PRINT: ISSN 0970-9274 ONLINE: 2456-6608

DOI: 10.31901/24566608.1990/01.01.06

JOURNAL OF
HUMAN ECOLOGY

J. Hum. Ecol., 1(1): 47-52 (1990)

Sex Differences in Physical Fitness and Exercise Induced Changes in Physiological Functions in a Hot Desert Environment

Anju Swami and S.L. Malik
Department of Anthropology, University of Delhi, Delhi-110 007, India

KEY WORDS Desert. Adaptation. Physical Fitness. Exercise. Sex Difference. Physiological Functions.

ABSTRACT Data were collected on 140 adult males and 140 adult females, in the age range of 18 to 60 years, from the endogamous group of Rajput, living in Jodhpur (Rajasthan). The study aims at investigating differences in physical fitness and physiological responses to work performed in a stressful hot dry desert environment. Males were physically more fit as compared to females. In both the sexes, there was a rise in body temperature, pulse rate and blood pressure with exercise. The sex differences in the increase in body temperature and pulse rate were statistically non-significant. However, the rise in blood pressure with exercise was significantly higher in males than in females. Females possessed more heat activated sweat glands, per square centimeter, than males. Most of the subjects (of both sexes) showed similar sweating pattern beginning from the forehead followed by limbs, chest and trunk respectively.

The people living in ecological zones with high temperature face the stress of heat in carrying out their daily routine activity. In conditions, such as deserts, where the supply of water is limited it causes further inconvenience and requires a series of modifications in body functional capacities. During work when heat is produced, the heat dissipation is a serious problem (Wyndham, 1973; Wells, 1980).

Males and females have different physiological response to heat stress due to several factors, including lower cardio-respiratory fitness (Avellini et al., 1980; Horstman and Christensen 1982), higher body fat content (Bailey, 1982; Stini, 1982; Susanne, 1980; Johnston, 1980), lower body weight (Hauspie et al., 1980), lower skin surface area to mass ratio in females than males (Fein et al., 1975). In addition, the fluctuating hormonal levels of estrogen and progesterone accompanying the menstrual cycle may also influence the tolerance of females to heat stress (Kawahata, 1960; Blittel and Henave, 1975). Several studies have demonstrated that females thermoregulate less efficiently than males, when exposed to heat stress (Nadel et al., 1978; Shapiro et al., 1980). Under the same heat stress, females start sweating at higher temperature, sweat less, store more heat, thus have higher core temperature and heart rates (Shephard, 1978; Shapiro et al., 1980). Therefore, the present study aims at examining the sex differences in physical fitness and physiological responses to performing work in a hot desert environment.

MATERIAL AND METHODS

The fieldwork was undertaken in June and July, 1987 in Jodhpur district of Rajasthan State (India). Engulfed in Thar desert, Jodhpur is characterized by harsh environmental conditions, such as, air temperature higher than that of the body core, high aridity, large diurnal variations, sparse vegetation, low food availability (both caloric and protein), limited water resources.

Data were collected on 140 adult male (mean age 29.1 years) and 140 adult female (mean age 34.4 years) Rajputs living in Salawas and Nandwan villages, in the age range of 18 to 60 years.

Harvard step test was used for evaluating physical work performance (Weiner and Lourie, 1969). The following measurements were taken before and after exercise (step test).

(i) *Body Temperature:* Skin temperature at six different sites of body, *i.e.* forehead, arm, hand, trunk, thigh and calf were taken with the help of fever meter tape and recorded in centigrade. Oral temperature was taken using a clinical thermometer.

(ii) *Pulse Counts:* Pulse counts at rest and between 60 and 90 seconds after exercise were taken using palpation method(Weiner and Lourie, 1969).

(iii) *Blood Pressure:* Pre-and post-exercise arterial blood pressure were measured indirectly following International Biological Programme recommendations (Weiner and Lourie, 1969) and recorded in mmHg.

(iv) *Activated Sweat Gland Count:* After exercise, pattern of onset of sweating and the number of sweat glands activated, per square centimeter, were determined at chest, scapular, forearm, deltoid, thigh and calf regions. For the enumeration of active sweat glands the plastic impression technique introduced by Thompson and Sutarman (1953) was used.

RESULTS AND DISCUSSION

Adult Rajput males and females differed significantly from each other in the Rapid Fitness Index (RFI). Males were physically more fit than their female counterparts (Table 1). Males,having lower body fat and higher haemoglobin concentration than females,are able to generate more aerobic energy (Astrand and Rodahl, 1977; Katch and McArdle, 1977;De Vries,1980), that culminates in their higher Rapid fitness index. Higher mean age of Rajput females seem to be an additional factor responsible for their lower RFI value, as is well established that the physical fitness decreases with age during adulthood, with the usual course of changes in maximum oxygen intake, body fat, muscle strength, vital capcity and heart rate (Astrand, 1973; Bailey et al., 1974; Roskman, 1973; Shephard, 1977). At least some population specific socio-cultural factors must have contributed to the sexual differences in Rapid fitness index. For example, the normal physical activity level between an average male and female Rajput differed; the former usually performing harder physical labour in economic pursuits. Socio-cultural constraints such as precluding women to do exercise and shyness must have been responsible for further enhancing the gap between two sexes in physical activity. Until recently, it was not socially acceptable for the Rajput women to undertake vigorous physical exercise, at least in the rural areas of Rajasthan.

The pre-and post-exercise temperature recorded at the forehead, arm, hand, trunk, thigh, calf and oral temperature showed significant increaase in temperature with exercise in both the sexes (Table 2). In normal healthy individuals core body temperature is maintained within a narrow limit by the factors that gain and dissipate body heat. The effectiveness of the heat dissipating processes depend largely on the gradient of heat between the body core and the external environment and the air movement. In a hot dry climate, environmental temperature is higher than that of body core temperature. As such heat can be gained but not lost by either convection or conduction. Under such conditions heat is likely to be absorbed from the environment by solar radiation and from the objects which are warmer than the body. Further, during exercise, muscles become active and produce tremendous amount of body heat. Vigorous exercise can increase the metabolic rate from 20 to 25 times, above the basal level, which can theoretically increase the core temperature by about 1°C every 5 minutes of exercise (McArdle et al., 1981). Thus, during exercise in a hot dry climate, both, the internally generated metabolic heat and the heat absorbed from the hotter external environment have to be dissipated. To protect the body from overheating the warm blood

Table 1: Sex differences in Rapid Fitness Index among Rajputs of Jodhpur

Measurement	Males			Females			Value of
	Mean	S.D.	S.E.	Mean	S.D.	S.E.	't'
RFI	112.32	15.67	1.32	93.14	23.19	1.96	4.16**

** Significant at 1% probability level.

Table 2: Impact of exercise on Body temperature, Blood pressure, Pules count among Rajputs of Jodhpur

Measurement	Males			Females		
	Pre-Exercise	Post-Exercise	Exercise Impact[1]	Pre-Exercise	Post Exercise	Exercise Impact[1]
BODY TEMPERATURE						
Forehead	99.62	100.66	14.85*	99.64	100.56	10.22*
Arm	98.95	99.60	3.61*	98.99	99.52	8.83*
Hand	98.87	99.45	9.61*	98.93	99.32	6.50*
Trunk	99.27	100.10	11.85*	99.13	99.86	14.60*
Thigh	98.96	99.85	2.53*	98.92	99.36	11.00*
Calf	99.34	99.53	2.18*	98.79	99.63	21.10*
Oral	99.64	100.87	14.87*	99.62	100.57	10.23*
BLOOD PRESSURE						
Systolic	124.14	134.17	6.15*	120.14	129.96	6.17*
Diastolic	68.19	75.31	6.24*	65.16	73.06	5.14*
PULSE COUNT	63.57	85.35	11.04*	68.44	83.90	11.04*

1. Values of t
* Significant at 5% probability level.

is diverted to the body shell by peripheral vasodilation for dissipation. Flushed or reddened face, while performing exercise in hot dry climate, is a direct consequence of such a process. This, nonetheless, causes a minor rise in the skin and the oral temperature, as observed in the present study. The increased skin and oral temperatures, in turn, assist in heat dissipation through the radiative heat transfer from the skin surface especially from the forehead, hands and forearm. This occurs before evaporative heat loss occurs at the maximal level and permits maintenance of body core temperature. In this way it minimizes the energy expenditure required for cooling the body and can be interpreted as an adaptive response in performing physical work in a hot climate. This also suggests that the Rajputs are well adapted to work in hot desert climate.

In spite of lower sweat output in females (Bar et al., 1968; Drinkwater, 1976) the increase in body temperature (both pre-and post-exercise) at six sites were, statistically non-significant at 5% probability level (Table 3). Females seem to be as efficient as males in temperature regulation, because of larger surface area to mass ratio which is a favourable dimensional characteristic for heat dissipation (McArdle et al., 1981). Consequently, under identical conditions of heat exposure, women tend to cool at a faster rate than men through a smaller body mass across a relatively large surface area.

In both the sexes, there is a lesser rise in temperature in limbs than the forehead or the oral temperature. The higher surface area to mass ratio of the limbs and their lower level of metabolic activity makes them potentially better in heat loss transaction. This in turn, accounts for a lesser increase in temperature of the limbs. Conversely, due to lesser exposed evaporative surface area of forehead and face, the rate of heat dissipation from there is slow as compared to limbs, thus accounting for greater increase in

Table 3: Sex difference in pre-and post-exercise Body temperatures, Blood pressure, Pulse count and Heat activated sweat glands among Rajputs of Jodhpur

	Pre-Exercise			*Post-Exercise*		
	Males	*Females*	*Sex Diff.*[1]	*Males*	*Females*	*Sex Diff.*[1]
BODY TEMPERATURE						
Forehead	99.62	99.64	0.25	100.66	100.56	0.19
Arm	98.95	98.99	0.80	99.60	99.52	0.15
Hand	98.87	98.93	2.10*	99.45	99.32	1.42
Trunk	99.27	99.13	2.80*	100.10	99.86	3.42*
Thigh	98.86	98.92	1.50	99.85	99.36	1.25
Calf	99.33	98.79	1.45	99.53	99.63	0.90
Oral	99.64	99.62	0.25	100.87	100.57	0.38
BLOOD PRESSURE						
Systolic	124.14	120.14	2.38*	134.17	129.96	2.79*
Diastolic	68.19	65.16	2.63*	75.31	73.06	2.15*
PULSE COUNT	68.57	68.44	0.12	85.35	83.90	1.05
HEAT ACTIVATED SWEAT GLANDS						
Chest Region	-	-	-	40.48	50.32	3.47*
Scapular Region	-	-	-	43.81	52.30	3.69*
Forearm Region	-	-	-	57.07	64.73	2.57*
Deltoid Region	-	-	-	45.47	52.58	2.35*
Thigh Region	-	-	-	33.31	44.01	4.11*
Calf Region	-	-	-	35.59	45.67	3.60*

1. Values of t
* Significant at 5% probability.

temperature of these regions.

Clothes impose a significant barrier to heat dissipation, because they seal off about 50% of the body surface from the benefit of evaporative cooling (Fox 1966; Mathews, 1969). In deserts, light weight, light coloured, loose garments are usually desirable as they favour ventilation and evaporation from the skin. Although, a light coloured external garment may reflect radiation, reducing heat gain (Hanna, 1983), people of Rajasthan prefer to wear deep coloured clothes such as red, black, and blue. The use of coloured clothes cannot be explained in terms of adaptation, as they would increase body heat partly due to heat absorption, but more importantly by decreasing heat dissipation. A possible explanation for this may be that in the arid monochromatic desert, human beings try to overcome dullness by wearing bright colour clothes.

In both the sexes post-exercise mean values of systolic and diastolic blood pressure, pulse rate were significantly greater as compared to pre-exercise mean values (Table 2). The observed increase in the mean values of blood pressure and pulse count in both the sexes during exercise, indicate cardiovascular stress. The increased surface blood flow in response to increased body heat content induces an increase in cardiovascular activity, by specifically increasing heart rate and blood pressure (Gislofi and Wenger, 1984). Though, the sex difference in pulse count was statistically not significant in the present study, but in blood pressure the increase among males was more than females, probably due to their smoking habits, opium addiction and harder physical labour. Among males, the use of intoxicants such as alcohol, tobacco, and opium was quite common and often has social sanction. Opium, for example, is used in the rituals, at the time of marriages and important festivals.

The region with the highest number of heat activated sweat glands in both males and females was the forearm (Table 3). The upper limbs had distinctly more heat activated sweat glands, per square centimeter, than the lower limbs, with the chest region having fewer activated glands than the trunk region. The generalized pattern for the heat activated sweat glands in both males and females was the same, with forearm region having the highest number of heat activated sweat glands followed by deltoid, scapular, chest, calf and thigh region respectively (Table 3). A possible explanation for this finding is that the sweat loss per unit surface from forearm region gives the maximum cooling benefit to an individual, as blood circulation in the skin at this region of the body is much more than any other site. A small amount of sweat whch is completely evaporated matches in cooling efficiency with that of the larger amounts secreted at other sites. An indication of this process was also given by different regions of the body, *i.e.* forearm, deltoid, scapular, chest, calf and thigh regions, which, however, differ widely from each other in the activation of sweat glands in two sexes because of the differences in sweat gland density at various sites in the body (Table 4).

Females possessed more heat activated sweat glands per unit than males at all sites (Table 3). Despite this, females sweat less profusely than males (Leithead and Lind, 1964; Wells, 1980) but show similar heat tolerance as males (Bar et al., 1968; Drinkwater, 1976). This finding suggest that females rely more on the circulatory mechanism for heat dissipation whereas males make greater use of evaporative cooling through sweating. The production of less sweat to maintain thermal balance provides significant protection from dehydration during work at higher ambient temperature among females, showing lesser ecosensitivity and greater adaptive capacity of females than males (Wolanski and Malik, 1984).

The pattern of sweating in majority of the subjects was of the following kind. Sweating first occured at forehead followed by limbs, chest and trunk respectively. The limbs serve as better organs in heat dissipation, because of their larger surface area to mass ratio and lower level of metabolic heat production. Other possible pattern types along with their frequency in both the sexes are summarized in Table 5. The observed pattern of sweating provides a much more efficient vector for heat loss in a hot dry environment at no further elevation in energy expenditure and

Table 4: Comparison of heat activated sweat glands per square centimeter in various body segment (Values of t-test)

Sites	*Ch.R.*	*S.R.*	*F.R.*	*D.R.*	*T.R.*	*C.R.*	
Ch.R.		0.69	4.60*	0.69	2.01*	1.48	
S.R.	1.48		4.43*	0.69	2.8*	2.28*	
F.R.	6.3*	5.52*		3.79*	6.59*	6.07*	
D.R.	1.97*	0.72	4.2*		2.6*	2.1	Females
T.R.	3.25*	5.25*	9.9	5.2*		0.5	
C.R.	2.0	3.2*	8.26*	3.8*	1.03	Males	

Female values above the diagonal line and male values below the diagonal line

ChR = Chest region; SR = Scapular region; FR = Forearm region; DR = Deltoid region; TR = Thigh region; CR = Calf region;

Table 5: Percentage distribution of various possible sweating pattern types among Rajputs of Rajsthan

	Pattern Types			*Males*	*Females*
1.	Forehead	---------------------- Limbs	---------------Chest/Trunk	80.71	85.12
2.	Limbs	-------------------Forehead	---------------Chest/Trunk	14.28	14.87
3.	Chest	-------------------Forehead	---------------------- Limbs	5.00	6.61

can thus reduce the perspiration required to maintain thermal equilibrium.

In conclusion, males are physically more fit as compared to females. Though the sex difference in increase in body temperature and pulse rate is not evident but it is much more marked in case of increase in blood pressure, and heat activated sweat glands per square centimeter.

REFERENCES

Astrand P.O.: Physiological basis for sport at different ages. In: *Sport in the Modern World—Chances and Problems*. O. Grupe, D. Kurz, J.M. Teipel and J.M. Berlin (Eds.). Springer-Verlag, Heidelberg (1973).

Astrand, P.O. and Rodahl, K.: *Textbook of Work Physiology*. McGraw-Hill Book Co., New York, 2nd Edition (1977).

Avellini, B.A. Kamon, E. and Krafewski, J.T.: Physiological responses of physically fit men and women to accli mation to humid heat. *J. Appl. Physiol., 49:* 254-261 (1980).

Bailey, D.A., Ross, W.D., Weese, C. and Mirwald, R.L.: A dimensional analysis of aerobic power in boys. *Proceedings of 6th Int. Symp. Pediat. Work Physiolog. Sec.* Czechoslovakia (1974).

Bailey, S.M.: Absolute and relative sex differences in body composition In: *Sexual Dimorphism in Homo sapiens: A Question of Size,* R.L. Hall (Ed.). Praeger Publishers, New York (1982) pp 363-390.

Bar, O. O., Landergren, H.M., Magnusson, I.J. and Buskrik, E.R.: Distribution of heat activated sweat glands in obese and lean men and women, *Hum. Biol., 40:* 235-248(1968).

Bittel, J. and Henave, R.: Comparison of thermal changes in men and women under natural and hot conditions. *J. Physiol. London, 250:* 475-489 (1975).

DeVries, H.: *Physiology of Exercise for Physical Education and Atheltics.* Wm. C. Brown Publishers, Ubuque, I.A. 3rd Edition (1980).

Drinkwater, B.L.: Aerobic power as a factor in women's response to work in hot environments. *J. Appl. Physiol., 41:* 815 (1976).

Fein. J.T., Haymes, E.M. and Buskirk, E.F.: Effects of daily and intermittent exposures on heat acclimation of women. *Int. J. Biometerol., 19:* 41-52 (1975).

Fox, E.: Effects of football equipment on thermal balance and energy cost during exercise. *Res. Quart., 37:* 322-328 (1966).

Gislofi, C.V. and Wenger, C.B.: Temperature regulation during exercise: Old concepts new ideas. In: *Exercise and Sports Science Reviews,* R.L. Terjung (Ed.). MacMillan Publishing Co., New York (1984).

Hanna, J.M.: Human heat tolerance: An anthropological perspective *Ann. Rev. Anthropol.,* 12: 259-84 (1983).

Hauspie, R., Watcholder A., Baron, G., Cantraine, F., Susanne, C. and Grafflar, M.: A comparative study of fit of four different functions to longitudinal data of growth in height of Belgian girls. *Ann. Hum. Biol., 7:* 347-358 (1980).

Horstman, D.H. and Christensen. E.: Acclimatization to dry heat. Active men *vs* active women. *J. Appl. Physiol., 52:* 825-831 (1982).

Herstmansen, L. and Anderson, K.L.: Aerobic work capacity in young Norwegian men and women. *J. Appl. Physiol., 20:* 425 (1965).

Johnston F.E.: Nutrition and Growth. In: *Human Physical Growth and Maturation: Methodologies and Factor,* F.E. Johnston, A.F. Roche and C. Susanne (Eds.), Plenum Press, New York (1980).

Katch, F.I. and McArdle, W.D.: *Nutrition Weight Control and Exercise.* Houghton Mifflin, Boston (1977).

Kawahata, A.: Sex differences in sweating. pp. 1-66 In: *Essential Problems in Climatic Physiology.* M.Yoshimura, K. Ogata and S. Ito (Eds.). Nankedo, Kyoto, Japan (1960).

Leithead, C.S. and Lind, A.R.: *Heat Stress and Heat Disorders.* Davis, Philadelphia (1964)

Mathews, D.K.: Physiological response during exercise and recovery in a football uniform. *J. Appl. Physiol., 26:* 611 (1969).

McArdle, W.B., Katch, F.I. and Katch, V.L.: *Exercise Physiology: Energy, Nutrition and Human Performance.* Lea and Febriger, Philadelphia (1981).

Nadel, E.R., Roberts, M.R. and Wenger, C.B.: Thermoregulatory adaptation to heat and exercise: comparative response of men and women. In: *Environmental Stress: Individual Human Adaptation,* C.J. Folinsbee, J.A. Wanger, J.F., Borgia and B.L. Drinkwater (Eds.). Academic Press, New York (1978).

Roskaman, H.: Units and age dependency in the adaptation of the heat to physical stress. In: *Sport in the Modern World—Chances and Problem,* O. Grupe, D. Kurz, J.M. Teipel and J.M. Berlin (Eds.). Springer-Verlag, Heidelberg (1973).

Shapiro, Y., Pandolf, K.B.,Avellini, B.A., Pimental, N.A. and Goldman, R.F.: Physiological responses ot men and women to humid and dry heat. *J. Appl. Physiol., 49:* 1-8 (1980).

Shephard, R.J.: Activity patterns of elderly men and women. *J. Gerontol., 32:* 25-32 (1977).

Shephard, R.J.: *Human Physiological Work Capacity.* University Press, Cambridge (1978).

Susanne, C.: Socio economic differences in growth patterns. In: *Human Physical Growth and Maturation: Methodologies and Factors.* F.E. Johnston, A.F.Roche and C. Susanne (Eds). Plenum Press, New York (1980).

Stini W.A.: Sexual dimorphism in nutrient reserves, In: *Sexual Dimorphism in Homo sapiens:A Question of Size.* R.L. Hall (Ed). Praeger Publishers, New York (1982) pp 363-390.

Thompson, M.D. and Sutarman: The identification and enumeration of active sweat glands in man from plastic impression of the skin. *Trans. R. Soc.Trop. Med.Hyg., 412:* 417 (1953).

Wells, C.L.: Responses of physically active and acclimatized men and women to exercise in a desert environemnt. *Med. Sci. Sports Exercise, 12:* 9-13 (1980).

Weiner. J.S. and Lourie, J.A.: *Human Biology: A Guide to Field Methods.* IBP Handbook No. 9. Blackwell Scientific Publications, Oxford (1969).

Wolanski, N. and Malik, S.L.: Human Ecology: The Need for a new emerging science. *Studies in Human Ecology, 5:* 7-13 (1984).

Wyndham, C.H.: The physiology of exercise under heat stress. *Ann. Rev. Physiol., 35:* 193-220 (1973).