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A Study on Basic Physiological Parameters and their Response to Exercise of Exotic Horses (*Equas cabellus*) kept under Sri Lankan Conditions

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ABSTRACT. *A series of experiments were conducted to determine the basic physiological parameters, their diurnal changes and response to exercise in exotic horses reared in Sri Lanka. Thirty two healthy horses (9 Thoroughbreds and 23 Selle Fransiasis) of the Sri Lanka Police Mounted Division at Colombo, Kandy and Nuwara Eliya were used for the study. Heart Rate (HR), Respiratory Rate (RR) and Rectal Temperature (RT) of individual horses at resting stage (T_0) at three locations were obtained at hourly intervals during 24-hour periods. Environmental Temperature (ET) and Relative Humidity (RH) were measured simultaneously. Individual RT, HR and RR were measured for 21 days, just after completing the following continuous exercise regime (T_1 to T_4) or traffic duty (T_5): T_1:0800-8010 h-walking (speed 100 m/min); T_2:0812-0822 h-trotting (speed 250 m/min); T_3:0824-0834 h-cantering (speed 350 m/min); T_4:0836-0900 h-parading(100 m/min) and T_5: 0800-0930 h-traffic duty. Horses were stabled after exercise/traffic duty and bathed from 1030-1100 h. RT, HR and RR were measured at 1000 h and 1100 h on stabling (T_6) and bathing (T_7). Data were analyzed using correlation, regression and GLM procedures. Overall mean±SD values of resting RT, RR and HR were 101.0±1.3 ^oF, 30.3±23.5 and 35.6±8.6 beats/min, respectively. Resting RT, RR and HR varied diurnally, signifying that ET>75 ^oF were thermally challenging. The RT, RR and HR increased ($p<0.05$) with increasing exercise intensity. Cantering and traffic duty had the most profound effects. Stabling and bathing lowered ($p<0.05$) RT, RR and HR, but not to pre-exercise levels. Close monitoring of physiological indices in horses is necessary during cantering and traffic duty at ET>75 ^oF.*

Keywords: *Exercise, exotic horses, physiological parameters, threshold temperature*

INTRODUCTION

Two main breeds of exotic horses, *viz.,* Thoroughbred and Selle Franciasis, have been importing to Sri Lanka for several centuries. Selle franciasis is a French breed, maintained by the Sri Lanka Police Department, while police Thoroughbreds are of Australian origin. These horses are used for traffic control, crowd control, ceremonial activities and escorting VIPs. The police horses in Sri Lanka are located mainly in three districts; Colombo, Kandy and Nuwara-Eliya. Climatic conditions existing in the three locations are different.

The climatic conditions prevailing during daytime hours in Sri Lanka seem to create thermal stress on exotic horses, especially on those which had been imported from temperate

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countries, when used for daytime duty. For example, in 1998 nine exotic horses imported to Sri Lanka Police Mounted Division (PMD) from Australia and France died within two months period, supposedly due to heat stress (PMD, 1998). By adopting diverse methods such as bathing during day time, providing good ventilation, avoiding exercise (riding) during hot hours, the Police Department was able to prevent further losses of horses. Establishment of physiological norms and threshold temperatures above which the exotic horses are subjected to heat stress under Sri Lankan conditions is needed to prevent recurrence of such incidents, save the valuable horses and facilitate their efficient usage. However, thus far, no study had been conducted in Sri Lanka to establish the physiological norms or determine the threshold temperatures in exotic horses under local conditions. This study was conducted to establish the basic physiological parameters, determine the threshold temperatures and assess the physiological response to exercise in exotic horses under local conditions, with the ultimate goal of averting exposure to thermal stress and making efficient use of exotic horses.

MATERIALS AND METHODS

Location: This experiment was conducted at the PMD of Colombo, Kandy and Nuwara Eliya. Among the three PMD stations, the experimental animals were rotationally transferred at every two months in a way that at any given time there were 12 horses stabled at Colombo, 10 horses at Kandy and 10 horses at Nuwara Eliya.

Animals: Thirty two (32) horses (9 Thoroughbreds and 23 Selle Fransiasis) belonging to the Sri Lanka PMD were used. The respective body weights and ages of Thoroughbred and Selle Franciasis horses were 450-580 kg and 11-19 years, and 550-730 kg and 5-12 years. All 32 horses were in good health condition and had no clinical evidence of disease or lameness. All had been appropriately vaccinated and de-wormed.

Management: Horses stationed at the three PMD locations were managed similarly. At 0600h they were fed with grain diet (8 kg/animal), and taken for exercise (riding) or traffic duty at 0800 h. Exercise was over at 0900 h while traffic duty continued till 0930 h. Between 1030 h and 1100 h the horses were bathed. Grain was offered (8 kg/animal) at 1100 h while in the stables. Then the horses were allowed to rest till 1500 h, and sent for free grazing on the ground for one hour (from 1500 -1600 h). At 1600 h the horses were brought back to the stables. Feed was offered again (8 kg/animal) at 1800 h. Horses had *ad lib* access to water at all times except during exercise (riding)/traffic duty periods. The days on which the horses were not sent for exercise traffic duty, they were kept in stables and subjected to other routine management practices.

Treatments:

Resting (T_0): Horses (n=32) were kept in stables under routine feeding and management practices at three PMD locations without being sent for exercise/traffic duty.

Exercise (T_1 - T_4): Below indicated routine exercise regime was given to the horses from 0800-0900 h. Of the 32 horses, as a routine, only 7, 5 and 5 horses were sent for exercise (rotational basis) on any given day at Colombo, Kandy and Nuwara Eliya PMD stations, respectively. These horses were used to obtain measurements on response to exercise.

T_1: 0800-8010 h-Walking (speed 100 m/min)
T_2: 0812-0822 h- Trotting (speed 250 m/min)
T_3: 0824-0834 h- Cantering (speed 350 m/min)
T_4: 0836-0900 h- Parade training/walking (100 m/min)

Traffic duty (T_5): Of the 32 horses, as a routine, only 5, 5 and 5 horses were sent for traffic duty from 0800 - 0930 h (rotational basis) on any given day at Colombo, Kandy and Nuwara Eliya PMD stations, respectively. These horses were used to obtain measurements on response to traffic duty.

Stabling (T_6): The horses were stabled following exercise (riding) from 0900 h or after traffic duty from 0930 h till 1000 h. These horses were used to obtain measurements on response to stabling.

Bathing (T_7): After stabling, the horses were bathed from 1030 h to 1100 h. These horses were used to obtain measurements on response to bathing.

Measurements: To estimate the normal physiological parameters and their diurnal changes, individual RT, RR and HR were obtained from individual horses at resting stage (T_0) at hourly intervals during 19 different 24-h periods (Colombo-8 periods, Kandy-4 periods and Nuwara Eliya-7 periods). There were 12 horses at Colombo, 10 horses at Kandy and 10 horses at Nuwara Eliya for obtaining measurements on resting values of physiological parameters. To relate the diurnal changes in physiological parameters to those of environmental conditions, environmental temperature (ET) and relative humidity (RH) were recorded simultaneously.

Rectal temperature was measured by inserting the tip of a plastic electronic digital thermometer 4 cm into the rectum, and keeping in touch with the rectal wall until it gives the beep sound. The digital value shown on the display was recorded as the rectal temperature (^{0}F).

Respiratory rate was measured by counting the number of exhalation/min while monitoring the airflow after placing the back of the palm against the nostrils of the horse. Simultaneously, thoracic movements resulted from respiration was counted, and the average value of both measurements was taken as the respiration rate (breaths/min).

Heart rate was measured by placing a stethoscope against the chest of the horse under the elbow (olecranon) for a minute and recording the value as beats/minute. At the same time, pulse rate was detected by placing fingers on external maxillary artery or facial artery and counting the pulse for fifteen seconds and then multiplying the value by four to estimate the (pulses/min). The value of pulse rate was used to confirm the value of heart rate.

Environmental temperature and RH were measured using an electronic hygrothermometer (model Oregon-Scientific BA112 Electronic Barometer- USA).

Physiological response to exercise was assessed by obtaining RT, RR and HR from individual horses immediately after completing T_1, T_2, T_3, and T_4 on a total of 21 different days (Colombo-10 days, Kandy-4 days and Nuwara Eliya 7 days).

The effect of traffic duty (T_5) on physiological parameters was examined using individual RT, RR and HR from horses immediately after completing traffic duty (between 0800-0930 h), on 21 different days (Colombo 10 days, Kandy 4 days and Nuwara Eliya 7 days).
The changes in physiological parameters in response to stabling (T_6) after exercise or traffic duty, was determined by obtaining individual RT, RR and HR at 1000h from the horses that were stabled following exercise or traffic duty.

The effect of bathing (T_7) after exercise or traffic duty on physiological indices was assessed by using individual RT, HR and RR at 1100 h from those horses that were bathed from 1030 to 1100 h following exercise or traffic duty.

Statistical analysis

Physiological norms of exotic horses under resting (T_0) condition were determined by estimating the statistical means and standard deviations of resting RT, RR and HR values. Correlation and regression analyses were performed to establish the interelationships among environmental variables and resting physiological indices, and to determine the thermally critical values of environmental conditions for exotic horses in Sri Lanka. During this analysis, obviously wrong values (recording errors) and incomplete data sets were discarded. Only the complete data sets were used for estimating the physiological norms and correlations. Generalized Linear Model (GLM) procedure was used to determine the effect of exercise, traffic duty and bathing on physiological parameters of horses. Duncan's Multiple Range Test was used to compare the means.

RESULTS AND DISCUSSION

Environmental Conditions

Mean values of ET and RH at three PMD locations are given in Table 1. The number of observations used to estimate mean values at each location were different due to differences in the number of 24 h periods in which the data were obtained at each location, and the removal of unreliable/incomplete data sets. Among the three study locations the highest mean ET was recorded at Colombo while the lowest ET was experienced at Nuwara Eliya. Relative humidity fluctuated more than ET in all three locations. Greatest fluctuation in ET and RH were recorded at Nuwara Eliya. In all three locations ET and RH fluctuated diurnally in opposite directions.

Table 1. Daily environmental temperature and relative humidity at 3 experimental locations

Location	Environmental temperature (^{0}F)	Relative humidity (%)
Colombo (n=565)	87.0±5.6	62.6±13.3
Kandy (n=154)	83.9±5.8	56.7±13.3
Nuwara Eliya (n=286)	65.3±10.2	62.6±20.2

Physiological Parameters and their Interrelationships in Exotic Horses at Rest

Table 2 shows the values of RT, RR and HR of exotic horses while resting. The number of observations used to estimate mean values were different due to reasons given above. There was no significant difference between the mean values of RT, RR and HR of the two breeds. Mean RT (99.7±1.7 ºF) and HR (37.3±6.1 beats/min) of exotic horses while resting were within the normal range of 99.5-101.5 ºF and 26-42 beats/min reported by Evans (1988) for equines. However, the resting RR (40.2±20.3 breaths/min) was higher than the normal values of 8-16 breaths/min reported by Evans (1988). Generally, RR increases in response to increase in body temperature, exercise, environmental temperature, pain and excitement (Evans, 1988). Since the horses used to obtain RR in this study were maintained under resting conditions and the body temperatures were within normal levels, this higher RR may be attributed to higher ET prevailing in Sri Lanka compared to the ET in countries of origin of these horses.

Table 2. **Resting h**eart rate**,** respiratory rate **and r**ectal temperature **of the** two **breeds of exotic horses**

Breed	Heart rate	Respiratory rate	Rectal temperature
Thoroughbred (n=351)	37.4±5.8	42.9±16.7	99.7±1.9
Selle Franciasis (n=654)	37.4±6.1	39.0±2.7	99.7±1.7

All three physiological parameters fluctuated during the course of 24 h day at three PMD locations. The relationship among the three physiological indices is given in Fig. 1. Both RR and HR showed a positive relationship with RT. When body core temperature is increased, more blood is diffused towards skin to facilitate heat dissipation through the skin, with resultant increase in HR and skin temperature. Increasing skin temperature increases the RR to facilitate heat dissipation through latent mode (Pollmann & Hornick, 1988).

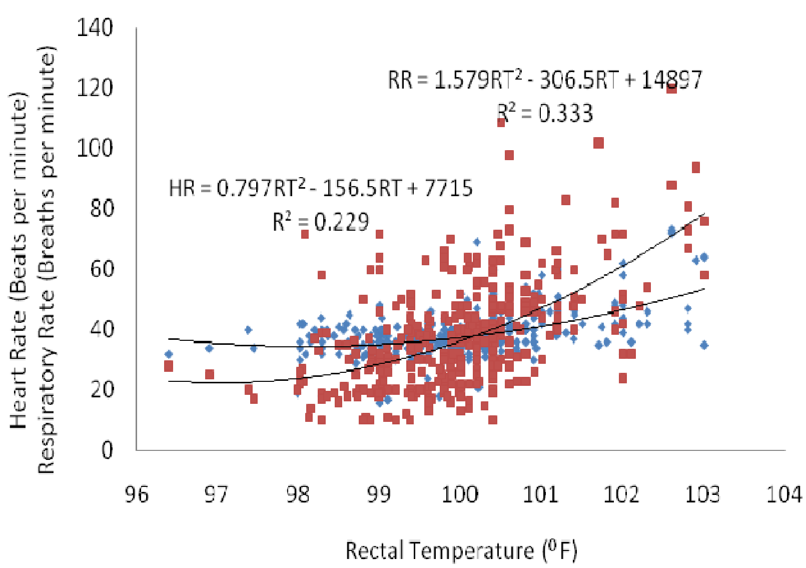

Fig. 1. **Relationship of heart rate, respiratory rate and rectal temperature of horses at rest**

Effect of location on physiological parameters of horses

The mean values of resting RT, HR and RR of horses stabled at Colombo, Kandy and Nuwara-Eliya stations are given in Table 3. Rectal temperatures of horses in Colombo and Kandy were significantly higher ($p<0.05$) than RT of horses at Nuwara-Eliya. When ET is low, heat dissipation from the body surface through conduction and convection is increased due to greater temperature gradient between the skin and the environment. Such augmented heat loss could be attributed to the lower RT observed among horses in Nuwara Eliya.

Table 3. Resting rectal temperature, respiratory rate and heart rate values of exotic horses at three experimental locations

Location	Rectal temperature (ºF)	Respiration rate (breaths/min)	Heart rate (beats/min)
Colombo (n=565)	101.4 ± 1.3^{a}	45.4 ± 21.1^{a}	38.4 ± 7.5^{a}
Kandy (n=154)	101.0 ± 1.1^{a}	23.7 ± 23.5^{b}	34.5 ± 8.3^{b}
Nuwara Eliya(n=286)	100.7 ± 0.7^{b}	21.7 ± 12.1^{b}	33.8 ± 8.6^{b}

$^{a, b,}$ Means with different superscripts within a column differ at $p<0.05$.

Mean RR of horses in Colombo (45.4 breaths/min) was significantly higher ($p<0.05$) than RR of horses in Kandy (23.7 breaths/min) and in Nuwara Eliya (21.7 breaths/min). Heat loss through respiratory evaporation becomes accelerated under conditions of high environmental temperatures and low humidity/ thermal stress (Morgan, 1997). Higher RR in Colombo could be indicative of the prevalence of stressful thermal environmental condition in this location.

Mean HR of the horses was significantly ($p<0.05$) higher in Colombo (38.4 beat/min). Heart rate indicates health status, excitement, thermal status and blood volume. Since the horses used for this study were in good health status and HR was measured under resting stage, high HR may be indicative of the prevalence of thermal stress. Collectively, these physiological parameters suggest that Nuwara Eliya as the least thermally stressful and Colombo as the most thermally stressful location for horses of the PMD in Sri Lanka.

Environmental factors and physiological parameters

In order to identify the most significant variables that affect physiological indices and thermoregulation of horses, hourly values of physiological indices were correlated with respective hourly values of ET and RH. Correlation analysis (Table 4) suggests ET as the main environmental variable that exerted the highest influence on RT, RR and HR. When ET increases, temperature gradient between horse skin and the environment reduces, sensitive modes of heat dissipation (conduction, convection and radiation) through the skin becomes impaired, and the resultant heat load induces heat dissipation through latent mode *via* respiratory and sweating pathways (Mansmann *et al.*, 1982).

The relationship of resting RT, RR and HR with ET (Fig. 2) were further analyzed to determine the critical values of ET that elevate the physiological indices above the norm. Of the three indices RR had the highest correlation with ET, followed by RT and HR. The absence of a significant relationship of HR with ET confirms the findings of Morgan (1997).

Table 4. Correlation coefficients of resting rectal temperature, respiratory rate and heart rate with environmental temperature and relative humidity

Physiological /environmental parameter	Environmental temperature	Relative humidity
Rectal temperature	0.47 [a]	-0.13
Respiratory rate	0.58 [a]	-0.05
Heart rate	0.23	-0.28

[a] Correlation between two variables is significant at $p<0.05$

In this study, RR increased with ET gradually to reach above normal levels when ET increased above 75 ºF. Similar elevation of horse RR with ET has been reported by Morgan (1997). The results of this study suggest that ET above 75 ºF as thermally challenging to horses in Sri Lanka even at resting stage.

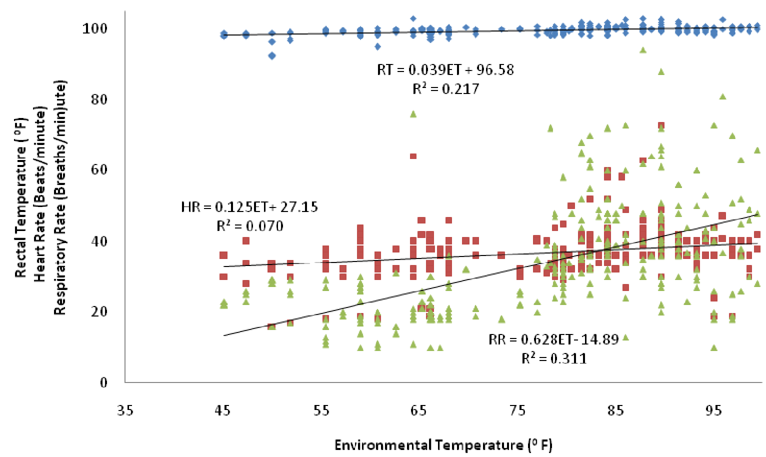

Fig. 2. Relationship of resting rectal temperature, heart rate and respiratory rate of horses with environmental temperature

Effect of exercise on physiological parameters

Mean RT, HR and RR of horses before and after different exercise regimes are given in Table 4. Mean resting RT of exotic horses before exercise under local conditions (99.7±1.7 °F) was within the normal range of 99.5-101.5 ºF reported for horses (David & Kathrin, 2002). Exercising of horses started at 0800h. After 10 minutes of walking at an approximate speed of 100 meters per minute, the RT increased to 100.2±1.0 °F. This RT was not significantly different ($p>0.05$) from that of the resting stage. After a further 10 min of trotting at an approximate speed of 250 m/min, RT reached a value of 101.1±0.9 °F. Although this increased RT was not significantly different to the RT after 10 min of walking, it was significantly higher ($p<0.05$) than resting RT ($p<0.05$). Further 10 min of cantering at an approximate speed of 350 m/min, elevated RT significantly ($p<0.05$) to reach the highest value of 103.4±1.7 °F. Mackay-Smith & Cohen (1982) reported that the horses can facilitate chemical dynamics of contraction untill muscle temperature increases up to about 103.1 ºF. The RT after 10 min cantering was at or above this level. Thus, it appears that, under this exercise regime, cantering increases body temperature to a critical point above which dynamics of muscle contraction may be impaired.

Heart rate of horses after 10 min of walking speed of around 100 m/min increased ($p<0.05$) to 45.2±6.3 beats/min (Table 5), from 37.3±5.7 beats/min at resting stage. After 10 min of trotting at a speed of about 250 m/min, HR further increased to 56.0±5.3 beats/min (Table 5). After 10 min of cantering at a speed of about 350 m/min HR increased to 62.0±13.0 beats/min. Such an increase in HR in response to increased exercise intensity has been reported by Betros *et al*. (2002)

Respiratory rate of horses increased significantly ($p<0.05$) to 55.3±20 breaths/min (Table 5) after 10 min of walk compared to the RR observed prior to exercise (40.2±19.4 breaths/min). Increased demand for oxygen for muscles that become active during walking may have contributed to this increase in RR. After 10 min of trotting the mean RR increased ($p<0.05$) further to 78.6±2 breaths/min (Table 5), while 10 min of cantering increased RR ($p<0.05$) to 96.0±28.7 breaths/min (Table 5). Positive relationship between RR and exercise intensity could be attributed to increased demand for oxygen for muscular activity with increasing exercise intensity (David & Kathrin, 2002).

When the simultaneous changes that took place in RT, HR and RR of horses in response to exercise, is considered it became evident that these indices changed in parallel with increasing exercise intensity. While the changes in RR were of greater magnitude, the RT reached upper limits. When exercise intensity increases, circulatory changes take place to divert more blood towards muscles and less blood to the skin. This could negatively affect the heat dissipation through the skin. Under such situation either the intensity of exercise or environmental conditions should be modified to facilitate sufficient heat dissipation. Even though this exercise regime was not considerably heavy, the respiratory heat dissipation has not been able to compensate the generated heat load to maintain RT within normal limits. Elevation of RT above 103.1 ºF has been reported to be critical for horses (Mackay & Cohen, 1982). Thus, special care must be taken to monitor physiological indices when horses are routinely exercised (especially during cantering) at ET of more than 75 ºF under local conditions.

The RT reduced to 102.6±1.5 °F after 30 min of walking at a speed of 100 m/min following cantering. HR and RR also declined (Table 5) significantly ($p<0.05$) to 46.9±10.0 beats/min and 80.3±30.7 breaths/min, respectively. These changes indicate that horses were able to return to normal HR within 30 min of cooling down after exercise, while RR did not returned to normal level. The reduction of RR after 10 min of cantering could be due to less oxygen demand or less need to dissipation of heat in walking horses compared to cantering horses.

Subsequently, even after horses were stabled and rested till 2000 h, HR did not change and retained around 47.2±13.4 beats/min, while RR also remained unchanged 85.5±23.7 breaths/min (Table 5). RT also retained higher than pre exercise values. None of the parameters returned to pre exercise values despite an hour long resting. This suggests that one hour of stabling after exercise is not sufficient for the horses to dissipate heat load acquired during exercise.

After one and half hours (0800-0930 h) of traffic duty, the RT, RR and HR of horses increased to a level higher than the value after trotting (Table 5). Mean HR, RR and RT of horses after one and half hours (0800-0930 h) traffic duty were 50.0±2.3 beats/min, 90.0±29.0 breaths/min and 101.8±1.8 ºF (Table 5), respectively. This high RR following traffic duty could be due to increased oxygen demand and greater heat load from direct sun light to which horses were exposed for one and half hours continuously. During traffic duty, the horses wore decorated blankets unlike during normal exercise. Those blankets cover a large area of the body surface and prevent evaporative heat dissipation. Heat gain from direct sunlight and reduced surface area for convective heat loss and air movement for heat dissipation could have increased heat load and respiratory rate of horses which performed traffic duty covered with blankets under direct sun light. Increase in RT could be attributed to heat generation through muscular contraction during traffic duty and radiation heat gained from direct sunlight. None of the parameters returned to pre traffic duty values despite half an hour of stabling resting. This suggests that ½ h of stabling following traffic duty is not sufficient for the horses to dissipate heat load acquired during traffic duty.

Bathing of horses sent for exercise or traffic duty after stabling significantly reduced ($p<0.05$) RR and RT to 69.5±14.7 breaths/min and 101.3 °F, respectively, but HR did not change (Table 5). This indicates the effect of bathing in body heat dissipation through conduction, convection and evaporation. However, none of the physiological indices returned to pre-exercise or pre-traffic duty values.

Table 5. Rectal temperature, heart rate and respiration rate of horses subjected to different exercise regimes

Time of measurement (h)	Exercise intensity	Rectal temperature (ºF)	Heart rate (beats/min)	Respiration rate (breaths/min)
0800 (T_0)	Before exercise	99.7±1.7[a] (n=125)	37.5±5.7[a] (n=125)	40.3±19.4[a] (n=125)
0810 (T_1)	After 10 min walk (speed 100 m/min.)	100.2±1.0[ab] (n=125)	45.2±6.3[b] (n=125)	55.4±20.7[b] (n=125)
0822 (T_2)	After 10 min trot (speed 250 m/min.)	101.1±0.9[b] (n=125)	56.0±5.3[c] (n=125)	78.6±24.0[c] (n=125)
0834 (T_3)	After 10 min canter (speed 350 m/min.)	103.4±1.7[c] (n=125)	62.0±13.0[d] (n=125)	96.0±28.7[d] (n=125)
0900 (T_4)	After 30 min parading (speed 100 m/min.)	102.6±1.5[c] (n=125)	46.9±10.0[b] (n=125)	80.4±30.7[c] (n=125)
0930 (T_5)	After normal traffic duty	101.8±1.8[c] (n=105)	50.0±2.3[bc] (n=105)	90.0±29.0[cd] (n=105)
1000 (T_6)	After stabling (resting)	101.5±1.5[c] (n=230)	47.2±13.4[b] (n=230)	85.5±23.7 [cd] (n=230)
1100 (T_7)	After bathing	101.3±1.8[b] (n=230)	47.2±6.5[b] (n=230)	69.5±16.4[bc] (n=230)

[a,b,c,d] Means within each column with different superscripts differ at $p<0.05$.

Considering the fact that the horses required more than the allocated time of resting, stabling and bathing to dissipate heat gained from exercise after cantering, and that the normal traffic duty elevated physiological indices to a level equivalent to the values achieved after cantering, it can be stated that traffic duty also exerted similar thermal stress on horse as cantering and that the given resting period is not sufficient to dissipate the acquired heat load. Therefore, it is suggested to closely monitor the physiological parameters of horses for signs of stress during traffic duty and cantering at ET of more than 75 ºF, to facilitate prevention of potential harmful effects.

CONCLUSIONS

Environmental temperatures >75 ºF are thermally chalenging to exotic breeds of horses in Sri Lanka. Close monitoring of physiological indices in exotic horses for signs of stress is needed during cantering exercise or traffic duty at environmental temperatures >75 ºF, to facilitate prevention of potential harmful effects. Further investigations are warrented to determine the required length of post-exercise or post-traffic duty stabling period to lower the physiological indices to pre-exercise/ pre-traffic duty levels.

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