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STUDIES ON BIO-ENERGETICS OF DRAUGHT BUFFALO

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K e y w o r d s: respiration rate, pulse rate, rectal temperature, humidity, temperature, speed, inclination of treadmill, draught and fatigue score.

A b s t r a c t

The effects of environment and work conditions on fatigue of draught buffalo have been studied under controlled condition using an animal treadmill. The physiological, hematological, biochemical, skin temperature, cardiovascular, and muscle strain responses along with distress symptoms of test draught he-buffaloes when exerting a draught of 0, 10 and 14% body weight at 1.5 and 2.0 km/h speed with 0, 5 and 10° inclination of treadmill at two temperatures (22 and 42°C) and two levels of humidity (45 and 90%) were studied for four effective hours or time till test draught he-buffalo reached a state of fatigue. Model developed with multiple linear regression technique which showed best fit for physiological, hematological, biochemical, mineral variables, skin temperature, cardiovascular, muscle strain parameters and duration of exercise.

STUDIA NAD BIOENERGETYKĄ BAWOŁU DOMOWEGO

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S ł o w a k l u c z o w e: częstość oddechowa, tętno, temperatura odbytnicza, wilgotność, temperatura, szybkość, nachylenie kieratu, wysiłkowe próby oddechowe.

A b s t r a k t

Badano wpływ środowiska i warunków pracy na wyniki prób wysiłkowych bawołu domowego w kontrolowanych warunkach podczas pracy w kieracie. Bawoły chodziły z prędkością 1,5 i 2,0 km/h,

z obciążeniem równym: 0, 10 i 14% masy ciała, w kieracie nachylonym pod kątami: 0, 5 i 10°, w warunkach: temperatura 22 i 42°C, wilgotność powietrza 45 i 90%. Wyniki: fizjologiczne, hematologiczne, biochemiczne, sercowo-naczyniowe, temperaturę skóry i napięcie mięśni oraz objawy zaburzeń, zebrano podczas czterech godzin efektywnego testu trwającego do zmęczenia bawołu. Techniką wielokrotnej regresji liniowej opracowano model parametrów opisujących otrzymane wyniki i pozwalających na dobór właściwego czasu trwania wysiłku.

Introduction

Animal traction has a long history in agricultural production. It is an appropriate, affordable and sustainable technology requiring very low external inputs. It has played and still playing an important role in meeting the power requirements of farming system in the country. The draught buffalo are in continuous stress during tillage operations especially in summer season and extreme winter and rainy seasons. The success of large-scale utilization of the draught animal power depends upon the scientific investigation undertaken to optimize animal power utilization. The physiological parameter of animals reflects the stress of work imposed on draught animals. Increase in respiration rate and rectal temperature after exercise has been reported by various researchers, MUKHERJEE et al. (1961), SINGH et al. (1968), DEVADATTAM, MAURYA (1978), UPADHYAY, MADAN (1985). Pulse rate also increases after work (THAKUR et al. 1989, AGGARWAL, UPADHYAY 1998)

The change in physiological parameters with the exercise often leads to fatigue in the field. This may give some reliable data on physiological responses while performing the exercise on animal treadmill at different speeds, draughts and treadmill inclination in various seasons. It was therefore, felt necessary to conduct extensive studies on physiological responses of draught buffalo taking these parameters in to account while performing the intense treadmill exercise under controlled condition. The experiment was conducted in department of Farm Machinery and Power Engineering, College of Technology, G.B. Pant University of Agriculture and Technology, Pantnagar. The site is situated at 29°N latitude, 29.3°E longitude and 283.8 m above the mean sea level and lies in a narrow belt to the south foothills of Shivalik range of Himalayas known as *Tarai* region. The experiments with the treadmill in controlled conditions at two speeds (1.5 and 2.0 km/h), three inclinations of treadmill (0, 5 and 10°), three draughts (0, 10 and 14% of body weight), two temperatures (22 and 42°C) and two levels of humidity (45 and 90%) were conducted for determining work efficiency without undue fatigue. The experiments were carried out under controlled environmental conditions with two replications for four effective hours in morning and evening or up to the period the test draught he-buffalo reached a state of fatigue.

Materials and methods

Male Murrah buffaloes of body weight 440 ± 5 kg were selected for the present investigation. A treadmill was used to control the speed and inclinations. The draught animals were trained for 15-20 days to walk on treadmill before recording the observations. The maximum and minimum temperatures and humidity were taken as 22 and 42°C and 45 and 90% respectively during the experiment.

The treadmill consisted of a conveyor belt on which the draught buffaloes were made to stand during the experiment. The length of the conveyor belt is 7500 mm with 1000 mm width and 10 mm thickness and was run by an electric motor (7.5 kW). With the rearward movement of the conveyor belt the draught buffaloes make forward movements in order to maintain its position on the belt. The draught buffalo was harnessed with Pant adjustable single animal collar harness and loaded with the help of hanging loads on a pan attached at rear of buffalo. During experiment, the physiological parameters were recorded on hourly basis. Each treatment was replicated twice.

During the course of investigation respiration rate and pulse rate was recorded using two channel Student Physiograph with the help of respiration belt and pulse transducers. The respiration belt transducer was placed around the chest of draught buffaloes and pulse transducer was placed on the middle coccygeal artery (about 100 mm below the level of anus) of the draught buffalo with the help of bandage provided with the sensors. The above transducers are connected with physiograph by means of wire, which senses signals of the respiration rate and pulse rate separately and transfer it to the physiograph with the help of strain gauge and pulse respiration coupler. The draught buffalo was not to be disturbed by any means prior to recording of data. The pointer attached with the physiograph marks the respiration rate and pulse rate of the draught buffalo on graph paper separately. Rectal temperature reflects core body temperature of the animals. The rectal temperature of draught buffalo was recorded at rectal mucous membrane. The rectal temperature was recorded with the help of digital thermometer.

On the basis of data obtained from the present investigation fatigue score card for test draught he-buffalo was developed. The values recorded for respiration rate, heart rate and rectal temperature before the start of the experiment and after 4^{th} h of exercise or till fatigue. The difference of the initial and final values of the respiration rate, heart rate and rectal temperature were divided in to five equal parts, after that fatigue points were assigned as 1, 2, 3, 4 and 5 on the basis of increment in the values of above parameters from initial hour of working. Other visual parameter such as frothing, leg un-coordination and tongue protrusion were taken in to consideration as suggested by UPAD-

HYAY, MADAN (1985). It was assumed that maximum fatigue point up to 30 during severe work load for test draught he-buffalo could be achieved. A critical fatigue point (15) was decided on the basis of 50% of maximum fatigue points achievable by test draught he buffalo (Table 1).

Table 1

Developed Fatigue score card for working buffalo

Parameters	Score card					Total points
	1	2	3	4	5	
Respiration rate, (blows/min)	R_0+37	R_0+74	R_0+111	R_0+148	R_0+185	5
Heart rate, (beats/min)	H_0+17	H_0+34	H_0+51	H_0+68	H_0+85	5
Rectal temperature, °C	T_0+1.40	T_0+2.80	T_0+4.20	T_0+5.60	T_0+7.00	5
Frothing	first appearance	dribbling of saliva starting	continuous dribbling	appearance of forth on upper lip	full mouth frothing	5
Leg uncordination	strides uneven	occasional dragging of feet	movement of leg uncoordinated and frequent dragging of feet	no coordination in fore and hind legs	unable to move because of uncordination	5
Tongue protrusion	mouth closed	occasional opening of mouth	frequent appearance of tongue	continuous protrusion of tongue	tongue fully out	5

R_0, H_0 and T_0 represent initial respiration rate, heart rate and rectal temperature respectively
Note – when the total score is 15 the working buffalo is under fatigue

Results and discussion

The mean values of respiration rate (blows/min) of draught buffaloes during exercise on animal treadmill under controlled environmental conditions at two speeds, three inclinations of treadmill, three draughts, two temperatures and two level of humidity have been depicted in Table 2. The variation in respiration rate with duration of exercise has been presented in Figure 1. It can be seen from the data that respiration rate increased with increase in speed, inclination of treadmill, draught at both the levels of temperature (22°C and 42°C) and humidity (45% and 90%). It is also clear from the Table 2 that at 90% humidity level the rate of respiration was higher in comparison to 45% humidity at both the temperatures in draught buffaloes for different combinations of speeds, inclination of treadmill and draughts. Higher respiration rate was found at 2.0 km/h speed, 10° inclination of treadmill and 14% draught for 22°C temperature and 90% humidity, while at 42°C tempera-

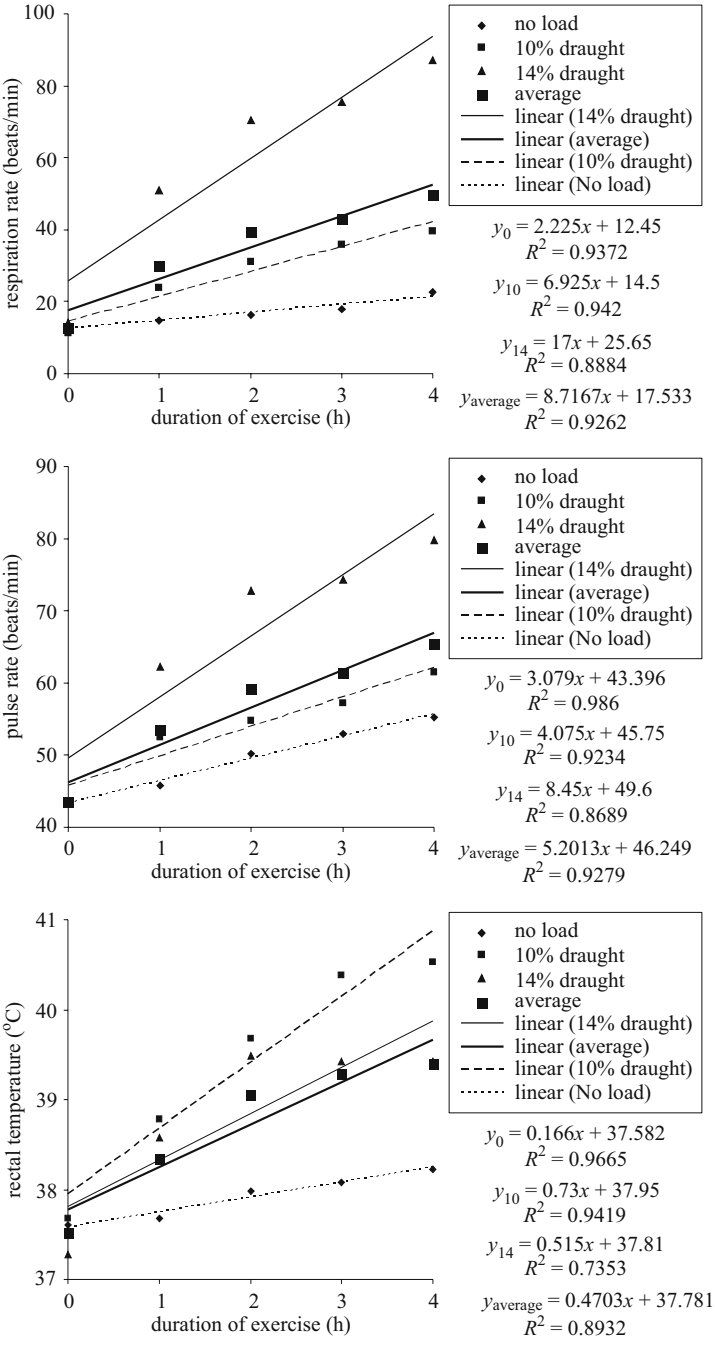

Fig. 1. Typical relationship of physiological parameters and duration of exercise

Table 2

Typical values of respiration rate (blows/min) Pulse rate (beats/min) and rectal temperature (°C) of test draught he buffalo on treadmill exercise under controlled condition at three draughts, two speeds, three inclination of treadmill, two humidity and two temperatures

Speed, km/h	inclination of treadmill, degree	draught,* (%)	humidity, % = 45					humidity, % = 90				
			duration of exercise, h					duration of exercise, h				
			0	1	2	3	4	0	1	2	3	4
Respiration rate, blows/min												
Temperature, °C = 22												
1.5	0	0	16.25	16.75	17.75	19.00	22.00	12.50	16.00	17.50	18.25	21.75
				3.08	**9.23**	**16.92**	**35.38**		**28.00**	**40.00**	**46.00**	**74.00**
2.0	10	14	17.00	158.00	#			16.00	156.00	#		
				829.41					**875.00**			
Temperature, °C = 42												
1.5	0	0	21.50	94.00	111.50	129.00	133.75	25.75	44.00	66.25	79.25	100.25
				337.21	**418.60**	**500.00**	**522.09**		**70.87**	**157.28**	**207.77**	**289.32**
2.0	5	14	62.50	169.00	#			46.75	166.00	196.00	#	
				170.40					**255.08**	**319.25**		
Pulse rate, beats/min												
Temperature, °C = 22												
1.5	0	0	42.00	49.75	50.25	55.50	56.25	48.00	48.75	51.00	53.00	58.00
				18.45	**19.64**	**32.14**	**33.93**		**1.56**	**6.25**	**10.42**	**20.83**
2.0	10	14	48.00	87.00	#			39.00	90.00	#		
				81.25					**130.77**			
Temperature, °C = 42												
1.5	0	0	45.75	51.00	53.25	56.75	59.75	40.50	55.25	58.75	61.25	65.50
				11.48	**16.39**	**24.04**	**30.60**		**36.42**	**45.06**	**51.23**	**61.73**
2.0	5	14	50.25	66.75	#			46.50	69.00	73.00	#	
				32.84					**48.39**	**56.99**		
Rectal temperature, °C												
Temperature, °C = 22												
1.5	0	0	37.26	37.80	37.83	37.90	37.95	37.14	37.40	37.24	37.43	37.68
				1.45	**1.53**	**1.72**	**1.85**		**0.70**	**0.27**	**0.78**	**1.45**
2.0	10	14	36.78	40.83	#			37.13	39.73	#		
				11.01					**7.00**			
Temperature, °C = 42												
1.5	0	0	38.16	39.14	39.62	40.28	40.67	37.06	37.84	38.34	38.55	39.11
				2.57	**3.83**	**5.56**	**6.58**		**2.10**	**3.45**	**4.02**	**5.53**
2.0	5	14	37.88	40.98	#			37.37.	41.68	43.83	#	
				8.18					**11.53**	**17.29**		

P.C. – percentage change

* – draught equivalent to percentage of body weight

– test draught he buffalo did not exercise due to fatigue

ture the increase in respiration rate was also recorded higher for 90% humidity with different combinations of speeds, inclination of treadmill and draughts. For 42°C temperature and 90% humidity, higher respiration rate was observed for 2.0 km/h speed, 5° inclination of treadmill and 14% draught. In general the figures reveal that the respiration rate of test draught he-buffaloes increases with increase in draughts. This result was in agreement with the findings of THAKUR et al. (1987), who reported an increase of approximately 100 to 570% in respiration rate from its resting level for Male Murrah buffalo pulling 30 to 120 kg draught in rotary mode of operation. Similar results were also observed by AGGARWAL, UPADHYAY (1998).

The increase in respiration rate with duration of exercise is mainly due to the effect that the muscles of the draught buffalo involved in draught work, produce more amount of carbon dioxide and lactic acid. The oxidative process due to increased carbon dioxide is triggered to remove excess lactic acid produced by muscles. Subsequently the requirement of oxygen is increased and to overcome oxygen debt, respiratory center is stimulated by increased level of carbon dioxide. This causes increase in respiration rate through increased respiratory frequency. The percentage increase in respiration rate was more pronounced during first two hour of exercise on treadmill at different combinations of speeds, inclination of treadmill and draughts (Tab. 2). This was mainly due to the fact that the draught buffalo attained the steady state after about 2h of exercise. However, no distinct steady state in respiration rate of draught buffalo could be obtained as the main avenue of heat loss in draught buffalo is through mouth. The draught buffalo frequently open the mouth and increase respiration to compensate the thermal loads. These results are consistent with the findings of AGGARWAL, UPADHYAY (1997) who reported an increase in respiration rate by 145.83% from its resting level after 1h exercise on treadmill in hot humid conditions.

The respiration rate values were statistically analyzed using four factorial completely randomized design (CRD). The ANOVA for respiration rate shows that speed, inclination of treadmill and draught were significant at 1% level of significance. The interaction terms (Speed x Draughts, Inclination of treadmill x Draughts) was also significant at 5% and 1% level of significance for 22°C temperature but no definite trend in ANOVA could be obtained from the data at 42°C. Only draught and interaction term (Speed x Inclination of treadmill x Draught) was found significant at 5% level of significance which may be due to changing environmental load and physiological parameters of the draught buffalo.

The mean values of pulse rate (beats/min) of draught buffaloes recorded during experiment have been shown in Table 2. The variation in pulse rate with duration of exercise has been presented in Figure 1. It is clear from the

data that pulse rate increased with increase in speed, inclination of treadmill, draught at both the levels of temperature (22°C and 42°C) and humidity (45% and 90%). It is also clear from the Table 1 that at 90% humidity the pulse rate was higher in comparison to 45% humidity at both the temperatures in draught buffaloes for different combinations of speeds, inclination of treadmill and draughts. Higher pulse rate was found at 2.0 km/h speed, 10° inclination of treadmill and 14% draught for 22°C temperature and 90% humidity, while at 42°C temperature the increase in pulse rate was also recorded higher for 90% humidity with different combinations of speeds, inclination of treadmill and draughts. In general the figures reveal that the pulse rate of draught buffaloes increases with increase in draughts.

The result revealed that increase in pulse rate was more prominent during 42°C than 22°C. This was mainly due to environmental conditions; especially air temperature which has more pronounced effect on pulse rate of draught buffaloes. Similar results were observed by AGGARWAL, UPADHYAY (1997). From, this discussion, it is clear that the pulse rate increased from its resting level more at higher draught at both speeds (1.5, and 2.0 km/h) at 22°C and 42°C. This was mainly due to fact that the effect of draught is more pertinent on pulse rate of draught buffalo. Thus with increase in draught, the draught buffalo are subjected to greater physiological strain.

The mean values of rectal temperature have been presented in Table 2. The variation in rectal temperature with duration of exercise has been presented in Figure 1. It is clear from Table 2 that rectal temperature increased with increase in speed, inclination of treadmill, draughts at both the levels of temperature (22°C and 42°C) and humidity (45% and 90%). It is also clear from the Table 2 that at 90% humidity the rectal temperature was higher in comparison to 45% humidity at both the temperatures in draught buffaloes for different combinations of speeds, inclination of treadmill and draughts. Higher rectal temperature was found at 2.0 km/h speed, 10° inclination of treadmill and 14% draught for 22°C temperature and 90% humidity, while at 42°C temperature the increase in rectal temperature was also recorded higher for 90% humidity with different combinations of speeds, inclination of treadmill and draughts. In general the figures reveal that the rectal temperature of draught buffaloes increases with increase in draughts. Similar trends were observed by SARMA (1994), AGGRAWAL, UPADHYAY (1998).

Just like other physiological parameters, the rectal temperature of draught buffalo increased with the exercise on treadmill for different combinations of speeds, inclination of treadmill and draughts. With the progress of exercise, the demand of oxygen to liberate energy from stored food by oxidation is increased, but the respiratory system is not able to cope up with the increased demand of oxygen resulting into anaerobic respiration rate to supplement

additional requirement of energy. In turn, anaerobic respiration results into lactic acid formation (a by-product) which accumulates in muscles causing its stiffness. This accumulated lactic acid is removed by oxidative process later on, liberating heat, resulting into increase in body temperature. The draught animals are homoeothermic like human beings. The environment surrounding of animal at any particular instant influences the amount of heat exchanged between it and that of environment, consequently it influences the physiological adjustments, and the animals must make to maintain a body heat balance. These adjustments cause a thermal stress on the animals. Due to these thermal stresses, the sweat glands get activated producing sweat and the evaporation of sweat causing cooling of skin (KACHRU et al. 1987). Draught buffaloes specifically have limitations over bullocks in terms of lower number of sweat glands (1.83 to 4.32 per mm^2 of skin) as compared to bullocks (13 to 16 per mm^2 of skin) thus; the buffalo cool slower by sweating. Moreover, colour of skin, its thickness and accumulation of fat layers under the skin which serves as an insulating media also affects the cooling process (COCKRALL 1974, THAKUR et al. 1987).

A comparative study of variation in rectal temperature at all speeds revealed that increase in rectal temperature was minimum at 1.5 km/h speed at 22°C temperature as well as at 42°C, followed by 2.0 km/h speed during 22°C and 42°C temperature respectively. The minimum increase in rectal temperature at 1.5 km/h was mainly due to the fact that the working speed of treadmill was less as compared to 2.0 km/h speed. The draught buffalo did not feel any stress and the rectal temperature along with other physiological parameters were well within the permissible range at a slow speed of 1.5 km/h compared to other higher speeds. In general, increase in rectal temperature was more at 14% draught during exercise on treadmill. This was mainly due to the fact that the effect of draught is more effective on rectal temperature of draught buffalo. A comparison of data of rectal temperature at 22°C and at 42°C indicated higher values of rectal temperature during 42°C which was mainly due to poor heat dissipation characteristics of draught buffalo in summer season.

The rectal temperature was statistically analyzed using four factorial completely randomized design (CRD) for different combinations of speeds, inclination of treadmill, draughts and combination of temperature and humidity. The ANOVA for rectal temperature shows that speed, inclination of treadmill and draught were significant at 1% level of significance and interaction term (Inclination of treadmill x Draughts) was significant at 1% level of significance for 22°C temperature but no definite trend in ANOVA could be obtained from the data at 42°C which may be due to changing environmental load and physiological parameters of the animal. Other parameters and their interactions show non-significant effect on rectal temperature.

The variation in fatigue scores of test draught he buffalo during exercise on treadmill under controlled environmental condition at two speeds, three inclinations of treadmill, three draughts and two level of temperature and humidity has been studied. The combinations of speed, inclination of treadmill, draughts and temperature and humidity causes fatigue to test draught he buffalo. The fatigue score card has been developed (Tab. 1) in the present investigation was used for fatigue analysis. During experiment, the fatigue of test draught he buffalo increased with the duration of exercise and the increase was more pronounced at higher speed, inclination of treadmill and draught for both the combinations of temperature and humidity. This is mainly due to the fact that the effect of draught is more prominent on all the physiological responses and on visual parameters of test draught he buffalo.

Summary and conclusion

The performance of test draught he-buffalo on animal treadmill at two speeds (1.5 and 2.0 km/h), three inclinations of treadmill (0, 5 and 10°), three draughts (0, 10 and 14% of body weight), two temperatures (22 and 42°C) and two levels of humidity (45 and 90%) were evaluated for determining work efficiency without undue fatigue. The experiments were carried out on animal treadmill under controlled environmental conditions with two replications for four effective hours in morning and evening or upto the test draught he-buffalo reached a state of fatigue. The respiration rate, pulse rate and rectal temperature increased with combinations of speeds, inclinations of treadmill and draughts. The physiological responses such as respiration rate, pulse rate and rectal temperature were more prominent during 42°C temperature and 90% humidity. The respiration rate of test draught he-buffalo was found to be more sensitive to increase during exercise on treadmill at different level of speeds, inclination of treadmill and draughts, therefore it can be considered as good indices of physiological response for quantifying fatigue. The percentage increase in pulse rate of test draught he-buffalo with duration of exercise and increasing speeds, inclination of treadmill and draughts were of minor nature and thus, pulse rate is not a good indicator of heat stress. The percentage increase in rectal temperature of test draught he-buffaloes with increasing speeds, inclination of treadmill, draughts and duration of exercise was more sensitive and thus can be considered as a good indicator of physiological load for the comparative study.

Fatigue score card prepared for test draught he-buffaloes showed the best performance upto 14% draught at 1.5 km/h speed followed by 2.0 km/h speed (upto 10% draught) for 0 and 5° inclination of treadmill during 22°C tempera-

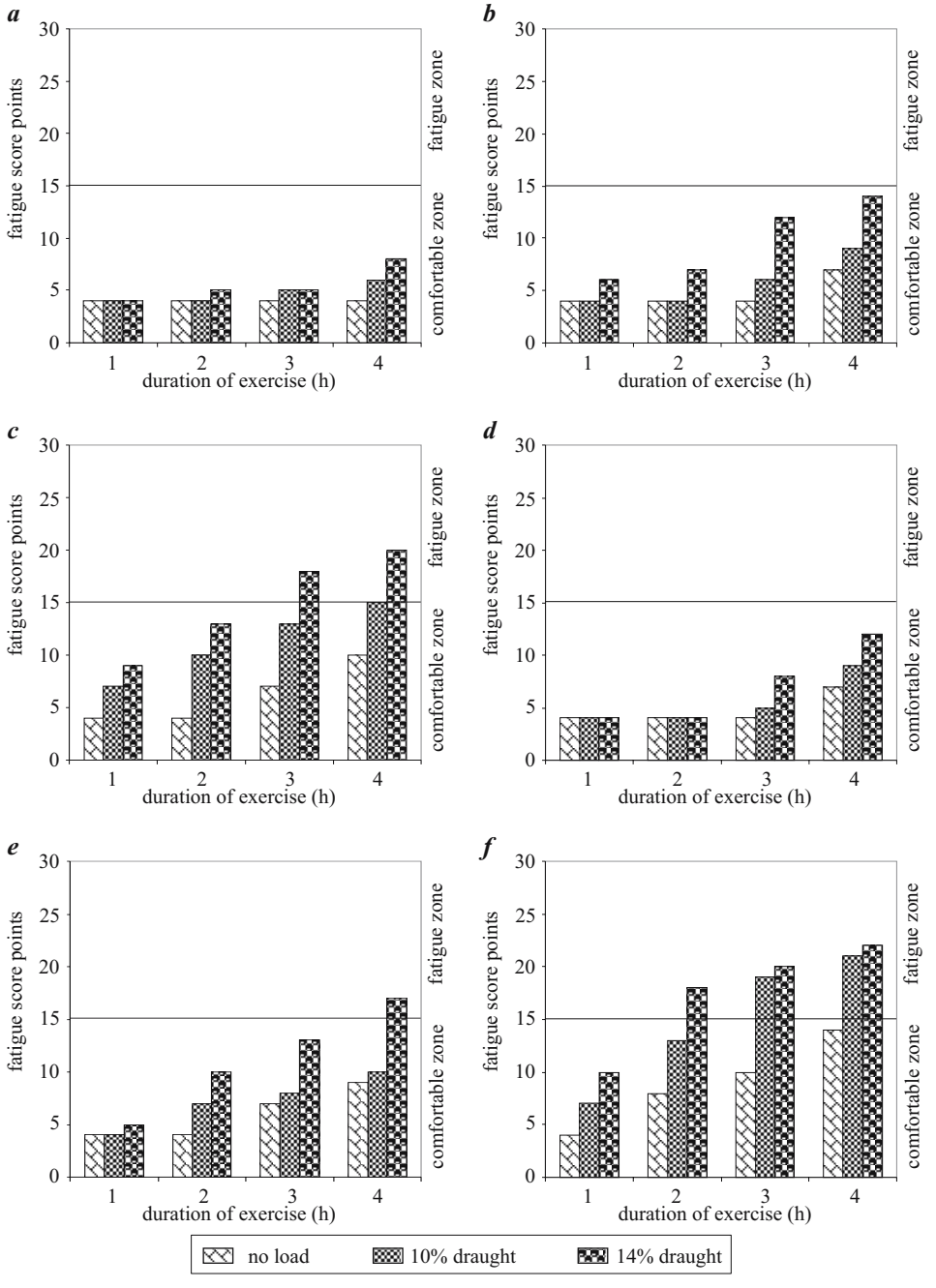

Fig. 2. Relationships between fatigue score points and duration of exercise at different draughts and test conditions

ture and 45% humidity upto 4th hour of exercise. At 22°C temperature and 90% humidity the best performance was shown at 14% draught for 0° inclination of treadmill 10% draught for 5° inclination of treadmill and 0% draught for 10° inclination of treadmill at 1.5 km/h speed while at 2.0 km/h speed the best performance was shown at 0% draught for 0, 5 and 10° inclination of treadmill. During 42°C temperature and 45% humidity the best performance was shown only for 0% draught at 1.5 km/h speed with 0° inclination of treadmill.

On the basis of above findings and velationships shown in Figure 2, it is concluded that out of two speeds (1.5 and 2.0 km/h), the 1.5 km/h speed showed the best performance (at 14% draught) for 0 and 5° inclination of treadmill followed by 2.0 km/h speed at 14 and 10% draughts respectively for 0 and 5° inclination of treadmill during 22°C temperature and 45% humidity. At 10° inclination of treadmill the test draught he-buffalo reached a state of fatigue beyond 1h at 1.5 and 2.0 km/h speed at 14% draught. During 22°C temperature and 90% humidity the best performance was shown at 14% draug0ht for 0° inclination of treadmill, 10% draught for 5° inclination of treadmill and 0% draught for 10° inclination of treadmill at 1.5 km/h speed beyond which the test draught he-buffalo reached the state of fatigue so this draught (14%) level could only be recommended only for very short duration of exercise.

The Hematological parameter such as hemoglobin, packed cell volume, total erythrocyte count, total leukocyte and chloride concentration show irregular but declining trend while potassium and sodium concentration shows irregular but increasing trend where mean corpuscular concentration shows variable but increasing trend during tread mill exercise. These results and relationships are presented in Table 3 and Figure 3.

Table 3

Hematological parameter (gm%) of test draught he-buffalo on treadmill exercise under controlled condition at three draughts, two speeds, three inclination of treadmill, two humidity and two temperatures

Parameters	Speed, 1.5 km/h				Speed, 2 km/h			
	humidity, % = 45		humidity, % = 90		humidity, % = 45		humidity, % = 90	
	temperature		temperature		temperature		temperature	
	22°C	42°C	22°C	42°C	22°C	42°C	22°C	42°C
Hemoglobin	8.23	19.27	8.99	15.84	4.34	17.14	12.54	15.23
Packed Cell volume	13.44	25.55	15.76	18.50	22.85	24.48	11.40	29.12
Total Erythrocyte count	12.98	19.30	10.85	17.90	8.51	11.80	12.31	5.76
Total Leukocyte	16.11	27.95	22.85	29.34	19.84	35.82	23.08	24.70
Potassium concentration	1.11	4.97	2.21	3.32	4.70	3.04	5.52	7.74
Sodium concentration	3.60	5.82	4.11	9.08	10.62	10.96	13.19	13.02

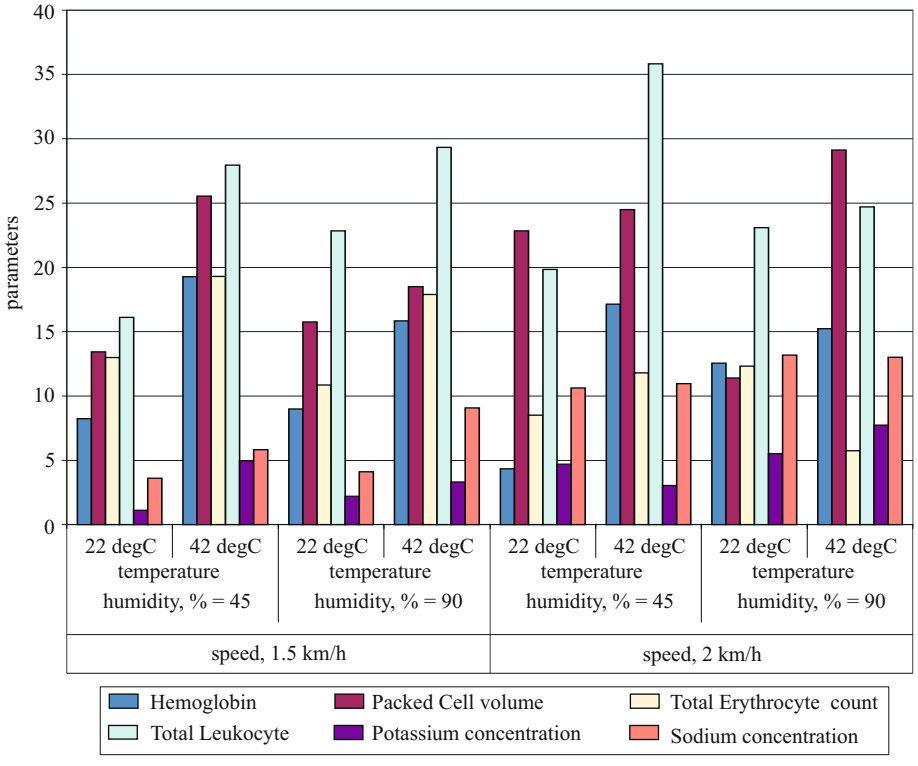

Fig. 3. Relationship between Hematological parameter (gm%) and three draughts, two speeds, three inclination of treadmill, two humidity and two temperatures of test draught he-buffalo on treadmill exercise under controlled condition

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