EFFECT OF EXERCISE ON THE PHYSIOLOGICAL NORMS OF HORSES

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "**Effect of exercise on the physiological norms of horses**" is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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EXTERNAL EXAMINER

TO MY ADVISOR

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MY FAMILY

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INTRODUCTION

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Horse power was safer when only the horse had it, Will Rogers (1879-1935). The world horse population declined greatly after the second world war, almost to the point where extinction of the species was feared. Since then, the horse population not only has become re-established, but actually has shown an upward trend. While the number of horses used for agriculture has steadily declined, the number used for recreation, racing and breeding has undergone both a relative and an absolute increase.

For the last several years, the type of horses used for sports and military purposes have undergone selection for endurance and speed. As a result of this, race horses of today can easily attain high speed which was not possible earlier. The muscles, tendons, ligaments and bones of the horses used for sports are exquisitely adapted for rapid movements. Muscular performance is directly dependent of the adaptability of the heart, circulation and organs of respiration as well as that of the nervous system. The performance of a horse depends upon several genetically determined factors, but the perfection depends upon the training and nutrition (Gunn, 1975).

Muscles are the agencies by which mechanical work is performed. In its contraction, nutrients are catabolised. The muscle has capacity to utilise energy aerobically as well as anaerobically. In peak muscular activity the glucose is anaerobically broken down in the glycolytic pathway. In this case the end product is lactate, whereas under aerobic conditions glycolysis stop at the pyruvate state, where pyruvate is converted by oxidation to acetyl coenzyme-A, which enters the tricarboxylic cycle for complete catabolism.

Accumulation of certain end products are damaging to the muscles. Training or conditioning eliminates these type of damages (Maynard *et al.*, 1979).

Several physiological norms are reported to be influenced by the microclimate and exercise. The extent to which these norms are influenced by the above two factors is not seen reported in the tropical hot humid conditions of Kerala. Similarly the rate at which the animal recovers to normal stage is also not reported.

Being a highly homeothermic animal, horses utilise various mechanisms like respiration and heart beat for gaseous and nutrient exchange to the tissues and also to keep the body cool. Reports on the rate of increase in these parameters, the rate of utilisation of nutrients and the rate of accumulation of end products according to the gait are scanty and scattered in the tropical climate. Similarly reports relating the rate of recovery of these parameters to normalcy is also scanty.

This work was therefore undertaken to find out useful information on exercise physiology, conditioning of horses and other scientific aspects in equine management.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

There are no other normal stresses to which the body is exposed that even nearly approach the extreme stresses of heavy exercise.

Exercise involves not only the intricate neuro muscular co-ordination of bodily movements but also many complex adjustments of metabolism, respiration and circulation. Practically the entire organism may be involved in the adjustment of living being when work is performed.

The actual co-ordination of movements depends on the nervous system. Energy is needed for the contraction of muscles while exercise. This is executed by complex physical changes involving both anaerobic as well as aerobic chemical reactions. For this purpose the tissue must be supplied with oxygen and excess carbondioxide must be removed from the body. The respiratory and circulatory systems are adjusted automatically for this purpose.

A large proportion of the energy released by the muscle takes the form of heat. This must be removed from the body especially in a hot humid tropical climate (Robinson, 1960).

Body temperature

Organic life depends on reactions by which chemical energy is transformed into heat. The rate of these reactions, is affected by temperature, so that the heat production of living cells will increase two or three times if the temperature is raised by 10°C. The degree of acceleration with rising temperature varies with different chemical reactions. A change in temperature also changes the character of the complicated biological process. This makes a relatively constant temperature. The higher animals have developed a heat regulating device that enables them to maintain a constant deep body temperature, regardless of the temperature of the surroundings.

Homeothermic animals maintain a constant body temperature with only a narrow fluctuation. Extensive work is carried out to record the body temperature of cattle under normal conditions and under hot humid conditions and is reported to range between 38.0°C to 39.5°C (Kibler *et al.*, 1950; Regan, 1951 and Brody, 1956).

The normal temperature in equine is reported to be between 37.7°C to 38.5°C by various workers (Miller and Robertson, 1959; Findlay, 1961; Campbell and Lasley, 1975; West, 1979).

Body temperature of horses under the climatic conditions prevailing at Mannuthy, Kerala was reported to be 37.3°C in the morning and 37.4°C in the afternoon (Cherian, 1983).

Early workers opinioned that body temperature of the animals are affected by age, feeding, stage of pregnancy, ambient temperature, season and humidity (Regan, 1951; Kibler and Brody, 1952; Findlay, 1953; Wrehn *et al.*, 1961; Mullick, 1965; Hafez, 1968; Taneja, 1969).

In horses exercise is one of the most important causes which affect body temperature (Swenson and Reece, 1966).

Guyton (1981) reported that body temperature is influenced by exercise in human beings. He further reported that when excessive heat is produced in the body by strenuous exercise, the rectal temperature can rise by 2 to 5 per cent.

In an elaborate work to study the draught efficiency of crossbred cattle, zebu and buffalo bullocks, Nagpaul *et al.* (1984) reported that temperature, pulse rate and respiration rate increased steadily after the start of work in all group of bullocks. They have further reported that temperature increase was more in crossbred cattle.

Following the onset of exercise there is a marked increase in the metabolic rate to provide energy for muscular contraction. Rose *et al.* (1990) reported a ten to twenty fold increase above resting metabolic rate in response to exercise. They have further reported that in horses taking heavy exercise, this increase is more than sixty fold and may be upto ninety fold. This result is also supported by Seeherman and Morris (1990). Hodgson *et al.* (1993) reported that horse has a low surface area: body mass ratio when compared to human beings and hence enormous demands are placed on the thermoregulatory system of the horse during exercise. The resultant heat stress is reduced to a great extent by evaporative cooling of sweat (Carlson, 1983) and from respiratory tract (Heileman *et al.*, 1990). Due to this regulatory mechanism, the horse, showed only a mild variation in the body temperature irrespective of the changes in the ambient temperature. Cherian (1983) in his report about the variation in the body temperature of horses noted only a nonsignificant variation in the body temperature. This is akin to the studies of Thiel *et al.* (1987) who measured a mean increase of 0.8°C in the rectal temperature in three horses, following six minutes walking, 11 minutes trotting and 14 minutes cantering.

Moderate elevation in the body temperature during exercise is reported to have several advantages. Body tissues provide a sink in which the heat produced due to muscular action can be stored and subsequently dissipated slowly. This process is useful for the subsequent muscular performance resulting in a better performance due to the warming up of the tissue. (Asmussen and Boje, 1945; Astrand and Rodahl, 1986; Hodgson *et al.*, 1993).

It is further reported that mild elevated body temperature is associated with an increase in maximal heart rate and a shift of the oxyhaemoglobin dissociation curve to the right, which could result in an increase in the oxygen delivery to the working muscles during exercise (Goetz and Manohar, 1990; Reeves, 1980).

The heat produced as a result of exercise is dissipated by various mechanisms to bring back the horse to normal condition. The most important of these are radiation, convection, conduction, evaporation from skin and respiratory tract (Mitchell, 1973; Mclean, 1973; Carlson, 1983; Heileman *et al.*, 1990). They have also reported that ambient temperature and humidity plays an important role in bringing back the horse to normalcy. Age of the animal and training of the animal are also important factors affecting the rate of return of the physiological norms to normalcy (Baum *et al.*, 1976; Costill, 1977; Rowell, 1983).

Data presented in the review shows that exercise generates enormous heat load in horses. Inspite of this, equally important mechanism exist in horses for dispersal of heat. As a result of this, horses are able to perform well during exercise with only a minor elevation of body temperature. The rate at which the animal return to normalcy is not reported by research workers.

Respiration

In domestic animals, increased respiratory activity is an important means of heat dissipation especially when the ambient temperature is increased. Respiration is usually the first visible sign of response to heat stress and is placed third in the sequence of adaptive reaction. The unnoticed process of vasodilation and sweating usually occur earlier (Mc Dowell, 1972). Increase in the rate of respiration causes an increased heat loss. The greater the volume of air that could be breathed in, warmed and humidified, the greater the resultant heat loss (Somanathan, 1980).

Scientists working in the field of physiological response of livestock are of the opinion that homeothermic animals maintain a fairly constant rate of respiration but respiration is directly proportioned to the ambient temperature and humidity. It shows an increasing trend as the ambient temperature increases (Kibler *et al.*, 1950;

Regan, 1951; Alcaide, 1953; Beakley and Findlay, 1955; Bianca, 1958; Mullick and Kehar, 1958; Rao and Mullick, 1965).

Increased respiratory activity is an important means of heat dissipation in domestic animals at high temperature. The reaction of breathing in response to heat is reported to have two phases. In the first phase, respiratory rate increases, while the breathing becomes shallower. In the second phase, the opposite occur and the air turn over, increases. The change from the first phase to the second phase is reported to take place in cattle at rectal temperature of about 40.5° C (Herz and Steinhauf, 1978). Following exposure to severe heat stress, at a rectal temperature of 40.6° C the rate of respiration of calves increased from 88 to 218 per minute and then fall to 167 per minute: Breathing at first became shallower and then deeper (Bianca, 1958).

In a study of the influence of solar radiation, air temperature, vapour pressure and wind velocity on the physiological response of dairy heifers, Williams *et al.* (1960) observed that the respiration rate was affected more by solar radiation than by other weather factors.

Raghavan and Mullick (1961) reported highly significant increase in the respiratory rate of buffalo bulls exposed to high ambient temperature.

Cherian (1983) reported the rate of respiration of horses as 18 per minute in the morning and 21 per minute in the evening. He has also reported a highly significant seasonal effect on respiration rate in horses. He has further observed that the mean value observed was much higher than earlier observations in other climatic zones (8-12/minute) (Miller and Robertson, 1959; Breasile, 1971 and West, 1979).

Dietz and Wiesner (1984) reported that the respiratory volume of the horse at rest is about four litres. It may increase during exercise to 15-20 L. Exercise leads to a marked increase in respiratory rate. They have further reported that there is no direct relationship between the respiratory rate and the sequences of foot beats during walk and trot. The respiratory volume and oxygen extraction are increased by training. As the training is increased, the animal no longer breaths at every second beat as in the case of an untrained horse. It breaths at every third or fourth beat. Whereas in the gallop, a direct relationship exist between beat of the gait and respiratory rate. The horse breaths once per gallop sequence. They have further reported that return of respiration to normal initial value takes 10-15 minutes in well trained horses and 25-30 minutes in poorly trained horses. During exercise the amount of oxygen entering the blood in the lungs is increased because the amount of oxygen added to each unit of blood and the pulmonary blood flow per minute are increased (Ganong, 1991).

The respiratory response due to exercise was believed to be due to chemical alteration of body fluids during exercise, including increase in Carbondioxide, increase of hydrogen ions and decrease of Oxygen. But further studies showed that not much appreciable changes take place to the above mentioned factors during exercise.

Guyton (1991) attributed this to the action of the brain and due to the body movements during exercise. According to him, the brain, on transmitting impulses to the contracting muscles, is believed to transmit collateral impulses into the brain stem to excite the respiratory centre, causing a rise in arterial pressure as well as an increase in ventilation. Again during exercise, the body movements especially of the limbs will increase pulmonary ventilation by exciting joint proprioceptors, which then transmit excitatory impulses to the respiratory centre.

Guyton (1991) further suggested that hypoxia developing in the muscle during exercise elicits afferent nerve signals to the respiratory centre to excite respiration. These factors, followed by chemical factors play a significant role in bringing about the final adjustment in respiration required to keep the Carbondioxide and hydrogen ion concentration of the body fluids as nearly normal as possible. Other factors like altitude, hot humid condition, training of the horse and abnormalities in the respiratory system etc. also affect the respiratory response in horses during exercise.

Guyton and Hall (1996) observed that the maximal breathing capacity is about 50 per cent greater than the actual pulmonary ventilation during maximal exercise in human beings. It is this factor that provides safety for athletes giving them extra ventilation than can be called on, in conditions like exercise at high altitude, under very hot conditions and in the case of respiratory abnormalities.

Heart beat

The rate of heart beat provides a particularly good means of the physiologic monitoring. The impulse for myocardial contraction originate within heart itself. This basal rate can be modified depending on demands by the nervous system (Dietz and Wiesner, 1984).

Metabolic influences play an important role in the control of the heart rate. A linear relationship exists between heart rate and metabolism, provided the oxygen requirement is met with. This linearity disappears during work under anaerobic conditions (Stegemann, 1967).

The heart rate like other physiologic parameters, undergoes change in response to exercise and fatigue. Dietz and Wiesner (1984) reported that the functional changes during the course of exercise can be divided into three phases. The adaptation phase is marked by initial adjustments of the circulation and metabolism. This phase is particularly influenced by the intensity of the exercise. Its duration is about 40 seconds during exercise of moderate intensity. This is followed by a stabilization phase in which the measurable parameters like oxygen intake, blood pressure etc. assume relatively constant values. The third phase involves the utilization of maximum performance reserves characterized by the break- down of this equilibrium. The animal is unable to maintain the stability of body functions and exhaustion ensures.

During exercise the stroke volume and cardiac output increase resulting in the acceleration of blood circulation. For this purpose increased amount of oxygen and nutrients are delivered to the working muscles. The nature and duration of training evoke various adaptive changes in the heart and cardiac muscles. Endurance training is associated with a fall in the resting heart rate. This is reported to be due to prolongation of diastolic phase.

A resting heart rate of 27-44 per minute is generally reported in horse. This rate gradually declines until about the age of 4 years. The resting heart rate varies in different breeds (Dietz and Wiesner, 1984). They have further reported that English Thoroughbreds have the lowest range (26-44 per minute). The most frequent rate was 32 per minute. Two year old fillies have higher heart rate than colts of equal age. The difference is about 2-4 beats per minute. This becomes more prolonged during the course of training. Trained horses have lower resting heart rate than untrained horses. The changes in the resting heart rate are considered to be an expression of adaptive cardiovascular changes in response to exercise.

Laguens and Gomez-Dumm (1967) reported that sustained training increases the content of actin and myosin, mitochondria and enzymes for nutrient utilization in the cardiac muscle fibres.

According to Sander *et al.* (1969) the cardiac muscle of the horse has a high content of potassium ions compared to other species, which contribute to the high working capacity of the equine heart.

In race horses heart beat of 58-132 was reported at walk. It is also reported that it is the emotional factor rather than physiological ones, are chiefly responsible for the increased heart rate at the walk (Dietz and Wiesner, 1984).

They have further reported that the heart rate of race horses range between 83 to 129 per minute. Eventhough the heart rate was higher at trot than walk, it showed a declining tendency in sustained trotting.

Wittke *et al.* (1968) and Ehrlein (1970) reported that the heart rate increased considerable in gallop. They have also reported that a clear linear relationship exist between the running speed and heart rate.

The behaviour of heart rate after exercise can be used as a good index of fitness of the animal. As a general rule the heart rate of a conditioned horse returns more quickly to the resting value after exercise than that of an untrained horse. The recovery phase can be divided into three phases. 10 minutes after exercise the heart rate is still relatively high. During the next 10 minutes it decline sharply and slowly return to the normal value over a period of one to several hours (Dietz and Wiesner, 1984).

Stewart (1972) reported a heart rate of 85 per minute after 30 minutes of gallop for a speed of 900 to 950 m/ minute and 60 per minute for a speed of 800 meter per minute.

Nowosinow (1971) measured a recovery period of 20±3.4 minute in sports horses that had performed exercise of moderate intensity. After trotting over about 2000 m, the heart rate of well trained horses return to normal in 50-60 minutes, compared to 70-80 minutes in poorly trained horses. He has further reported that as the fitness of the animal improves with training, recovery proceeds at a more rapid rate.

Haematological response to training

As exercise involve greatly enhanced metabolic activity, it is but natural to expect haematological changes due to work. Many workers have therefore used investigation on the blood pictures as a means of assessing the effect of work on different type of animals. Limits are imposed on muscle performance by the capacity to deliver oxygen and metabolic substrates to the working muscles and the efficiency of removal of waste products from the muscles. Blood is the pathway by which oxygen and substrates are supplied to the muscle and the waste products, including heat, are removed. When an animal exercises, the changes observed in circulating blood are remarkably rapid.

Total erythrocyte count

The cardio vascular system has the ability to transport large quantities of oxygen to working muscles. In the horse and the dog, as well as several other species, the spleen acts as a reservoir of erythrocytes. A large number of erythrocytes can be released to the circulation within minutes following excitement or strenuous exercise. The spleen is capable of supplying an erythrocyte volume equal to about 1/3 of circulating erythrocyte mass (Benjamin, 1974). The release of blood erythrocytes from the spleen into systemic circulation is under the influence of the sympathetic nervous system and circulating catacholamins. The smooth muscle capsule of the spleen is innervated by postganglionic sympathetic neurons. Any factor that increases sympathetic nervous activity or plasma catacholamin, such as asphyxia, haemorrhage, excitement and exercise, as well as excitation; causes an increase in the circulating erythrocyte volume at an essentially unchanged or reduced plasma volume. This results in an increased packed cell volume, haemoglobin concentration and blood cell count.

McLeod *et al.* (1946) reported an erythrocyte count of 9.5 to 11.5 millions/cubic millimetre in Thoroughbreds.

Hansen *et al.* (1950) and Coffin (1953) reported that the normal erythrocyte count for horses ranged from 6.23 to 13.1 million per cubic millimetre.

Hansen *et al.* (1950) reported that erythrocyte count for pregnant mares as 10.52 $\pm$0.102 x 10^6/cubic millimetre. Schlichting (1956) reported a high value of erythrocytes in British Thoroughbred trained horses, (11.93 x 10^{12} per litre).

Schalm (1958) observed that erythrocyte count for cold blooded horses ranged from 5.5 - 9.5 x 10^6 and for hot blooded horses 7 to 13 millions per cubic millimetre.

Singh *et al.* (1968) observed that as a result of exercise there was a decrease in total erythrocyte count.

Sastry *et al.* (1970) observed that the erythrocyte number decreased in Sahiwal bullocks and increased in crossbred bullocks during a submaximal exercise of two hour duration.

Jeffcott (1971) reported that the erythrocyte count showed the following variations according to the age of the horse.

Age	*Erythrocyte count x $10^{12}/L$*
1 month	9.85 ± 1.3
1 - 9 month	10.33 ± 1.2
Yearly	9.91 ± 1.1
2 years	9.86 ± 0.9
3 years	9.71 ± 1.0
4 years	9.28 ± 0.9
Over 4 years	8.80 ± 1.0

According to him the count showed an increasing trend from first month to ninth month and there after a decreasing tendency as the age advances.

The erythrocyte count is affected by age, sex, exercise, nutritional status, lactation, pregnancy, excitement, egg production, blood volume, stage of oestrus cycle, breed, time of day, environmental temperature, altitude and other climatic factors (Swenson, 1977).

The total red blood cell count in equine ranged from 6-12 million/microlitre (Fraser *et al.*, 1986).

Mill and Wolf (1977) observed that there was an increase in erythrocyte count from 10.16 millions to 13.3 millions in horses that were exercised year round. In horses that were exercised only at intervals there was a rise from 8.76 millions to 11.95 millions per cubic millimetre.

Dietz and Wiesner (1984) reported that the amount of erythrocyte release during exercise correlates clearly with the intensity of exercise and a marked increase was observed even after a brief period of strenuous exercise. They have further reported that intensive training lead to a physiologic erythrocytosis in the horse due to hypoxia that accompanied strenuous exercise.

Rubido *et al.* (1996) noted that red blood cell count increased significantly at the trotting and galloping, with a greater increase after galloping. The return to normal level was earlier for trotting than for galloping.

Erythrocyte sedimentation rate

The erythrocyte sedimentation rate reported in horses were between 24 to 60 mm for 30 minutes and hourly sedimentation rates were 51-63 mm by Wintrobe method (Coffin, 1953 and Osbaldiston, 1971).

During sustained physical activity a decline in the fibrinogen content of the plasma was observed. This is reported to be, due to an activation of plasminogen leading to an associated decrease in the erythrocyte sedimentation rate (Takagi and Sakurai, 1971).

ESR is lower after exercise than in the resting state. This decrease is more pronounced in older horses than in the younger ones for the same exercise. Sustained mild exercise produces no change in erythrocyte sedimentation rate.

Marbach (1978) reported that erythrocyte sedimentation rate was more than 3 and less than 51 mm per hour in top performing horses during exercise.

The average erythrocyte sedimentation rate of a trained two year old Thoroughbred horse was observed as 20 mm after 10 minutes rest and 40 mm after 40 minutes rest (Dietz and Wiesner, 1984).

Packed cell volume

The observed packed cell volume in cold blooded horses ranged from 24 to 44 per cent and in hot blooded horses 32 to 55 per cent (Schalm, 1958 and Schalm, 1959). Swenson and Reece (1996) reported that cold blooded (draft) horses usually have packed cell volume (PCV) values from 35 to 38 per cent.

Workers have indicated that haematocrit value increases with age. They have also reported that this value shows an increase after exercise.

Mill and Wolf (1977) observed that there was an increase in haematocrit from 42.2 per cent to 54.5 per cent in horses that were exercised throughout the year and a rise from 40.9 per cent to 57.5 per cent in horses that were exercised only at intervals.

Haematocrit values reported by various workers are as follows.

Age/breed	Value (%)	Author(s)
Thoroughbred less than 1 month	38	Jeffcott (1971)
Thoroughbred 1 to 9 month	34	Jeffcott (1971)
Thoroughbred yearling	38	Jeffcott (1971)
Thoroughbred 2 year	40	Jeffcott (1971)
Thoroughbred 3 year	41	Jeffcott (1971)
Thoroughbred 4 year	41	Jeffcott (1971)
Thoroughbred average	31	Trum (1952)
Thoroughbred trained	43	Brenon (1958)
Thoroughbred trained	44	Sreter (1959)
Thoroughbred average	42	Schalm (1965)

Keenam (1980) observed that the packed cell volume increased from 40 per cent to 53 per cent at the barrier, 68 per cent 10 minutes after racing and 41 per cent three hours after racing.

Haematocrit increased significantly after trotting and galloping with a greater increase after galloping and the return to normal was earlier for trotting than for galloping (Rubido *et al.*, 1996).

Haemoconcentration due to dehydration, asphyxia, or excitement causing release of erythrocytes concentrated in the spleen can result in abnormally high packed cell volume values. A marked increase in the cell plasma ratio of the peripheral venous blood takes place during exertion, with an associated shift of intravascular to extravascular fluid. The increase in packed cell volume (PCV) is a function of exercise intensity, a linear relationship between packed cell volume and speed exists upto a packed cell volume of approximately 60 to 65 per cent. This 'outotransfusion' of erythrocytes during exercise boosts the oxygen carrying of the blood and is thought to be a significant factor contributing to the very high maximal oxygen consumption of the horse and dog compared to other species. Exercise causes little change or a small reduction in plasma volume which is attributed to fluid shift from the intravascular to extravascular compartment as a result of fluid loss through sweating and or panting (Swenson, 1996).

Glucose

In mammalian species the characteristic sugar of blood and other tissue fluids, is glucose. Blood glucose and glucose in certain tissue fluids are drawn upon by cells of the body to produce energy. In aerobic system, the foodstuffs are oxidised to produce energy. Glucose, fatty acids and amino acids from the foods after some intermediate processing combine with oxygen to release tremendous amounts of energy that are used to convert AMP and ADP into ATP.

Loh (1966) reported an average glucose level of 3.5 millimole per litre in cold blooded horses and 3.4 millimole per litre in warm blooded horses. Fraser (1986) reported a glucose level of 62.2 to 111 mg per cent in the blood of horses. Consumption of starch ration show an elevation of blood glucose level from 0.5 to 1.6 millimole per litre (Galle, 1969).

Takagi and Sakurai (1971) observed a 9 per cent decrease in glucose concentration in the short distance run of horses. In the long distance experiment they have observed 20 per cent reduction in the blood glucose level.

Evans *et al.* (1974) reported a rhythmic change over a period of 24 hour period in plasma glucose concentration in horses in which a high value is observed at noon and low value in the morning.

Studies in blood glucose before and after trotting over 2100 metres at speeds of 650 and 730 metre per minute revealed marked differences as function of effort. Scientists in this field of exercise physiology in horses had observed reduction in the level of blood glucose due to exercise (Solun, 1934; Bornert, 1969; Kryzwanek, 1973; Dietz and Wiesner, 1984).

Lukomski and Bienkowski (1977) studied the changes in the level of blood glucose after intravenous administration of glucose and observed that after short, intense exercise blood glucose remained above the original level but after prolonged effort it fell to below the original level and in horses given glucose by mouth or no glucose at all, exercise reduced blood glucose to below normal, particularly after short intense exercise.

Glucose metabolism in the race horse is influenced largely by exercise and the main reason for the change is not an increase in immuno reactive insulin (IRI) sensitivity, but a greater and more rapid secretion of IRI from the pancreas (Takagi, 1983).

Lactic acid

Lactic acid is an end product of glycolysis and is formed by hydration of pyruvic acid that does not enter the Krebs cycles. In most animal tissue, lactic acid forms as an intermediary product only in the presence of an oxygen deficit. Part of the lactic acid formed, enters the circulation and can be demonstrated there. Therefore determination of lactic acid in the serum and muscles is often considered as an index of the internal stress produced by physical exertion.

Considerable variation is noted in the resting value for serum lactic acid level by various workers.

Author	Lactic acid in mmol per litre
Dukes (1955)	1.103 - 1.765
Bohn (1957)	0.849 - 1.147
Wittke and Bohn (1959)	0.982
Schulze (1970)	0.491
Krzywanek (1974)	0.476
Aitkan *et al.* (1974)	0.309 - 1.213
Kolb (1976)	0.662
Dietz and Weisner (1984)	0.331 - 1.765
Swenson and Reece (1996)	1.103 - 1.76

Exercise in the general endurance range such as sustained walking, trotting or cantering is reported to cause little or no rise in the serum lactic acid. The degree of increase depends on the extent and intensity of exercise and the animals stage of fitness.

Wittke and Bohn (1959) reported a negative correlation between respiration and lactic acid level and a positive correlation between pulse rate and lactic acid levels.

Lindholm and Saltin (1974) found that exercise for a distance of 400 meter were too short to produce a rise of the heart rate and lactic acid level. Work outs over six hundred metre at near maximal speed were sufficient to produce lactic acid level like that occurring after a race.

Krzywanek (1974) observed a lactic acid increase from 0.476 millimole per litre to 3.375 millimole per litre after standard exercise in horses that were good performers. In poor performers, the value rose to 6.536 millimole per litre. This level increased further to 9.946 millimole per litre after the exercise.

Snow and Mackenzie (1977) studied the effects of prolonged cantering before and after a 10 week training programme and observed that the exercise caused slight increase in lactate level.

Lucke and Hall (1980) reported that the small increase in blood lactate after long distance exercise in horses was likely to be the result of reduced tissue perfusion and suggested that haemoconcentration with reduced tissue perfusion might contribute to exhaustion during long distance exercise and the speed of recovery might be improved by intravenous administration of the balanced electrolyte solution. Dybdal *et al.* (1980) observed little change in plasma lactate during exercise.

Poso *et al.* (1983) reported that the recovery from the increased lactate level was faster in Standard breeds than in the Finnish breeds and this suggested that the Standard breed horses have higher aerobic capacity than the Finnishbreeds.

The slight elevation of the lactic acid level after exercise, as the animals' stage of fitness improves was reported to be due to an increase in the oxidation capacity of the muscle tissue, better oxidation of the pyruvic acid formed by the glycolysis, a higher NADH oxidase activity and an increase of haemoglobin and myoglobin (Dietz and Wiesner, 1984).

Saibene *et al.* (1985) studied the blood lactate level in horses before and five minutes after galloping over distances of 200, 300 and 400 meter at maximum speed. The highest net lactate concentration of 14-15 millimole per litre was attained by the Polo ponies and the highest speed by the Thoroughbred. The maximum rate of lactate production was about 35 millimoles per litre for the Polo ponies and 20 to 24 millimoles per litre for the Standard breds and Thoroughbreds.

MATERIALS AND METHODS

MATERIALS AND METHODS

The experimental work was carried out on six horses of twleve years of age from the 1(K) R and V Squadron NCC of the Kerala Agricultural University. They were maintained under the normal management practice of the squadron. These horses were divided at random into two groups of three animals. Out of the two groups, first group was subjected to an exercise regime in the first month while other one remained as control. The groups were switched over every month until the experiment was completed.

The control group of animals remained in the stable and their observations were taken. The first set of observations were taken immediately before the start of the exercise in the treatment group while the animals are in the stable. The treatment group was taken to the riding school and was given a carefully planned regime of exercise. The second set of observations were taken immediately after the exercise and the third set of observation were taken after 1 hour 30 minutes rest.

Exercise regime

Consisted of walk (1 minute) trot (5 minute) trot and gallop (5 minute) and gallop (5 minutes).

Observation

In the pre-exercise, post exercise and after rest included physiological and haematological parameter.

Physiological changes

(a) Respiration rate was ascertained with the use of stethoscope and also by counting the movement of coupling region in one minute.

(b) Heart beat was measured over the left side of chest using stethoscope for one minute.

(c) Body temperature was taken by inserting a clinical thermometer deeply in the rectum for one minute.

The physiological parameters were also recorded in the morning at 7.00 AM and in the evening at 2.00 PM on a thrice weekly schedule.

Haematological status

Blood was collected from the jugular vein using ethylene diamine tetraacetic acid (EDTA) as anticoagulant. Total erythrocyte count (Benjamin, 1974) packed cell volume (Benjamin, 1974) and erythrocyte sedimentation rate (Benjamin, 1974) were estimated before the start of exercise and immediately after exercise and after rest.

Serum glucose was estimated by GOD/POD method. Blood lactic acid was estimated by the method of Barker and Summerson (Oser, 1965).

Statistical analysis

Mean and standard error were calculated from the data collected. Comparison was made by using `t' test as suggested by Snedecor and Cochran (1967).

RESULTS

RESULT

Mean ambient temperature recorded in the morning and evening are presented in Table 1 and Figure 1, 2 and 3. Lowest average ambient temperature was recorded in the morning during the month of February (21.68 ± 0.271). During the morning hours, highest temperature was recorded during the months of April-May (24.59 ± 0.142). In the evening the lowest temperature was recorded in the month of July (28.87 ± 0.372) and highest in the month of March (35.63 ± 0.167).

Table 1 Mean ambient temperature (°C)

Month	Ambient temperature		Mean
	Morning	Evening	
December	22.09 ± 0.228	30.31 ± 0.194	26.20
January	23.03 ± 0.228	31.86 ± 0.194	26.94
February	21.68 ± 0.271	33.78 ± 0.211	27.73
March	23.52 ± 0.266	35.63 ± 0.167	29.58
April	24.39 ± 0.142	35.26 ± 0.163	29.80
May	24.39 ± 0.231	34.36 ± 0.186	29.37
June	23.39 ± 0.158	32.30 ± 0.376	27.84
July	22.34 ± 0.148	28.87 ± 0.372	25.60
Mean	22.98 ± 0.383	32.796 ± 0.847	27.88 ± 0.528

On an average the ambient temperature ranged between 25.6 °C in the month of July to 29.8°C in the month of April with an over all mean of 27.88 ± 0.528.

The differences in the ambient temperature recorded between morning and evening were found to be significant. Mean body temperature observed in the morning and evening are presented in Table 2 and Figure 1 and 4.

Table 2 Average body temperature of horses (°C)

Month	Body temperature		Mean
	Morning	Evening	
December	37.52	37.85	37.68
January	37.52	37.89	37.71
February	37.41	37.95	37.63
March	37.56	38.123	37.79
April	37.60	38.12	37.85
May	37.65	37.97	37.79
June	37.53	37.91	37.72
July	37.58	37.64	37.72
Mean	37.54 ± 0.021	37.93 ± 0.051	37.73 ± 0.023

Average body temperature of horses was found to be 37.54 ± 0.021 in the morning. The temperature in the morning was found to vary from 37.41°C in the month of February to 37.65°C in the month of May.

An average body temperature of 37.93 ± 0.051°C was observed in the evening, with a variation of 37.64°C in the month of July, to 38.12°C in the month of March and April.

Eventhough the body temperature was found to show significant variation between morning and evening, a fairly constant body temperature was noticed when it was considered in general (37.63°C to 37.85°C) with an overall mean of 37.73 ± 0.023°C.

The respiration rates observed in the morning and evening are presented in the Table 3 and Figure 2 and 4.

Considerable difference in the rate of respiration was observed in the evening hours. Lowest rate of respiration in the evening hours recorded was 24.13 ± 0.632 in the month of July and highest in the month of March (27.71 ± 0.48).

Mean rate of respiration observed, showed a variation from 20.77 in the month of July to 24.30 in the month of April.

Table 3 Mean rate of respiration of horses per minute

Month	Respiration rate		Mean
	Morning	Evening	
December	17.42 ± 0.434	25.42 ± 0.645	21.42
January	17.75 ± 0.532	26.46 ± 0.531	22.105
February	17.54 ± 0.715	26.99 ± 0.53	22.265
March	19.63 ± 0.541	27.71 ± 0.487	23.67
April	20.92 ± 0.45	27.69 ± 0.43	24.30
May	20.58 ± 0.596	26.58 ± 0.425	23.12
June	19.29 ± 0.491	26.08 ± 0.50	22.68
July	17.42 ± 0.394	24.13 ± 0.632	20.77
Mean	18.82 ± 0.518	26.382 ± 0.501	22.54 ± 0.49

In the morning, the lowest rate of respiration was observed in the months of December, January, February and July (17.42 ± 0.434) and highest in the month of April (20.92 ± 0.45).

Mean heart beat observed per minute in the morning and evening are presented in Table 4 and Figure 3 and 4.

Table 4 Mean heart beat per minute in horses

Month	Heart beat		Mean
	Morning	Evening	
December	24.38 ± 0.385	30.98 ± 0.131	27.67
January	23.79 ± 0.511	31.96 ± 0.638	27.87
February	24.13 ± 0.566	32.78 ± 0.57	28.46
March	25.38 ± 0.561	35.75 ± 0.733	30.565
April	26.29 ± 0.423	35.69 ± 0.631	30.99
May	26.54 ± 0.511	33.17 ± 0.557	29.85
June	25.42 ± 0.317	31.54 ± 0.421	28.48
July	24.63 ± 0.355	29.54 ± 0.482	27.08
Mean	25.07 ± 0.354	32.675 ± 0.771	28.87 ± 0.47

In the morning the lowest heart beat per minute was observed to be 23.79 ± 0.511 in the month of January and highest in the month of May (26.54 ± 0.511).

Comparatively higher heart beat per minute was observed in the evening hours. Lowest heart beat per minute was recorded in the month of July (29.54 ± 0.482) and highest in the month of March (35.75 ± 0.733).

The mean heart beat per minute was found to vary from 27.08 to 30.99 in horses.

The relative humidity observed during the period of research work, in the morning and evening are presented in the Table 5 and Figures 1, 2 and 3.

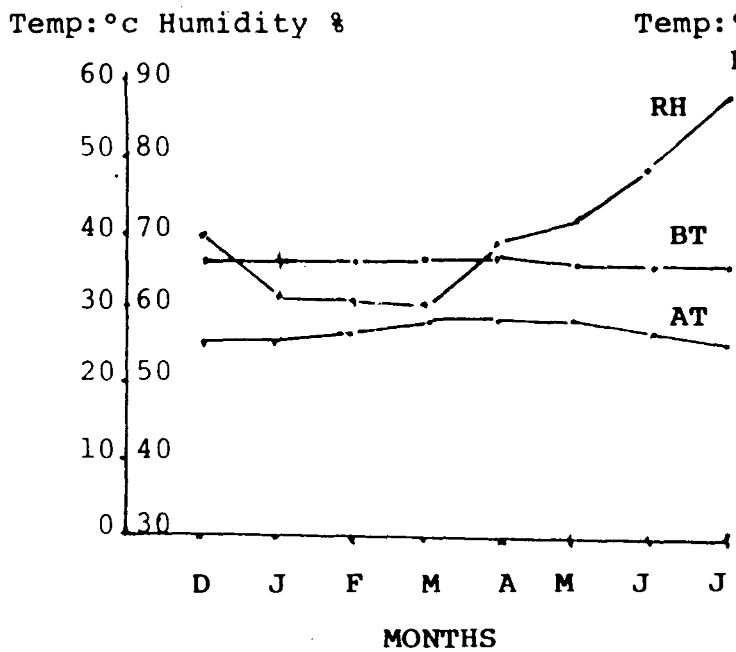
Table 5 Mean relative humidity (%)

Month	Relative humidity		Mean
	Morning	Evening	
December	81.50 ± 1.232	59.75 ± 2.917	70.625
January	78.25 ± 1.341	47.58 ± 1.012	62.91
February	81.42 ± 3.289	41.42 ± 2.065	61.42
March	84.25 ± 1.269	37.67 ± 3.283	60.96
April	84.92 ± 0.633	53.50 ± 0.792	69.21
May	87.58 ± 0.782	57.00 ± 1.424	72.29
June	91.50 ± 0.911	66.08 ± 3.07	78.79
July	95.25 ± 0.490	84.50 ± 2.191	89.87
Mean	85.58 ± 1.88	55.938 ± 5.266	70.75 ± 3.29

In the morning the lowest relative humidity was observed in the month of January (78.25 ± 1.341) and highest in the month of July (95.25 ± 0.490).

Fig. 1

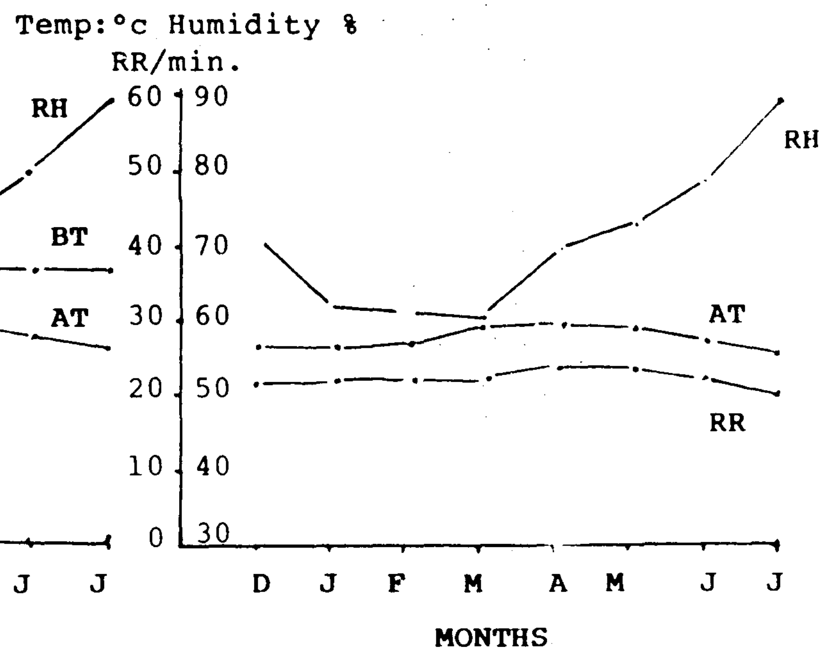
AMBIENT TEMPERATURE, RELATIVE HUMIDITY AND BODY TEMPERATURE



1mm=1°c, 1% RH

Fig. II

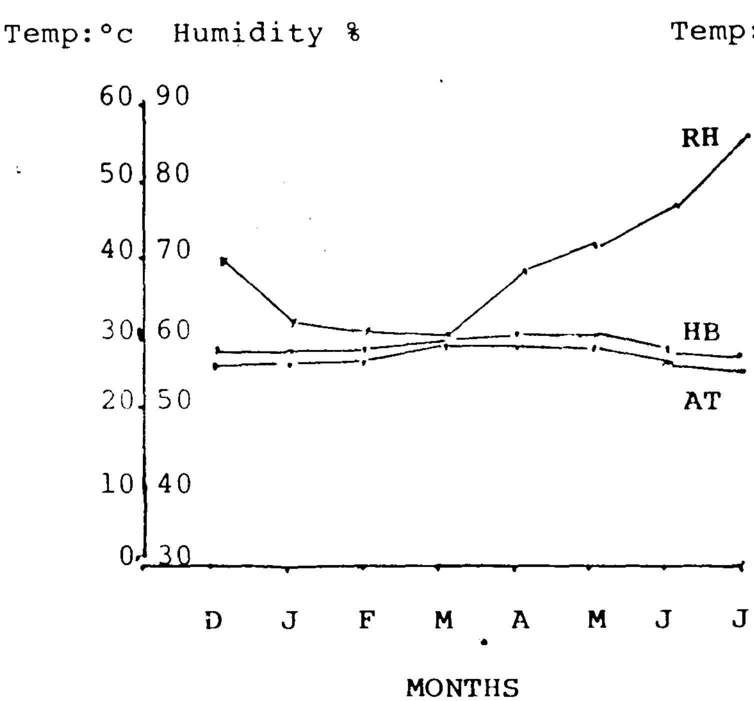
AMBIENT TEMPERATURE, RELATIVE HUMIDITY AND RESPIRATION



1mm=1°c, 1% RH and 1 RR/min

Fig.III

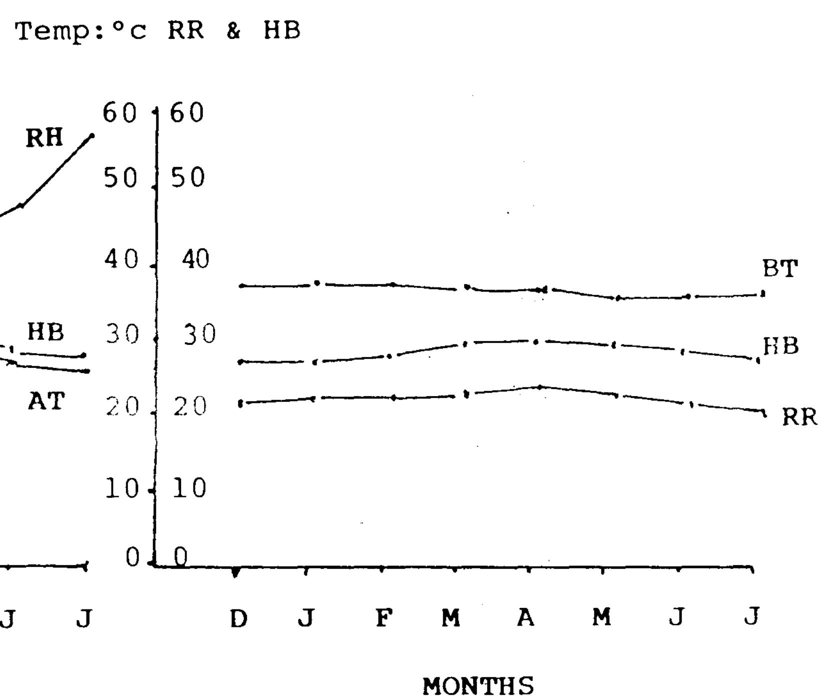
AMBIENT TEMPERATURE, RELATIVE HUMIDITY AND HEART BEAT



1mm=1°c, 1% RH, 1HB

Fig. IV

BODY TEMPERATURE, RESPIRATION AND HEART BEAT



1mm=1HB,1°c,1RR/min

RH=Relative Humidity   BT=Body Temperature   AT=Ambient Temperature

RR=Respiratory Rate   HB=Heart Beat

In the evening lowest relative humidity was observed in the month of March (37.67 ± 3.28) and highest in the month of July (84.50 ± 2.191).

On an average lowest relative humidity was observed in the month of March (60.96) and highest in the month of July (89.87).

The difference in the relative humidity noted between morning and evening was found to be significant.

The average body temperature before exercise after exercise and after rest observed are presented in Table 6 and Figure 5.

Table 6 Average body temperature before exercise, after exercise and after rest in horses (°C)

No.	Before exercise	After exercise	After rest
1	37.81	39.07	37.92
2	37.51	39.01	37.62
3	37.96	38.96	38.58
4	37.88	39.11	38.44
5	37.51	39.16	38.11
6	37.55	39.01	37.81
7	37.82	39.14	37.87
Mean	37.72 ± 0.065	39.06 ± 0.027	38.08 ± 0.116

't' value Before exercise and after exercise = 17.7**
't' value Before exercise and after rest = 2.139^{NS}
't' value After exercise and after rest = 10.924**
** Highly significant NS - Non-significant

Mean body temperature before exercise was found to be 37.72 ± 0.065°C (37.51°C to 37.96°C). After exercise mean body temperature was found to increase by 3.55% (39.06 ± 0.027°C).

The body temperature after rest was found to be more than that at rest (38.08 ± 0.116°C). But this difference was not found to be significant. Whereas highly significant difference was noticed between the body temperature before and after exercise and body temperature after exercise and after rest.

Rate of respiration per minute, before exercise, after exercise and after rest observed is presented in Table 7 and Figure 6.

The rate of respiration before exercise was found to be 21.14 ± 0.538. The rate of respiration showed a variation between 19.3 to 23.3 per minute.

After exercise the rate of respiration showed considerable increase. Average rate of respiration was found to increase to 84.28 ± 0.805 (74.0 to 95.3). The difference in the rate of respiration before exercise and after exercise was found to be highly significant.

Table 7 Mean rate of respiration before exercise, after exercise and after rest in horses (No/mt)

No.	Before exercise	After exercise	After rest
1	20.66	78.00	26.66
2	22.66	95.33	25.33
3	23.33	74.00	23.66
4	19.33	83.33	24.00
5	21.33	88.66	22.66
6	20.66	92.66	22.33
7	20.00	78.00	26.66
Mean	21.139 ± 0.538	84.28 ± 0.805	24.47 ± 0.63

\`t' value Before exercise and after exercise = 20.231**
\`t' value Before exercise and after rest = 3.864*
\`t' value After exercise and after rest = 19.004**
** Highly significant * Significant

The mean rate of respiration after rest was observed as 24.47 ± 0.63. The difference observed in the rate of respiration was found to be significant when compared that of before exercise and highly significant when compared that of after exercise.

Average heart beat per minute measured in the study in horses, before exercise, after exercise and after rest is presented in Table 8 and Figure 7.

Table 8 Average heart beat per minute before exercise, after exercise and after rest in horses

No.	Before exercise	After exercise	After rest
1	39.33	70.66	47.33
2	35.33	61.33	38.66
3	34.66	69.33	66.00
4	34.66	64.00	44.66
5	36.00	69.33	39.33
6	34.00	64.00	39.48
7	39.33	67.33	46.00
Mean	36.19 ± 0.843	66.57 ± 1.32	41.63 ± 1.53

`t' value Before exercise and after exercise = 19.383**
`t' value Before exercise and after rest = 2.973^{NS}
`t' value After exercise and after rest = 11.898**
** Highly significant NS - Non-significant

An average of 36.19 ± 0.84 heart beat per minute was observed in the horses (34 to 39.33).

Heart beat was found to increase considerably after exercise. It varied between 64.0 to 70.66 with an average of 66.57 ± 1.32.

The difference in heart beat observed before exercise and after exercise was found to be highly significant.

An average of 41.63 ± 1.53 heart beat per minute was observed after rest. This difference observed in the heart beat per minute in horses was found to be significant when compared that of before exercise and highly significant when compared that of after exercise.

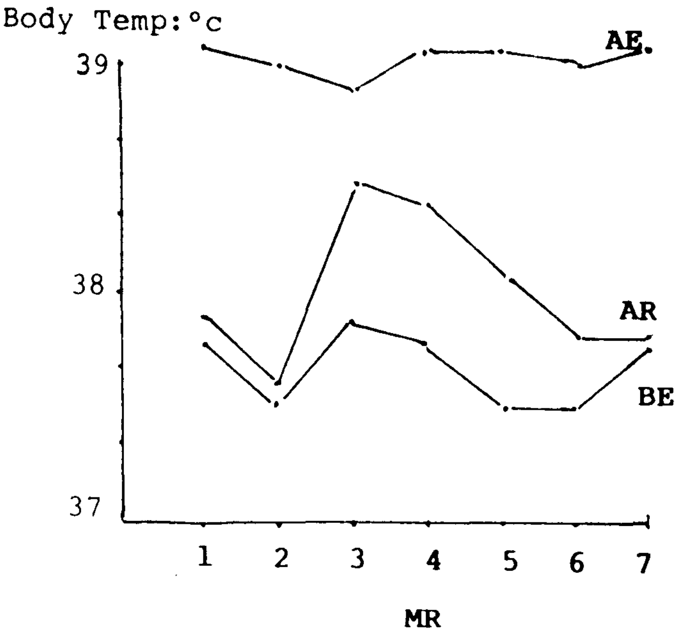
The Red Blood Cell count observed before exercise, after exercise and after rest is presented in Table 9 and Figure 8.

The red blood cell count was found to vary between 7.13 to 7.5 millions per cubic millimetre with an average of 7.29 ± 0.049.

The count was found to increase from 7.9 to 8.2 millions per cubic millimetre with an average of 8.03 ± 0.039 millions/cubic millimetre in horses after exercise. The difference in red blood cell count observed after exercise and before exercise was found to be highly significant.

Fig. V

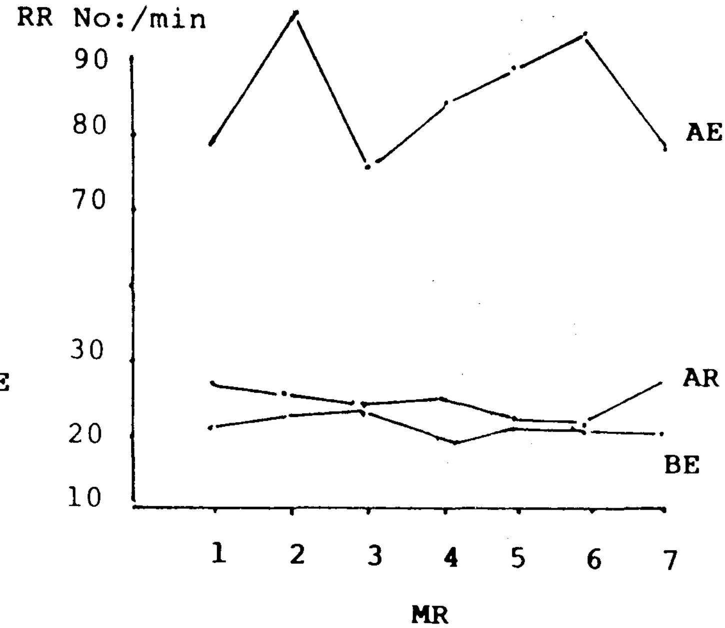
BODY TEMPERATURE, BE,AE AND AR IN HORSES



3mm=0.1°c

Fig. VI

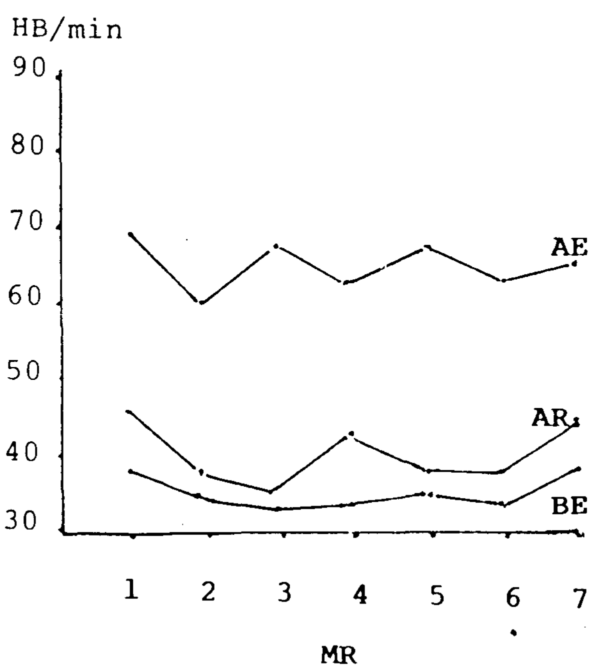
RESPIRATION BE, AE AND AR IN HORSES



1mm=1R

Fig.VII

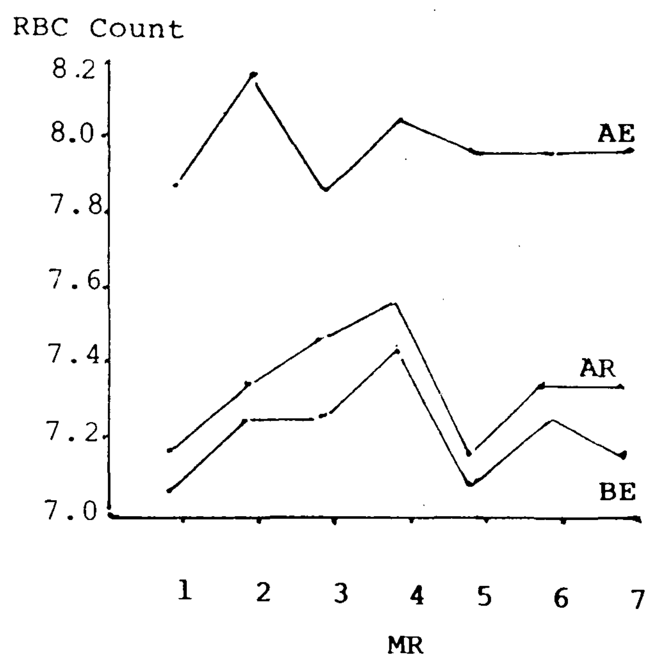
HEART BEAT.BE,AE AND AR IN HORSES



1mm=1H.B

Fig.VIII

RBC COUNT.BE,AE AND AR IN HORSES



5mm=0.1 million RBC

AE=After exercise. AR=After rest. BE=Before exercise. HB=Heart beat

Table 9 Mean red blood cell count before exercise, after exercise and after rest in horses (millions per cubic millimetre)

No.	Before exercise (million)	After exercise (million)	After rest (million)
1	7.153	7.940	7.276
2	7.353	8.20	7.48
3	7.33	7.90	7.51
4	7.50	8.13	7.64
5	7.13	8.00	7.27
6	7.366	8.00	7.46
7	7.233	8.06	7.48
Mean	7.295 ± 0.049	8.03 ± 0.039	7.44 ± 0.0498

`t' value Before exercise and after exercise = 11.603**
`t' value Before exercise and after rest = 2.1546^{NS}
`t' value After exercise and after rest = 9.247**
** Highly significant NS - Non-significant

After rest the red blood cell count showed considerable reduction in number (7.44 ± 0.047) from that of, exercise value. The values observed after rest was found to be highly significant compared to that after exercise. The average RBC count after rest was found to be non-significant when compared with that observed before exercise (7.29 vs. 7.45 millions per cubic millimetre).

Percentage of packed cell volume before exercise, after exercise and after rest, measured in horses is presented in Table 10 and Figure 9.

Table 10 Average percentage of packed cell volume before exercise after exercise and after rest in horses

No.	Before exercise (%)	After exercise (%)	After rest (%)
1	35.00	42.33	37.00
2	34.66	44.00	34.88
3	31.33	40.80	33.20
4	39.66	42.33	39.67
5	36.33	48.00	37.24
6	37.58	47.68	38.41
7	34.00	44.00	34.70
Mean	35.50 ± 1.011	44.16 ± 1.033	36.44 ± 0.8123

\`t' value Before exercise and after exercise = 5.975*
\`t' value Before exercise and after rest = 0.703^{NS}
\`t' value After exercise and after rest = 5.7239*
* Significant NS - Non-significant

An average percentage of packed cell volume of 35.50 ± 1.011 was observed before exercise in horses. The value showed variation from 31.33to 39.6 per cent.

The percentage of packed cell volume showed a significant increase after exercise. The mean value was found to be 44.16 ± 1.033 per cent with a variation from 40.8 per cent to 48.00 per cent.

Mean packed cell volume percentage after rest was found to be 36.44 ± 0.812 (33.20 to 39.67). The mean value of PCV observed after rest was found to be significantly lower than that noticed after exercise. The values before exercise and after rest from termination of exercise were similar.

Average erythrocyte sedimentation rate before exercise, after exercise and after rest in horses is presented in Table 11 and Figure 10.

The erythrocyte sedimentation rate showed a variation from 53.0 millimetre per 30 minutes to 61.6 millimetre per 30 minutes with an average of 56.51 ± 1.106 millimetre per 30 minutes before exercise.

The erythrocyte sedimentation rate showed considerable decrease after exercise. The average erythrocyte sedimentation rate observed was 37.97 ± 2.93 after exercise with a variation in value from 30.00 to 51.33 millimetre per 30 minutes. The difference in the value of ESR obtained before exercise and after exercise was found to be significant.

Table 11 Average Erythrocyte sedimentation rate (millimetre/30 minutes) before exercise, after exercise and after rest in horses.

No.	Before exercise	After exercise	After rest
1	56.33	30.66	53.33
2	53.00	30.00	52.00
3	56.00	35.60	52.00
4	54.30	34.56	53.28
5	61.66	38.66	46.66
6	55.33	51.33	54.00
7	59.00	45.00	49.00
Mean	56.517 ± 1.106	37.972 ± 2.93	51.46 ± 0.952

`t' value Before exercise and after exercise = 5.905*
`t' value Before exercise and after rest = 3.365*
`t' value After exercise and after rest = 4.343*
* Significant

The average erythrocyte sedimentation rate observed after rest showed considerable increase (51.46 ± 0.952) than that of after exercise value (37.97 ± 2.93), but slightly less than the normal value before exercise (56.517 ± 1.106).

The erythrocyte sedimentation rate observed after rest was found to be significant with the value observed before exercise and after exercise.

Average percentage of glucose observed in the study before exercise after exercise and after rest is presented in Table 12 and Figure 11.

Table 12 Average percentage of glucose before exercise, after exercise and after rest in horses (mg%)

No.	Before exercise	After exercise	After rest
1	71.66	56.66	68.33
2	73.26	60.03	72.50
3	74.66	59.56	73.60
4	73.33	60.33	72.76
5	72.66	57.80	71.96
6	73.00	62.30	72.93
7	72.66	59.50	70.90
Mean	73.03 ± 1.698	59.45 ± 1.242	71.85 ± 1.68

\`t' value Before exercise and after exercise = 19.1089*
\`t' value Before exercise and after rest = 0.9880
\`t' value After exercise and after rest = 12.94*
* Significant

Mean percentage of glucose observed in the study was 73.03 ± 1.69 before exercise, with a variation from 71.66 to 74.66.

Glucose percentage was found to reduce considerable after exercise (mean 59.45 ± 1.24). The difference obtained was found to be highly significant with that observed before exercise.

The percentage of glucose was found to increase considerably (mean 71.85 ± 1.69) after rest, but did not reach normal value (73.03 ± 1.698) during the rest period. The difference observed after rest in the value of glucose was found to be highly significant with that after exercise and non-significant when compared with the value before exercise.

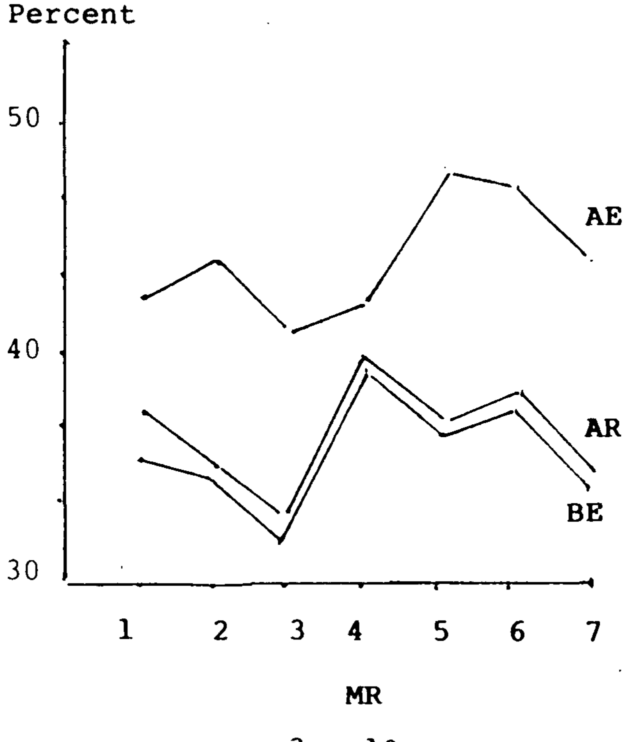
Average Lactic acid content of the blood of horse before exercise after exercise and after rest is presented in the Table 13 and Figure 12.

Average lactic acid content of the blood was found to be 1.60 ± 0.095 milli mol/litre before exercise in horses. The value showed a variation from 1.31 to 1.83 milli mol/litre.

After exercise the lactic acid content of the blood showed considerable increase in value (mean 1.79 ± 0.108 milli mol/litre). The difference in the lactic acid content observed between after exercise and before exercise was found to be significant.

Fig. IX

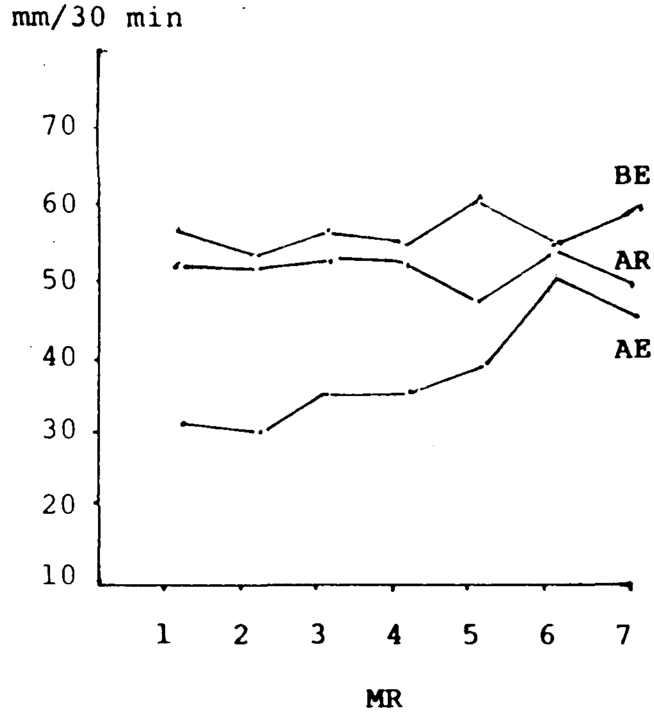
PCV.BE,AE AND AR IN HORSES



3mm=1%

Fig. X

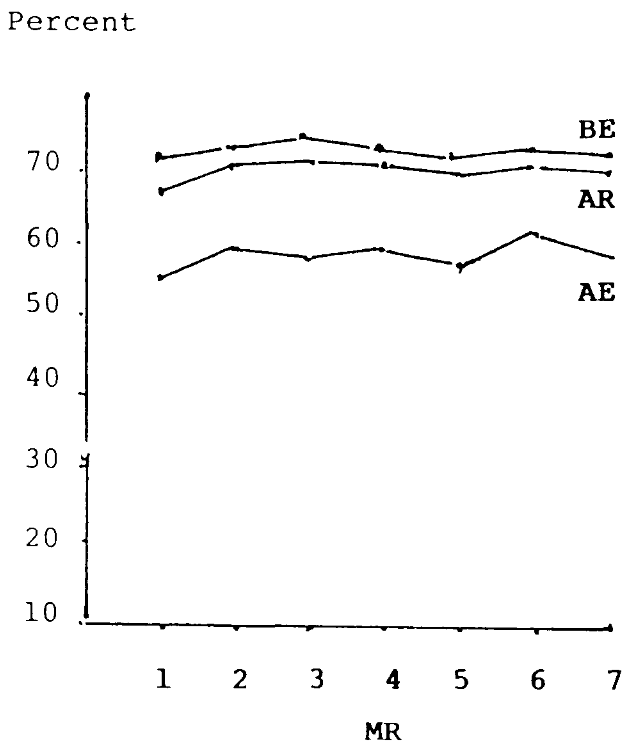
ESR.BE,AE AND AR IN HORSES



1mm=1mm/30 min

Fig.XI

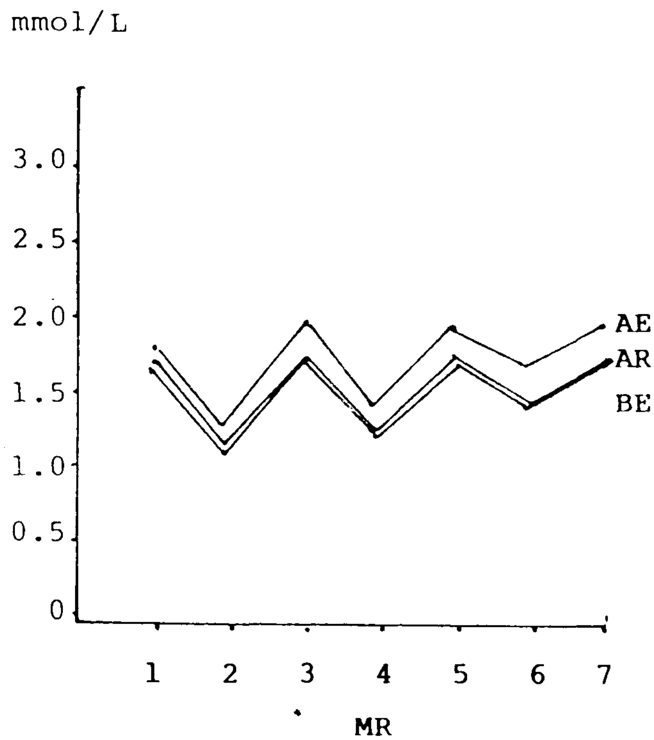
BLOOD GLUCOSE.BE,AE AND AR IN HORSES



1mm=1%

Fig.XII

LACTIC ACID.BE,AE AND AR IN HORSES



20mm=1mmol

AE=After exercise AR=After rest BE=Before exercise

Table 13 Average lactic acid content of blood of horses before exercise, after exercise and after rest (mmol/L)

No.	Before exercise	After exercise	After rest
1	1.76	1.88	1.77
2	1.17	1.35	1.17
3	1.83	2.09	1.82
4	1.31	2.43	1.31
5	1.82	2.04	1.81
6	1.58	1.74	1.59
7	1.79	2.05	1.80
Mean	1.60 ± 0.095	1.79 ± 0.1081	1.61 ± 0.0953

`t' value Before exercise and after exercise = 6.2576*
`t' value Before exercise and after rest = 0.5614^{NS}
`t' value After exercise and after rest = 6.3460*
* Significant NS - Non-significant

The lactic acid level of the blood after rest showed considerable reduction in its value (mean 1.61 ± 0.095 milli mol/litre) from after exercise level and was found to be similar like the before exercise level.

DISCUSSION

From the present study it was found that the body temperature of the horses showed only a narrow margin of variation in the morning from 37.41 to 37.65° C with an average of 37.54 ± 0.021° C. The fluctuation noticed was only 0.2° C. The lowest body temperature in the morning was noticed in the month of February (37.41° C) and highest in the month of April - May (37.6° C).

Ambient temperature also was showing the same trend. In the morning the ambient temperature recorded a lower value of 22.98 ± 0.038° C with a variation of 21.68° C to 24.39° C. The lowest ambient temperature was noticed in the month of February and highest in the month of April - May. The fluctuation in the body temperature noticed was in accordance with that of the ambient temperature.

The relative humidity ranged from 78.25 per cent in the month of January to 95.25 per cent in the month of July with an average of 85.58 ± 1.88 per cent. Body temperature also showed a fluctuation from a lower level during the months of January and February to higher level in the month of April to July in the morning. Body temperature showed a highly significant positive correlation (+0.756) when compared to the ambient temperature in the morning.

The body temperature obtained in the present study is in agreement with Miller and Robertson (1959), Findlay (1961), Campbell and Lasley (1975) and Cherian (1983) in horses.

In the evening the average body temperature showed a mild increase of 0.4° C (37.93 ± 0.051° C). It ranged from 37.64° C in the month of July to 38.12° C in the month of April. The lowest body temperature in the evening was noticed in the month of July and highest in the month of April.

The corresponding ambient temperature observed also was lowest in the month of July (28.87° C) and highest in the month of March (35.63° C).

The trend in the relative humidity observed in the evening was reverse. The lowest body temperature and ambient temperature were observed in the month of July in the evening and correspondingly the relative humidity observed was highest in the month of July (84.50 per cent).

The ambient temperature and body temperature were showing a higher trend in the months of March. April (35.63° C and 38.12° C respectively) when the relative humidity was recorded lowest (35.67 per cent).

The finding also is in agreement with that of Miller and Robertson (1959), (1961), Findlay (1961) and Cherian (11983) in horses.

Body temperature showed a highly positive correlation with ambient temperature (+0.950) in the evening and negative correlation with relative humidity (-0.792).

The increase in the relative humidity during the months of June and July corresponds with heavy rain in Kerala which decreases the ambient temperature and there by cool the body temperature of horse giving lower body temperature during these months.

Immediately after the exercise the body temperature was found to increase 3.55 per cent than the body temperature immediately before exercise (38.96° C to 39.16° C) with an average of 39.06 ± 0.027. This difference was found to be highly significant.

Body temperature after rest was found to reduce considerably (38.03 ± 0.116° C) but was 0.82 per cent above than the body temperature before exercise and 2.70 per cent less than the body temperature after exercise. The difference between body temperature after exercise and after rest was found to be highly significant.

Due to the difficulty observed in providing exercise and management practice of the Mounted Squadron NCC the time taken by the animal to reach normalcy like that of before exercise could not be observed.

Swenson and William (1966) reported that exercise is one of the most important cause which increases the body temperature. Similar increase in body temperature due to exercise or work was also reported in draught cattle (Nagpaul *et al.*, 1984).

The percentage of increase in the body temperature after exercise is in agreement with the report of Guyton (1981) in human beings.

The increase in the body temperature due to exercise is due to the marked increase in the metabolic rate of the animal to provide energy for muscular activity. The resultant heat generated in the body is dissipated by various thermoregulatory mechanism to bring back the horse to normal condition (Mitchell, 1973; Carlson, 1983; Goetz and Manohar 1990; Heileman *et al.*, 1990; Hodgson *et al.*, 1993).

Cherian (1983) reported only a non-significant variation in the body temperature of horses that were not engaged for sports. This fact is also supported by Thiel *et al.* (1987) who also observed a mild increase of 0.8°C in the body temperature of horse after exercise.

In spite of the enormous heat load during exercise in horses equally important mechanisms exist in horses for dispersal of heat. As a result of this horses are able to perform well during exercise with only minor increase in body temperature.

After one and a half hours of rest the body temperature showed considerable reduction from the after exercise level (38.08°C from 39.06°C). But the horses could not return to the normal state of body temperature recorded before exercise.

Maynard *et al.* (1979) reported that conditioning of horses increase the size and number of mitochondria per cell, increases aerobic capacity of the muscles, increase the glycogen content of muscles, increases the turn over rate of adipose tissue fatty acid, increases the efficiency and rate of utilisation of free fatty acid, decreases the lactate production and, thus, increase the efficiency of energy utilisation by muscles. In conditioned horse therefore the increase in body temperature due to exercise though occurs, is not significant as the body resort to other neuromuscular mechanism to keep it cool. Even if the body temperature is elevated upward, it is brought back quickly to normalcy immediately after exercise. This view is also supported by Lindholm *et al.* (1974).

In the present study the horses were not in a position to return back to normalcy even after one hour 30 minutes indicating that horses of the Mounted Squadron are either old or are not given proper Training and hence are not conditioned.

The rate of respiration in horses showed wide variation in the morning (20.09%). Lowest respiration was observed in the month of July (17.42 per minute) and the highest in the month of March - April (20.92 per minute) with an average of (18.82 ± 0.518) per minute.

The ambient temperature in the morning was showing a different trend. The lowest ambient temperature recorded was during the month of February (21.68 ± 0.271) and highest in the month of April (24.39 ± 0.142).

Similar trend was noted in the body temperature of horses in the morning. Lowest (37.41° C) in the month of February and the highest (37.61° C) in the month of May indicating that the body temperature showed a similar trend like that of ambient temperature in morning.

Where as the relative humidity recorded the highest value in the month of July (95.25%) where the respiration rate per minute was lowest (17.42) similarly the highest respiration (20.92 per min.) in the morning was recorded in the month of March - April when comparatively the relative humidity was lower.

In the evening also the lowest respiration rate per minute was recorded in the month of July (24.13) and highest in the month of March - April (27.71 per minute) giving an average of 26.38 ± 0.501. In the evening also a variation of 14.83 per cent was noted in the respiration rate per minute in horses.

The respiration rate showed a similar trend with ambient temperature in the evening. In both the cases lowest respiration rate and ambient temperature were recorded in the month July and highest respiration rate and ambient temperature was recorded in the month of March - April giving a highly significant correlation coefficient in the morning (0.978) and evening (0.958).

In the case of relative humidity, the highest value was recorded in the month of July where the respiration rate was lowest both in the morning and evening and the lowest relative humidity was recorded in the month of March when the highest respiration per minute was observed in the horses in the evening giving a highly significant negative correlation between respiration rate and relative humidity in the evening (-0.865).

The average respiration rate per minute in the morning observed in the study (18.82 ± 0.518) is in agreement with the report of Cherian (1983) who observed a respiration rate of 18.6 ± 0.2514 in horses.

The mean respiration rate per minute in the evening noted in the study (26.38 ± 0.501) is much higher than the report of Cherian (1983) who observed only 21.49 ± 0.2947.

The mean value observed in the present study is much higher than early observations. (Miller and Roberstson 1959; Breasile, 1971; West, 1979). They all observed a much lower respiration rate of 8-12 per minute in horses. This lower rate of respiration may be due to the colder climatic effect of temperate climate.

Similarly the lower respiration rate observed in the month of July also may be due to the heavy rain of tropical climate where the ambient temperature is brought down there by cooling the body temperature and reducing the respiration rate.

Immediately after exercise the respiration rate per minute was found to increase 251.5 per cent (21.139 ± 0.538 to 84.24 ± 0.805). Even after 1 hour 30 minutes rest the respiration rate was found to be 15.75 per cent (24.47 ± 0.63) more than the rate before exercise.

The increase in the respiration rate noted after exercise and reduction in the respiration rate after rest was found to be highly significant. The same before exercise and after rest also was found to be significant.

The increase in the respiration rate noted in the present study is in agreement with that of Dietz and Wiesner (1984) who have reported that exercise leads to marked increase in the respiration rate.

Excessive increase in the respiration rate after exercise is also an indication of the old age and or poor conditioning of the horses. Conditioning is proved to show an increase in the respirations rate but not to such an extent as that found in the present study (251.5%).

The study revealed that even after one hour 30 minutes of rest the horse could not return to normalcy in the respiration rate per minute. This is not in agreement with the study of Dietz and Wiesner (1984) who reported that return of respiration to normal initial value takes 10-15 minutes in well trained horses and 25-30 minutes in poorly trained horses.

The horse used in the present study could not reach to normalcy even in 1 hour 30 minutes of rest indicating that these horses are not only poorly conditioned but also old animals.

It may also be noted that the heavy rise in respiration rate (251.5%) immediately after exercise and not much increase in body temperature after exercise (3.55%) clearly shows that, a highly homeothermic animal like horse keeps the body temperature fairly constant, in spite of exercise, by other mechanisms like respiration, increasing it to the extent of 251.5 per cent.

The heart beat per minute in horses showed a variation of 11.57 per cent in the morning. The lowest was recorded in the month of February (23.79 ± 0.511 per minute) and the highest in the month of May (26.54 ± 0.051). The average heart beat per minute was found to be 25.07 ± 0.354.

The fluctuation in the heart beat in the morning also follows a trend like that of ambient temperature which also showed a variation of 12.5 per cent in the morning and also like that of relative humidity which showed a fluctuation of 21.72 per cent in the morning.

But in spite of the increase and fluctuation in the ambient temperature and relative humidity the body temperature remained fairly constant showing a fluctuation of only 1.06 per cent in the morning indicating that the body takes up other mechanism like respiration rate and heart beat to keep the body temperature fairly constant.

The rate of heart beat in the evening recorded as average of 32.675 ± 0.771. The lowest heart beat was recorded in the evening in the month of July (29.54 ± 0.482) and highest in the month of March (35.75 ± 0.733). A variation of 21.01 per cent was observed in the evening in the rate of heart beat per minute. This variation noticed in the rate of heart beat in the evening may be due to a similar variation observed in the ambient temperature (23.41%) in the evening and relative humidity (124.49%) which has resulted in a variation in the respiration rate per minute (14.83 per cent).

In spite of all these fluctuations the body temperature in the evening kept a fairly constant level with only a mild variation (1.77%). The fluctuations in the ambient temperature, relative humidity and the body responses like respiration rate and heart beat indicate that the horse used these responses to keep its body cool, in orders to keep a fairly constant body temperature is in agreement with similar report of Cherian (1983) in horses.

Immediately after exercise the rate of heart beat showed an increase of 83.93 per cent (66.57 ± 1.32 per minute). This increase was also similar to that of ambient temperature and relative humidity and respiration rate.

The heart beat per minute though reduced considerable after 1 hour 30 minutes rest but was 59.90 per cent more than the heart beat before exercise.

The increase in the heart beat noted between before exercise and after exercise and after exercise and after rest was found to be highly significant and significant before exercise and after rest.

The heart beat observed in the present study is similar to that reported by Dietz and Wiesner (1984) before exercise, but is much less than after exercise value, as observed by Ehrlein (1970), Wittke *et al.* (1968), Stewart (1972) and Nowosinow (1971). This increase may be probably due to the severe exercise for long duration.

From the study it was clearly found that on exercise, the body responses like respiration rate and heart beat increase considerably in a homeothermic animal to provide increased nutrient and cool air to the body to keep the body cool and keep a fairly constant body temperature.

Even though not much research work was carried out in the hot humid tropical climate, the present work is in agreement with that of Cherian (1983) who also reported similar results in horses.

The Red Blood Cell count before exercise, after exercise and after rest when taken was showing fairly constant values within the group.

But the mean Red Blood Cell count before exercise (7.295 ± 0.049 millions) and after exercise (8.03 ± 0.039 millions) showed a variation of 10.15 per cent. The higher value of Red Blood Cell count obtained after exercise was found to be highly significant.

The Red Blood Cell count though reduced to (7.44 ± 0.04 million) after a rest of 1 hour 30 minutes was found to be highly significant between after exercise and after rest.

The count was showing 2.05 per cent more after 1 hour 30 minutes rest than before exercise and the difference was found to be non significant.

None of the physiological parameters studied so far was found to reach normalcy even after 1 hour 30 minutes rest, as against the report of Dirtz and Wiesner (1984) who reported normalcy in all physiological parameters in 10-15 minutes time in well trained horses.

The red blood cell count obtained in the present study is less than the report of Mcleod *et al.* (1946), Hansen *et al.* (1950) and Schlichling (1956). They have reported an red blood cell (RBC) count of 10-13.1 millions per cubic millimetre of blood. The result of the study is in agreement with that reported by Schalm (1958), Jeffcott (1971) and Franser *et al.* (1986).

The increase in the RBC count due to exercise obtained in the present study is in agreement with the reports of Mill and Wolf (1977), Swenson (1977) and Dietz Wiesner (1984). They have all reported an RBC count due to exercise up to 11.95 to 13.3 millions per cubic millimetre of blood in horses.

Rubido *et al.* (1996) reported that red blood cell count increased significantly at the trotting and galloping with greater increase after galloping. They have further reported that the return to normalcy was earlier for trotting than for galloping.

The return to normalcy was delayed in the present study mainly due to the old age and poor conditioning of horses.

Erythrocyte sedimentation rate observed in the horses was found to be 53.00 to 61.66 millimetre per 30 minutes with an average of 56.51 ± 1.106 millimetre per 30 minutes. The value observed in this work was found to be slightly more than the earlier workers [Coffin, 1958; Osbaldistone, 1971].

Immediately after the exercise the erythrocyte sedimentation rate reduced considerably to an average of 37.97 ± 2.93 millimetre per 30 minutes (30.00 to 51.33 millimetre per 30 minutes). The difference observed was found to be significant.

Decrease in the value of erythrocyte sedimentation rate after physical activity is also reported by Takagi and Sakurai (1972). According to them the reduction in value is due to the decline in the fibrinogen content of the plasma because of the sustained physical activity which causes activation of plasminogen causing decrease in the erythrocyte sedimentation rate value.

After 1 hour 30 minutes rest the erythrocyte sedimentation rate increased to 51.46 ± 0.952 millimetre per 30 minutes (46.66 to 54.00). In spite of the rest the value did not reach normalcy.

An average packed cell volume of 35.50 ± 1.011 per cent was observed in horses before exercise.

The average packed cell volume observed in this work was found to agree with reports of Trum (1952), Schalm (1958), Jeffcott (1971) and Swenson (1992).

Immediately after exercise the packed cell volume showed 24.39 per cent increase (44.16 ± 1.033) from the packed cell volume before exercise. This difference was found to be statistically significant.

The result of the present study is in agreement with Mill and Wolf (1974) who observed increase in the packed cell volume due to exercise. They have further reported an increase from 42.2 to 54.5 per cent in horses that were exercised all the year round and 40. 9 to 57.5 per cent in horses that were exercised only at intervals.

Haemoconcentration due to dehydration, asphyxia or excitement causing release of erythrocytes concentrated in the spleen can result in abnormally high packed cell volume (Dietz and Wiesner, 1984). They have further reported that the increase in packed cell volume is a function of exercise intensity. According to them a linear relationship exists between packed cell volume and speed up to packed cell volume of approximately to 60-65 per cent.

The packed cell volume returned to almost normal value (36.44 ± 0.812) after 1 hour 30 minutes of rest.

This result is not in agreement with Keenam (1980) who observed 41 per cent increase even 3 hours after exercise.

An average of 73.03 ± 1.698 mg per cent blood glucose level was observed in the horses before exercise. The result of the present work is in agreement with Fraser (1986).

Blood glucose and glucose in certain tissue fluids are drawn upon by cells of the body to produce energy. As a result of this, blood glucose level after exercise shows a reduction in its concentration.

In the present study an average blood glucose level of 59.45 ± 1.242 per cent was observed after exercises. This was 18.59 per cent less than the value before exercise. The decrease observed was found to be statistically significant.

Scientists in the field of exercise physiology in horses observed reduction in the level of blood glucose due to exercise (Solun, 1934; Bornet, 1969; Krzywanek, 1973; Evan *et al.*, 1974; Dietz and Wiezner, 1984).

The result of the present study is in agreement with Takagi and Sakurai (1971). They have observed 9 per cent reduction in glucose concentration in the blood after short distance run and 20 per cent reduction in glucose level in the blood after long distance run.

After 1 hour 30 minutes rest the blood glucose level showed an average of 71.85 ± 1.68 per cent. This level is only 1.6 per cent less than the glucose level before exercise and 20.85 per cent less than the value after exercise.

The difference in glucose concentration before exercise and after rest is not significant, but before exercise and after exercise and after exercise and after rest were found to be statistically significant.

The lactic acid content in the blood of the horses before exercise showed a range of 1.31 milli moles per litre to 1.82 milli moles per litre with an average of 1.60 ± 0.095 milli moles per litre.

Lactic acid is an end product of glycolysis and is formed by hydration of pyruvic acid that does not enter the Krebs cycle. In most animal tissue, lactic acid forms as an intermediary product only in the absence of oxygen or in the presence of an oxygen deficit. Therefore lactic acid content in the serum and muscle is often considered as an index of the internal stress produced by physical exertion.

The result obtained in the present study agrees with Dukes (1955), Bohn (1957), Dietz and Wiesner (1984) and Swenson and Reece (1996). They have all reported a normal value of lactic acid level of 1.103 to 1.76 milli moles per litre in the blood of horses.

The result of the present study is not in agreement with Wittke and Bohn (1959), Schulze, (1970) Krzywanek, (1974), Aitkan *et al.* (1974) and Kolh (1976). These workers have reported a lower value of lactic acid in the blood of horses (0.491 milli mole per litre to 1.213 milli mole per litre).

Immediately after exercise the level of lactic acid increased 11.87 per cent from the value before exercise. The lactic acid content of the blood increased from 1.60 $\pm$ 0.095 before exercise to 1.79 $\pm$ 0.1081 after exercises.

The result of the present study is in general agreement with the report of Takagi and Sakurai (1971), Lindhem and Saltin (1974), Krzywanek (1974), Snow and Mackenzie (1977) and Saibene *et al.* (1985). These workers have observed considerable increase in the blood lactic acid level of horses due to exercise. The rate of lactate production was reported to be about 35 milli mole per litre for the Polo ponies and 20-24 milli moles per litre for the Standard breds and Thoroughbreds.

Exercise in the general endurance range such as sustained walking, trotting or cantering is reported to cause little rise in the serum lactic acid level. The degree of increase depends on the extent and intensity of exercise and the animals stage of fitness.

Immediately after exercise the lactic acid level returned to normalcy in 1 hour and 30 minutes time. Reduction in the value of lactic acid was found to be 10.05 per cent from the level after exercise to after rest. The difference in the level of lactic acid from after exercise to after rest was found to be statistically significant. But the level between before exercise and after rest was found to be statistically non significant.

The result of the present study is in agreement with that of Poso *et al.* (1983). They have reported that the recovery from the increased level was faster in Standard breds than in imported breds and thus suggested that the standard breds have higher aerobic capacity than imported breds.

SUMMARY

SUMMARY

The study was carried out on six horses of twelve years of age from the 1 (K) Mounted Squadron NCC of Kerala Agricultural University. These horses were divided at random into two groups of three. Out of the two groups, first was subjected to an exercise regime in the first month while the other remained as control. Groups were switched over every month until the experiment was completed.

The control group of animals remained in the stable and its observations were taken. The treatment group was taken to the riding school and was given a carefully planned regime of exercise. First set of observations were taken before exercise in the stable. The second set of observations were taken immediately after the exercise and the third set after 1 hour and 30 minutes of rest.

Physiological parameters like body temperature, respiration rate and heart beat were recorded before exercise, after exercise and after 1 hour and 30 minutes rest.

The haematological values of the horse like, Red Blood Cell count, packed cell volume, erythrocyte sedimentation rate, serum glucose and lactic acid of blood before exercise, after exercise and after rest were also found out.

Average body temperature before exercise, after exercise and after rest were found to be 37.72 ± 0.065, 39.06 ± 0.027 and 38.08 ± 0.116°C respectively. A highly

significant increase in the body temperature, due to exercise was observed in the study. Similarly a highly significant difference between the body temperature after rest and after exercise also was noticed in the present study. However the body temperature did not return to normalcy even after 1 hour 30 minutes of rest.

An average rate of respiration of 21.139 ± 0.538, 84. 28 ± 0.305 and 24.47 ± 0.63 were recorded before exercise, after exercise and after rest respectively in horses. The rate of respiration per minute was found to increase 251.5 per cent after exercise. The same was reduced to 15.75 per cent from after exercise to after rest. The respiration rate per minute did not return to normalcy even after 1 hour and 30 minutes of rest.

Mean heart beat per minute before exercise, after exercise and after rest observed in the present study were 36.19 ± 0.843, 66.57 ± 1.32 and 41.63 ± 1.53 respectively. A highly significant increase in the heart beat (83.94%) was noticed immediately after exercise. The difference between the heart beat noted after exercise and after rest also was found to be highly significant (59.91 per cent). As in the case of other physiological parameters the heart beat did not return to normalcy even after 1 hour and 30 minutes rest.

Average red blood cell count before exercise, after exercise and after rest were found to be 7.295 ± 0.049, 8.03 ± 0.039 and 7.44 ± 0.049 millions per cubic millimetre of blood respectively. A highly significant increase in the count could be noticed after exercise, but this could not reach normalcy even after 1 hour 30 minutes of rest.

Average packed cell volume observed before exercise, after exercise and after rest were 35.50 ± 1.011, 44.16 ± 1.033 and 36.44 ± 0.812 per cent respectively. A significant increase could be observed immediately after exercise, which fall to normal values on giving a rest of 1 hour 30 minutes.

The erythrocyte sedimentation rate noted before exercise, after exercise and after rest were 56.51 ± 1.106, 37.972 ± 2.93 and 51.46 ± 0.92 millimetre per 30 minutes respectively. A significant reduction in the count could be noticed immediately after exercise. As in the case of other parameters the erythrocyte sedimentation rate did not reach normalcy even after 1 hour 30 minutes of rest.

Average percentage of glucose in the blood of horse before exercise, after exercise and after rest were found to be 73.03 ± 1.698, 59.45 ± 1.242 and 71.85 ± 1.68 respectively. A highly significant reduction (18.59 percent) in the percentage of glucose level could be noticed after exercise. Eventhough the glucose level increased much after 1 hour 30 minutes of rest, it did not return back to normalcy.

Mean lactic acid levels noticed before exercise, after exercise and after rest were 1.60 ± 0.095, 1.79 ± 0.10081 and 1.61 ± 0.0953 millimoles per litre of blood respectively. Significant increase (11.76 percent) in lactic acid level could be noticed after exercise. This parameter reached almost normal level after 1 hour and 30 minutes of rest.

Out of the physiological parameters studied, body temperature was the only one kept fairly constant in horses. A sharp rise in the rate of respiration per minute (25.51 per cent) and heart beat (83.93 per cent) indicate that a highly homeothermic animal like horse uses physiological parameters like respiration rate and heart beat to keep the body cool and there by keep the body temperature fairly constant.

In spite of providing a rest of one and half hours, none of the physiological and haematological parameters except lactic acid level and packed cell volume could not return back to normal stage indicating the old age and poor conditioning of the horses studied.

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EFFECT OF EXERCISE ON THE PHYSIOLOGICAL NORMS OF HORSES

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ABSTRACT OF A THESIS

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ABSTRACT

In order to study the effect of exercise on the physiological norms of the horses, six horses belonging to the I (K) Mounted Squadron N.C.C. of Kerala Agricultural University were divided at random into two groups of three animals. First was subjected to an exercise regime in the first month while the other remained as control. Groups were switched over every month.

The parameters studied were body temperature, respiratory rate, heart beat, red blood cell count, packed cell volume, erythrocyte sedimentation rate, glucose and lactic acid, before exercise, after exercise and after one and half hours of rest. The results obtained are tabulated.

Parameters	Before exercise	After exercise	After rest
Body temperature (°C)	37.72 ± 0.064	39.06 ± 0.027	38.08 ± 0.116
Respiration rate per minute	21.13 ± 0.538	84.28 ± 0.805	24.47 ± 0.63
Heart beat per minute	36.19 ± 0.083	66.57 ± 1.32	41.63 ± 1.53
RBC count per million/cc	7.29 ± 0.049	8.03 ± 0.039	7.44 ± 0.0498
PCV (%)	35.50 ± 1.011	44.16 ± 1.033	33.44 ± 0.812
ESR mm/30 minutes	56.51 ± 1.106	37.97 ± 2.93	51.46 ± 0.95
Glucose (mg%)	73.03 ± 0.698	59.45 ± 1.242	71.81 ± 1.68
Lactic acid(mmol/L)	1.60 ± 0.095	1.79 ± 0.103	1.61 ± 0.095

Exercise significantly changes all the physiological parameters except body temperature which was kept fairly constant by horses. Ambient temperature and relative humidity were found to cause stress in the horses. Parameters like respiratory rate and heart beat were considerably increased after exercise to keep the body temperature fairly constant in horses.

In spite of one and half hours of rest the body temperature, respiratory rate, heart beat, red blood cell count, erythrocyte sedimentation rate and glucose content could not reach the normal level.

However the lactic acid level and packed cell volume could be brought back to the normal level after one and half hours of rest.

Age and stages of conditioning of horses were found to influence the level of physiological parameters and time needed to bring them back to the normal level.