlated to each other as for HR (A) towards temperature (B) and humidity (C) with 0.6 strength of correlation factor. While the correlation between HR (A) towards feels-like temperature (D) and THI (E) result is 0.7.

In this 80 km category on the second loop, we could observe that the horses heart rate starts to show an effects which increase in pattern when the ambient temperature and humidity factors rise.

4.3 Spearman's Test analytical data result for both 40km and 80km category on the third loop to see significant correlation between variables

Table 4: Spearman's Test Correlation Statistical Analytical result between variables for each distance on the Third loop.

P-values (Loop 3)	**Environ.**	Temperature	Humidity	FL Temp.	THI
Parameter	**Distance (km)**				
Heart Rate	80	.015	.101	.013	.014
Mucous Membrane	80	.821	.001	.559	.745
Capillary Refill Time	80	.243	.492	.310	.304
Skin Recoil	80	.425	.190	.420	.426
Gut Sound	80	.251	.727	.327	.301

In the third loop, the findings show that the heart rate for loop 3 is significantly positively correlated to all the environmental factors except for humidity as in the P values is less than 0.05.

Analysis of data set for Loop 3 in 80km from Table 4, the heart rate in this category is show significant correlation to ambient temperature only. Based on Appendix 3: mean value for HR is 52.57 (A) whereas the mean values for temperature, feels-like temperature and THI are 27.10 (B), 30.54 (C), 80.19 (D). The tabulate data above shows (A to B), (A to C), (A to D) that compute $P<0.05$ indicate there is significantly correlation between the HR and the environmental factors and also showing positive correlation to each other (0.5). Therefore, when the surrounding temperature and humidity rise, horse's heart rate will increase indicating an effects from the environmental factors.

The result also shows that the mucous membrane for this loop is also significantly correlated to the humidity which having negative correlation between both of them.

When the humidity increase, the mucous membrane will become congested. (Appendix 3): mean value for MM is 1.29 (E) whereas the mean values for humidity (%) is 80.14 (F).

Therefore, in this category, it shows that the horses performance is influenced and affected by the environmental surrounding factors.

4.4 Spearman's Test analytical data result for both 40km and 80km category on the final loop (4th loop) to see significant correlation between variables

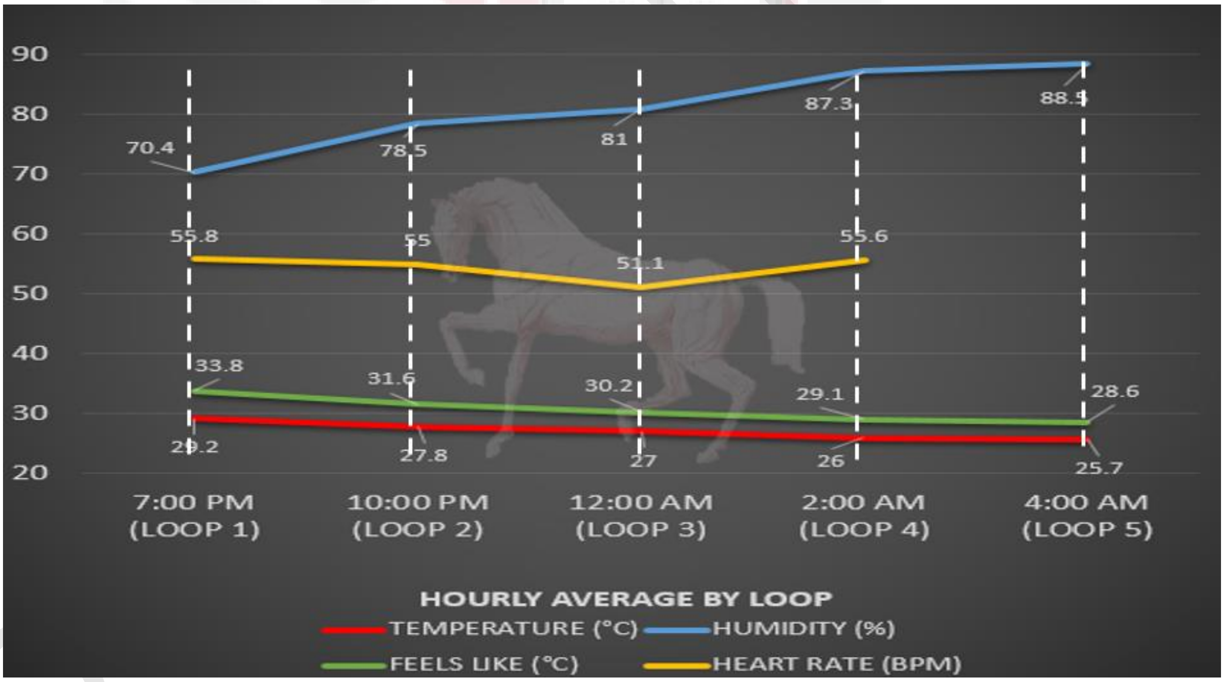
Table 5: Spearman's Test Correlation Statistical Analytical result between variables for each distance on the Forth loop.

P-values (Loop 4)	**Environ.**	Temperature	Humidity	FL Temp.	THI
Parameter	**Distance (km)**				
Heart Rate	80	.150	.390	.362	.263
Mucous Membrane	80	.383	.547	.194	.228
Capillary Refill Time	80	.906	.743	.858	.883
Skin Recoil	80	.678	.186	.775	.646
Gut Sound	80	.406	.630	.649	.504

On the forth loop which is the last loop for 80km category, (Table 5) there is no significant correlation between both metabolic parameter variables and environmental factors variables. This is possibly due to longer recovery period of 30 minutes given at this last loop for 80km which is the 4th loop.

All the results shown above were conclude in Figure 2 below shows that the overall pattern for the temperature and humidity versus the heart rate (bpm) following the respective loop. When the temperature decreases which is cooler, then the heart rate will also be slower but as the humidity rises throughout the night and early midnight, the heart rate rises to prove that eventually high humidity will reduce the capabilities for heat to dissipate faster.

Figure 3: Overall correlation pattern between Heart Rate parameter and Temperature and Humidity factors for all loops for 80km category that showing significant correlation.



5.0 DISCUSSION

Ambient conditions will affect the thermal response to exercise. As reported by Hinchcliff et al., (2008) when ambient temperature surpasses skin temperature (>35-36C), the gradient for heat transfer is reversed and the body collects heat from the environment. As humidity increases, the gradient between skin and ambient dew point is reduced and evaporative heat loss is disturbed. Therefore, during performances under conditions of high ambient heat and humidity, the rate of heat dissipation may be insufficient to avoid the progressive rise in body core temperature based on the results above.

In the final loops of this study for each distance resulting towards no significant correlation between the variables which shows P>0.05, it is may be due to the long recovery provided as compared to other loops as shown in Figure 4. Indirectly this factor also will give an effects for both final loops in 40km and 80 km category that reflects no significant correlation between surrounding environmental factors with overall horse performance.

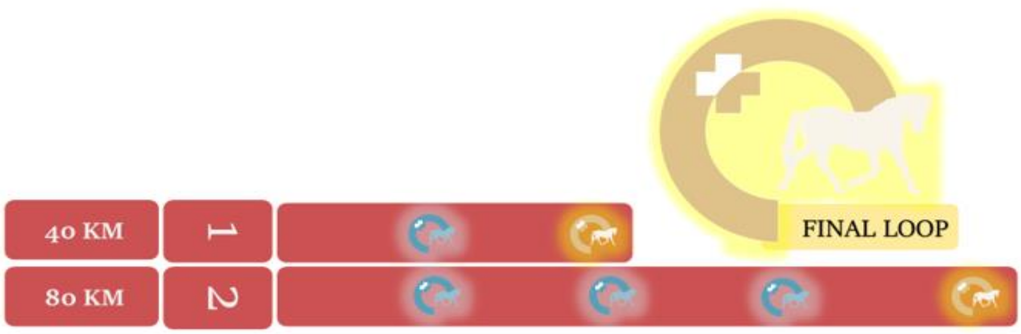


Figure 4: Longer recovery time provided for every final loops before veterinarian check-up that finalized whether there is completion or elimination based on horse vital parameters.

Result shows in 80km category for the second and third loop where there are significant correlation between surrounding temperature and overall horse performance ($P>0.05$). The heart rate parameters is the only parameter that shows the effects towards the environmental temperature and humidity factors.

This is because when the horse performs physical activities under hot and humid surroundings, it will result in a remarkable obstacle to the thermoregulatory system (D.J. Marlin et al., 2001). And Li HX. (1997), reported that as in homosapien, skin is the one and only way for equine species to dissipate their heat; through the high up metabolism and heat production level and heat dissipation, to resulting in the body surface temperature increase. As heat transfer rate from the centre core of the horse body to the outer surface of the body is one of the major way which is via blood vessels for heat to be removed (Mario Rizzo, Francesca Arfuso, Elisabetta Giudice, Francesco Longo, Giuseppe Piccione; 2017).

Therefore, the main physiologic mechanism conducting to heat dissipation is characterized by the increase in cardiac output that leads to heat flow from core to the blood circulation of the skin (Priego Quesada JI, Carpes FP, Bini RR, Palmer RS, Perez-Soriano P, Cibrian Ortiz de anda RM; 2015).

The skin is the biggest organ of the human; and also animal. So, it was the vasodilation process that permits higher blood circulation towards the skin layer to release heat by convection and conduction process; and shift to sweating mechanism if the heat dissipation process does not meet the requirement and could not be compensated (Charkoudian; 2019).

Also declining overall performance of the horses has been showed in the previous study by Kozlowski S. et al., (1986) which states higher heart force load in distributing blood circulation purposely to encourage dissipation of heat faster will eventually give a detrimental effect towards muscle blood flow, oxygen absorption and overall metabolism.

Besides in exposing physical activities towards hot and humid environments will cause the horse having hyperthermia in compensating the heat load in the body. Longer duration with uncontrolled hyperthermia has various effects for athletic performance such as dehydration, decrease circulating blood volume, hemoconcentration, rise in viscosity of the blood and disturbed level and distribution of blood flow, reduced cardiac output are the outcomes of drop right atrial filling pressure and high vascular resistance, and decline in stroke volume. Both skin and or muscle blood flow will be compromised due to reduction of the cardiac output (Nadel ER, Fortney SM, Wenger CB; 1980).

Hyperthermia will eventually amplify the period and rate of sweating and lead to dehydration. As reported by Charkoudian (2010), vasodilation permits more blood to flow via the arteriole, and eventually release the heat by convection and conduction process; but if these process does not meet the body heat dissipation rate, sweating starts. As sweating could be the one and only means of thermolysis in high hot surroundings.

Sweating can eventually cause fluid and electrolyte imbalance. If the body could not compensate, it can result in thermoregulatory imbalance, instability in electrolyte serum composition, and when it keeps being endure, horses can display clinical signs of dehydration that also will interrupt the physical performance (Hinchcliff et al., 2004; Assenza A et al., 2014).

Dragging out sweating process will result in the development of marked dehydration that may eventually reduce sweating rates that will trigger body temperature to rise continuously (Greenleaf JE, Castle BL; 1971). When exercise allowed to proceed in the above situation, then the performance of the horse will drop vigorously as mixture of severe and acute hyperthermia and dehydration may cause a serious threat to health (Hales JRS; 1987, Carlson GP; 1985).

Piccione G et al., (2007) state that sweating process will lead to electrolyte disturbance and resulting in the onset of peripheral exhaustion and weakness. In a worse scenario of hyperthermia, it will increase cardiac output due to elevated heart rate for blood circulation for heat dissipation. When hypovolemia is visible, there is a struggling for blood flow and thermolysis will be reduced by shifting blood to other organs (Flaminio MJ et al., 1996; Naylor JRJ et al., 1993). These condition will eventually lead to low blood flow to the splacnic area that will results in hypoperistaltism which lead to paralytic ileus and clinical signs of colic.

5.1 Factors that may influence the analytical data interpretation.

There were several factors that may influence the overall performance of the horse. All of these factors that this projects cannot discriminate well such as the conditioning program, tactical strategy, the horse rider combination, breed predisposition, sex and age of the horse will be discussed further to recommend for future project taking into control for all this factors.

Conditioning program can be strategized differently to achieve the success point of fitness level, the horse must be subjected to gradually increase in workload with each new level of training being maintained until the horse can fully adapts to the additional stress given. This factor also varies towards difference individual.

Besides, tactical strategy is based on the experience of the rider. Tactical strategy such as cooling method for their animals will eventually give rise to overall recovery for the horses that could manipulate horse recovery. In a study from Yuji Takahashi et al., (2020) showering horses continuously with tap water (at 26°C) was the best cooling method rather than irregular application of cold water (10°C) after exercising in hot and humid conditions. In addition, many riders that participate in an equestrian event anecdotally use scraping off method as they actually does not aware the efficacy level of doing that even by using the help of fans and misting fan (Jeffcot I., I.eung WM, Riggs C; 2009).

Regarding horse rider factor, it shows that the pattern in which a horse is ridden could also stress up the animal (Normando S. et al., 2011; McLean AN et al., 2010). It is also proved that the recovery period of the heart rate is also related to the body weight and the rider weight (Foreman JH and Lawrence LM; 1991). The lack of significance of metabolic disorder in these study may be due to the effects of rider's perspective, the favourable usage of the terrain which was more comfortable for most of the horses which has also been shown by Adamu I., Adzahan NM, Abdullah R, Ahmad B (2012).

Breed predisposition is much more related to influence of the body to adapt to the environmental factors. It is reported by D.J Marlin et al., 2001 that breed may be crucial elements in establishing response to tough physical activity and tournament in hot or humid surroundings. In a study by I. Adamu et al., (2014) and Nagy et al., (2012) and Fielding et al., (2011) that the major elimination could be due to breed's disposition which most of the eliminations were among the Arabian crosses than the Arabian breed.

Also in the previous study that age and horse's experience will eventually influence the overall performance. I. Adamu et al., (2014) show that most of the horses that are successful in completion were mainly between 6-10 years of age and the higher numbers of the elimination from the events were in the 11 to 15 years group. This is may be due to the lack of knowledge or ability for the horse owners and riders to choose the proper training protocols for optimal performance for their veteran horse. Similarly to Harrington McKeever (2003) study that horse's lifetime endurance experience also will effects their performance. Therefore, higher number of elimination in a study could be influenced by the horse's age and the environmental conditions at the time of the race (I. Adamu et al., 2014). These factors which the genetics and breed predisposition are associated with the performance of the equine athlete and it is also supported by findings from Nagy et al., (2012), Fielding et al., (2011), Whiting., (2009), and Harrington McKeever., (2003).

5.2 Recommendation for future studies

To conduct future study, it is recommended to maintain and fix some of the factor as shown in this study such as terrain and track design, feed nutrition prior to competition and the acclimatization factor.

5.2.1 TERRAIN TRACK DESIGN

In this study we could control the terrain and track design for all 10 events that were held in Terengganu International Endurance Park (TIEP). Although some other study controlling of factors by using indoor track design such as in analytical study by Williams et al (2002) that is conducted to determine the influence of surrounding temperature and humidity on thermoregulatory effects on the exercise workout in a laboratory by utilizing a temperature-controlled environment and a high accelerated treadmill. However, it is shown by Hargreaves et al., (1999) that workout established in an indoor accelerated treadmill may not always mimic the actual environment which athlete horses were expose during competition. Foreman et al., (1995) also stated that indoor project cannot be use to assess the real effect of radiant heat load in the course of exercise. Furthermore, the cooling response of the horse trotting into and out of the air differ from the fans that was set-up in front of the accelerated treadmill, and consequences of the terrain, will effects the physiological response (Geor et al., 1996).

This is mainly because certain study has proven that outdoor terrain and track design have significantly influenced the overall performance of endurance horses that could also lead to elimination in competition. As reported by A. Nagy, J.K Murray, S.J

Dyson (2012), higher risk for elimination in several countries maybe due to their terrain and track design. Tough terrain such as slippery, too hard, too soft track, or abrupt changes of track can lead to high elimination rates for lameness, mainly if the speed is fast (A. Nagy, J.K Murray, S.Dyson; 2010). Consequently, exhaustion and change of the interpretation of lameness and metabolic problems that causes eliminations were significantly influenced by the geographical region where the endurance ride was held (Foreman JH 1998).

5.2.2 FEED AND NUTRITION

Diet is also a major factor that could contribute significantly towards horse overall performance.

This is well supported by Kronfeld DS, (1999) study that reports loss of sweat and breath vapour through physical activities are crucially affected by the energetic efficiency of the diet. Dietary composition for equine athlete can influence the efficiency of conversion of the chemical energy (feed) to the kinetic energy of locomotion (performance). Furthermore, their body thermal status and the response to physical activities are strongly influenced by the feeding design together with the energetic efficiency of the diet. Therefore, it is acknowledged that every feature of performance is influenced by feeding management (David S. Kronfeld; 2001). As in this study, feed and nutrition supplied to the horses were set as controlled. This is because all horses were fed with similar kind of feed and diet which are hay, performance diet (Maxwin) and similar electrolyte, that was well managed by Royal Terengganu Endurance Stable (RTES) club.

5.2.3 ACCLIMATIZATION

Acclimatization factor should be considered to be controlled for study as it could probably contribute in changing the overall performance of the horse. As reported by C.Rammerstorfer et al., (2001) state acclimatized horses will eventually perform better rather than un-acclimatized horse. It has been proven in other conducted study that acclimatization can greatly increase the horse's performance to allow thermal load based on the reduction in respiration rate and rectal temperature (Synder JL et al., 1981).

It is expected that group of horses that stay and train in cool surroundings conditions are have higher risk of fatigue if they endure in new manipulated environmental conditions, including high in temperature, humidity and altitude (Nagy A, Dyson SJ, Murray JK; 2012). Marlin DJ, Scott CM, Schroter RC, Mills PC, Harris RC and Harris PA et al., (1996) also state that un-acclimatized horses from cool and dry and hot and dry surrounding will drop their performance under hot and humid conditions.

6.0 Conclusion

From this retrospective study, it is concluded that metabolic parameter through heart rate, colour of mucous membrane, capillary refill time, skin recoil and gut sounds for horse performance are significantly influenced by the ambient temperature, relative humidity and feels-like temperature. The design pattern for all the analytical statistics that were categorized by 40km and 80km were found to significant towards the surrounding climate of Temperature, Humidity and Feels-like temperature.

7.0 Recommendations

It is recommended to control factors that may influence the data interpretation such as conditioning program, tactical strategy from the riders, horse rider combination, breed predisposition, and age of the equine athletes in future studies.

The terrain outdoor design used for competition and feeding are also recommended to be standardised with the 80km or 120km category to give sufficient duration time for environmental factor towards the overall performance of the horses.

In addition, air speed factor from the environment also played a role in dissipating heat from the animal's body during the endurance event. Therefore, study on air speed and movement are also highly recommended.

APPENDICES

	40KM			80KM		
	Count	Mean	Standard Deviation	Count	Mean	Standard Deviation
HEART_R_L1	43	52.56	4.50	28	57.93	5.75
MM_L1	43	1.12	.32	28	1.29	.46
CRT_L1	43	1.12	.32	28	1.29	.53
SR_L1	43	1.05	.21	28	1.04	.19
GS_L1	43	1.33	.57	28	1.32	.48
TEMP_L1	43	29.10	.92	28	29.76	1.10
HUMID_L1	43	69.95	7.37	28	69.75	8.00
FL_TEMP_L1	43	32.79	2.76	28	34.79	4.09
THI_L1	43	82.56	2.37	28	84.02	3.13

Appendix 1: **Animal sample (count); mean; standard deviation on Loop 1 for 40 and 80km category**

	40KM			80KM		
	Count	Mean	Standard Deviation	Count	Mean	Standard Deviation
HEART_R_L 2	43	51.84	5.15	28	57.14	7.55
MM_L2	43	1.19	.39	28	1.54	.64
CRT_L2	43	1.23	.43	28	1.32	.55
SR_L2	43	1.05	.21	28	1.18	.39
GS_L2	43	1.58	.63	28	1.61	.63
TEMP_L2	43	27.41	1.08	28	27.98	1.31
HUMID_L2	43	78.33	4.77	28	78.21	5.34
FL_TEMP_L2	43	30.79	2.53	28	32.29	3.80
THI_L2	43	80.66	2.90	28	82.01	3.68

Appendix 2: **Animal sample (count); mean; standard deviation on Loop 2 for 40 and 80km category**

	80KM		
	Count	Mean	Standard Deviation
HEART_R_L3	28	52.57	8.34
MM_L3	28	1.29	.46
CRT_L3	28	1.25	.44
SR_L3	28	1.04	.19
GS_L3	28	1.54	.58
TEMP_L3	28	27.10	1.67
HUMID_L3	28	80.14	3.43
FL_TEMP_L3	28	30.54	3.08
THI_L3	28	80.19	4.06

Appendix 3: Animal sample (count); mean; standard deviation for Loop 3 for 80km category

	80KM		
	Count	Mean	Standard Deviation
HEART_R_L4	28	55.79	5.97
MM_L4	28	1.36	.56
CRT_L4	28	1.18	.39
SR_L4	28	1.05	.21
GS_L4	28	1.39	.57
TEMP_L4	28	26.02	2.07
HUMID_L4	28	87.50	4.69
FL_TEMP_L4	28	29.18	3.81
THI_L4	28	78.33	5.05

Appendix 4: Animal sample (count); mean; standard deviation for Loop 4 for 80km category

REFERENCES

A. Nagy, J.K. Murray, S.Dyson (2010)

Elimination from elite endurance rides in nine countries: A preliminary study. Equine veterinary journal, 42(38), 637-643.

A. Nagy, J.K Murray, S.J. Dyson (2013)

Descriptive epidemiology and risk factors for eliminations from Federation Equestre Internationale endurance rides due to lameness and metabolic reasons (2008-2011). Equine Veterinary Journal, 46, 38-44.

Ana Munoz, Cristina Castejon-Riberm Maria Esqueva, Pablo Trogo, Francisco Castejon (2017)

Current knowledge of pathologic mechnisms and derived practical applications to prevent metabolic disturbances and exhaustion in the endurance horse. Journal of equine veterinary science, 51, 24-33.

Carolyn Hammer, Mattia Gunkelman (2019)

Effect of different blanket weights on surface temperature of horses in cold climates. Journal of equine veterinary science, 85, 102848.

C. Langdon Fielding, Chloe A. Meier, Olin K. Balch, Phillip H. Kass (2011)

Risk factors for the elimination of endurance horses from competition. JAVMA, 239(4), 493-498.

C.Rammerstorfer, G.D. Potter, G.W. Brumbaugh, P.G. Gibbs, D.D. Varner, E.H. Rammerstorfer. (2001)

Physiologic responses of acclimatized or non-acclimatized mature reining horses to heat stress: Heart rate, respiration rate, lactate, rectal temperature, cortisol and packed cell volume. Journal of equine veterinary science, 21(9), 431-438.

Cristina Castejon Riber (2014)

Field and treadmill exercise tests in the endurance horse: Methodology, measurements and interpretation. 316.

David S. Kronfeld (2001)

Body fluids and exercise: Influences of nutrition and feeding management. Journal of equine veterinary science, 21(9), 417-428.

D.J. Marlin, R.C. Schroter, P.C. Mills, S.L. White, P.L. Maykuth, D.Votion, N.Waran (2001)

Performance of acclimatized European horses in a modified one star (*) three-day event in heat and humidity. Journal of equine veterinary science, 21(7), 341-349.

D.J. Marlin, R.C Schroter, S.L. White, P. Maykuth, G. Matthesen, P.C Mills, N. Warran, P. Harris (2001)

Recovery from transport and acclimatisation of competition horses in a hot humid environment. Equine veterinary journal, 33(4), 371-379.

10th Edition Federation Equestre International (FEI) Endurance Rules (2020)

Points awarded based on Horse's Results, 4.3(3), 69.

Fernande Gatti de Oliveira Nascimento, Hellen Cris Pinto Aguiar, Gustavo Moya Rodrigues, Ednaldo Carvalho, Guimaraes, Mara Regina Bueno de Mattos Nascimento., (2019)

What is the best temperature-humidity index equation to index heat stress in crossbred dairy calves in a tropical environment? V4, n.1.

Hinchcliff, K. W., Kaneps, A.J., Geor, R.J (2008).

Equine Excercise Physiology: The Science of Excercise in the Athletic Horse.

Hinchcliff, K. W., Kaneps, A.J., Geor, R.J (2014).

Equine Sports Medicine and Surgery (Second Edition).

Joseph O. Ayo, Tavershima Dzenda, Friday O. Zakari (2008)

Individual and diurnal variations in rectal temperature, respiration, and heart rate of pack donkeys during the early rainy season. Journal of equine veterinary science, 28(5), 281-288.

Kelly S. Carlson (2017)

Influence of ambient temperature and relative humidity on young performance horses. Sam Houston University, 33.

Lawan Adamu, Noraniza Mohd Adzahan, Abdullah Rasedee, Bashir Ahmad (2013)

Physical parameters and risk factors associated with the elimination of Arabian and crossed Arabian endurance horses during a 120-km endurance race. Journal of equine veterinary science, 34, 494-499.

Maria Rizzo, Francesca Arfuso, Elisabetta Giudice, Francesco Abbate, Francesco Longo, Giuseppe Piccione (2017)

Core and surface temperature modification during road transport and physical exercise in horse after acupuncture needle stimulation. Journal of equine veterinary science, 55, 84-89.

Maria Soroko, Krzysztof Dudek, Kevin Howell, Ewa Jodkowska, Radomir Henklewski (2014)

Thermographic evaluation of racehorse performance. Journal of equine veterinary science, 34, 1076-1083.

Noakes, T.D. (2003).

Lare of running. Ed. 4. Human Kinetics Publishers. p 175.

Nur Zul Izzati Mohd Rajdi, Noraniza Mohd Adzahan, Lawan Adamu, Abdullah Rasedee (2017)

Rates and causes of elimination in Malaysian endurance horses. Article tandfonline: 1447826.

S.P. Webb, G.D. Potter, J.W. Evans, G.W. Webb (1990)

Influece of body fat content on digestible energy requirements of exercising horses in temperate and hot environments. Equine veterinary science, 10(2), 116-120.

Yuji Takahashi, Hajime Ohmura, Kazutaka Mukai, Tomoki Shiose, Toshiyuki Takahashi (2020)

A comparison of five cooling methods in hot and humid environments in Thouroughbred horses. Journal of equine veterinary science, 91, 103130.