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PHYSIOLOGICAL STUDIES OF HEAT STRESS ACCLIMATION DURING A SPECIFIC EXERCISE REGIMEN

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ABSTRACT

Eleven subjects were used to determine if the exercise regimen of racquetball could be used as a heat stress acclimator. Core temperature, skin temperature, sweat production, and weight loss were recorded during a racquetball match. Skin and core temperatures were determined by using thermistors. Sweat was collected with modified stress electrodes. Weight loss was recorded by comparing nude weights at the beginning and end of a match. The results indicated that an hour of strenuous racquetball play caused a significant increase in core temperature with subsequent sweating which resulted in a significant decrease in skin temperature and weight loss. The exercise regimen of racquetball can act as a good heat stress acclimator because it produces sufficiently high levels of hyperthermia.

INTRODUCTION

It has been known for some time that heat stress adversely affects human performance (Nunneley and James, 1977; Ramsey et al., 1975). Most authors now agree that physical training in a cool environment improves heat tolerance and heat acclimatization (Cohen and Gisolfi, 1982; Pandolf et al., 1977). The retention of heat acclimatization responses also appears improved in physically trained individuals (Pandolf et al., 1977). The maintenance of a high level of sweating, lowered heart rate, and lowered internal body temperature are mentioned as the physiological changes associated with improved exercise heat tolerance or heat acclimatization during physical activity in a hot environment. These adaptive responses to heat stress can be established by engaging in endurance training programs that increase the heart rate to at least 60% of the maximum heart rate reserve (MHRR) and that cause high levels of sweating (American College of Sports Medicine position statement, 1978).

Studies on the effects of endurance training programs have been in running, cycling or swimming (Henane et al., 1977; Roberts et al., 1977). Other forms of physical activity have not been thoroughly investigated. Recent studies (Morgans et al., 1982) have shown that the exercise regimen of racquetball can increase heart rate. It was reported by these authors that during a racquetball match, which lasted for an hour, the players attained an average of 75% of their MHRR. At no time during the match did the heart rate drop below 60% of the MHRR. Additional data on changes in body temperature and in rate of sweat production are required to understand the influence of a racquetball game on thermal acclimatization. The purpose of this study is to determine the changes in skin temperature, core temperature, and sweat production during a racquetball match in order to examine the effectiveness of this indoor game as a heat acclimator which produces hyperthermia within a physiological range.

MATERIALS AND METHODS

Total body weight loss and percent body weight loss were calculated by comparing nude weights before and after a match (Health o meter scales, Continental Scale Corp.). Before the weights were recorded, the subjects showered with warm water in order to remove as much body oil, sweat, cellular debris, etc. from the body as possible. Input or output of solid or liquid was prohibited during the match.

Skin and core temperatures during the match were monitored with thermistors (YSI, 400 series). A Cole-Parmer thermistor thermometer meter was used to record the temperatures. The skin thermistors were attached to the chest and the core thermistors were inserted approximately 8-10 cm into the rectum. Temperature recordings were made immediately prior to the commencement of the match and every ten minutes during the match.

Disposable stress electrodes (Ludlow Medical Products) were modified so that they could be used to collect sweat. The modification consisted of removing the viscous spongy center of the electrode and replacing it with some water absorbent material (Dririte) which was covered by some filter paper that was glued to the central portion of the electrode. These electrodes were weighed and a single electrode was attached to (1) the superior portion of the back area; (2) the chest, and (3) the forehead. At the end of the match, the electrodes were re-weighed and the quantity of sweat produced was calculated.

Wet bulb, dry bulb, and relative humidity recordings were made with a sling psychrometer. These recordings were made on the racquetball court before and after every racquetball match. The recordings were almost identical for each match (22.8°C db, 18.4°C wb, 68%rh).

The experiments were performed at a local racquetball-health spa (Arkansas Health World-South). Players were matched as closely to someone of their own ability level so that a maximum effort could be attained (Montgomery, 1981).

Significant differences between two means (e.g., core temperature differences before and after a match) were calculated by using a Student's t-test. Correlations between various parameters, such as between sweat rate and weight loss, were determined by using Pearson Correlation Coefficients (Snedecar and Cochran, 1967).

RESULTS

The changes that occurred in core temperature are shown in Figure 1. Rectal temperatures rose from 37.6 °C at the beginning of the match to 39.0 °C at the end of the match. This increase was significant ($P < .001$). The rise in temperature was sustained throughout the entire match and a steady state was never reached, even at the end of the hour (Figure 1).

There was a significant decrease in skin temperature ($P < .025$) during one hour of racquetball play. The skin temperature decreased from 32.6 °C at the beginning of the match to 31.1 °C at the end of the match (Figure 2). However, there was a small rise in temperature at the 40 minute mark of the match.

Sweat rates, weight losses, and percent weight losses of the subjects while they played racquetball for an hour are shown in the Table. An hour of racquetball play caused an increase in sweat excretion. The rates of sweat production were observed to vary greatly among players. The recorded values were between 0.95 $mg/cm^2/min$ and 2.05 $mg/cm^2/min$. The average sweat excretion was 1.58 $mg/cm^2/min$. per individual.

There was no marked decrease in body weights. Average weight reduction was 1.21 kg or 1.53% of the total body weight.

Pearson correlation coefficients showed that a positive correlation existed between sweat rates and weight losses ($r = 0.66$) and between sweat rates and core temperature changes ($r = 0.84$).

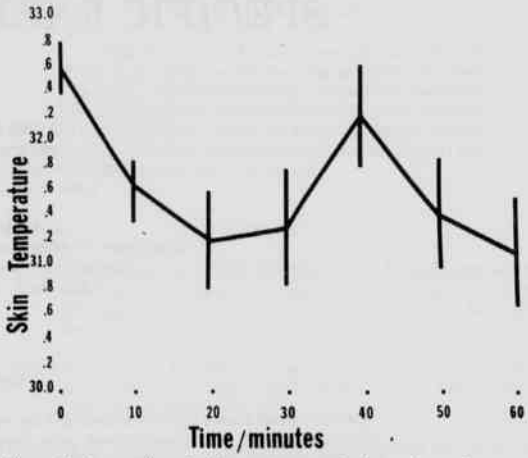

Figure 2. A recording of skin temperature during an hour of racquet ball play. (X ± SE).

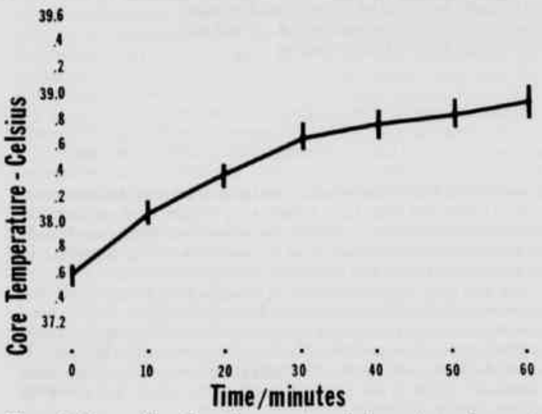

Figure 1. A recording of rectal temperature during an hour of racquet-ball play. (X ± SE).

Table. Sweat rate, weight loss and percent weight loss of subjects while they played racquetball for one hour.

Subjects	Sweat rate ($mg/cm^2/min$)	Weight Loss (kg)	% weight loss
1	1.77	**ND	** ND
2	1.32	0.91	1.05
3	2.03	1.70	2.32
4	1.73	2.04	2.58
5	1.56	1.36	1.60
6	1.49	1.07	1.43
7	1.39	1.02	1.22
8	2.00	0.91	1.09
9	1.29	0.79	0.92
10	1.90	1.59	2.05
11	0.95	0.68	1.07
*$\bar{x}$ ± SD	1.58 ± 0.32	1.21 ± 0.42	1.53 ± 0.56

* $\bar{x}$ ± SD = mean ± standard deviation
** ND = no data

DISCUSSION

An hour of racquetball play caused a significant increase in core temperature, a marked decrease in skin temperature, sweating, and a weight loss.

Rectal temperature rose by 2.0 °C. The elevation in core temperature was due to an increase in catabolism which was accelerated by the exercise regimen (racquetball). Similar increases in central body temperature have been reported in running (Gisolfi, 1973), cycling (Henane et al., 1977), ice hockey (MacDougall, 1979), and squash (Blanksby et al., 1980). A maximal increase of core temperature was reported in runners who participated in races of three or more miles. In these men the rectal temperatures increased to 41.1 °C (Gisolfi et al., 1977). In the present study, the core temperature was not observed to reach a steady state probably due to the fact that the muscular work was not prolonged until the heat level in blood reached the altered set point in the hypothalamic thermal regulatory system.

The significant decrease in skin temperature during a racquetball match was due to a combination of conduction, convection, and radiation and chiefly due to evaporation of sweat. Similar decreases in skin temperature have been observed in various exercise regimens (Drinkwater et al., 1977). The cooling effect is a physical, rather than a physiological mechanism. A gram of water absorbs 580 calories of heat in order to change state from a liquid to a vapour. This amount of heat is absorbed from the skin and surroundings.

The subjects were observed to sweat profusely. The sweating was due to the hyperthermia involved in the exercise regimen. Sweat glands provide the major physiological defense against overheating. The heat loss during exercise and in heat stress is from evaporation of actively secreted sweat. The evaporation of a liter of sweat requires approximately 580 kcal of heat which is obtained from the body surface and from surrounding air or objects. Sweat rates as high as 3.88 kg/hr have been reported for short, severe bouts of exercise in hot environments (Bean and Eickna, 1943). The subjects in this study showed similar sweat rates.

The observed weight loss is due to the amount of water lost in the form of sweat and in the expired air. The decrease in body weight is proportional to the amount of water lost by these two components in this experiment. Football and basketball players may lose from 3-7 percent of their body weight during the course of a contest (Buskirk and Bass, 1980). The average football and basketball game lasts two to three hours. In this experiment, the racquetball match lasted only an hour.

Therefore, if one corrects for the time factor, i.e., consider weight loss in terms of body weight lost/hour, then the results of the two exercise regimens (football and basketball vs. racquetball) are comparable.

Correlation coefficients showed that a positive correlation existed between sweat rates and weight losses and between sweat rates and increases in core temperature. As the core temperature increases, the hypothalamic heat regulatory center is altered towards cooling the inner body tissues. The main mechanism that humans use for losing excess heat is by the evaporation of sweat. The same type of relationship between sweat rate and core temperature has been shown with female distance runners and basketball players (Kobayoski et al., 1980) and with male distance runners, cross country skiers, and competitive swimmers (Baum et al., 1976; Henane et al., 1977).

Therefore, the results of these experiments have shown that the exercise regimen of racquetball can act as a good heat stress acclimator because it produces hyperthermia, sweating, a significant decrease in skin temperature, and a weight loss.

ACKNOWLEDGMENT

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LITERATURE CITED

AMERICAN COLLEGE OF SPORTS MEDICINE-POSITION STATEMENT. 1978. The recommended quantity and quality of exercise for developing and maintaining fitness in healthy adults. Med. Sci. Sports. 10(3):VIII-X.

BAUM, E., K. BRUCK, and H. P. SCHWENICKE. 1976. Adaptive modifications in the thermoregulatory system of long distance runners. J. Appl. Physiol. 40:404-410.

BEAN, W. B., and L. W. EICKNA. 1943. Performance in relation to environmental temperature reactions of normal young men to simulated desert environment. Fed. Proc. 2:144.

BLANKSBY, B. A., B. C. ELLIOT, K. H. DAVIS, and M. D. MERCER. 1980. Blood pressure and rectal temperature responses of middle-aged sedentary, middle-aged active, and "A"-grade competitive male squash players. Br. J. Sports Med. 14(2-3):133-138.

BOLLINGER, R. R., and B. R. CARWELL. 1975. Biomedical cost of low-level flight in a hot environment. Aviat. Space Environ. Med. 46:1221-1226.

BUSKIRK, E. R., and D. E. BASS. 1980. Climate and exercise. pp. 190-205, In: Structural and physiological aspects of exercise and sport (W. R. Johnson and E. R. Buskirk, eds.) Princeton Book Company, Princeton, 283p.

COHEN, J. S., and C. V. GISOLFI. 1982. Effects of interval training on work-heat tolerance of young women. Med. Sci. Sports Exercise 14(1):46-52.

DRINKWATER, B. L., I. C. KUPPRAT, J. E. DENTON, and S. M. HORVATH. 1977. Heat tolerance of female distance runners. The marathon: physiological, medical, epidemiological and psychological studies. Annals N.Y. Acad. Sci. 301:777-792.

GISOLFI, C. V. 1973. Work-heat tolerance derived from interval training. J. Appl. Physiol. 35:349-354.

GISOLFI, C. V., N. C. WILSON, and B. CLAXTON. 1977. Work-heat tolerance of distance runners. The marathon: physiological, medical, epidemiological, and psychological studies. Annals N.Y. Acad. Sci. 301:139-150.

HENANE, R., R. FLANDROIS, and J. P. CHARBONNIER. 1977. Increase in sweating sensitivity by endurance conditioning in man. J. Appl. Physiol. 43:822-828.

KOBAYASKI, Y., Y. ANDO, N. OKUDA, S. TAKABA, and K. OHARA. 1980. Effects of endurance training on thermoregulation in females. Med. Sci. Sports Exercise 12(5):361-364.

MACDOUGALL, J. D. 1979. Thermoregulatory problems in ice hockey. Can J. Appl. Sport Sci. 4(1):35-38.

MONTGOMERY, D. L. 1981. Heart rate response to racquetball. Phys. Sportsmed. 9(10):59-64.

MORGANS, L. F., J. A. SCOVILL, and K. M. BASS. 1982. Heart rate, oxygen consumption, and caloric expenditure while playing racquetball. Manuscript has been sent to Research Quarterly for Exercise and Sport.

NUNNELEY, S. A., and G. R. JAMES. 1977. Cockpit thermal conditions and crew skin temperatures measured in flight. Aviat. Space Environ. Med. 46:1221-1226.

PANDOLF, K. B., R. L. BURSE, and R. F. GOLDMAN. 1977. Role of physical fitness in heat acclimatization, decay and reinduction. Ergonomics 20:399-408.

RAMSEY, J. D., D. DAYAL, and B. GHAHRAMANI. 1975. Heat stress limits for the sedentary worker. Am. Indust. Hyg. Assoc. 36:259-265.

ROBERTS, M. F., C. B. WENGER, J. A. J. STOLWIJK, and E. R. NADEL. 1977. Skin blood flow and sweating changes following exercise training and heat acclimation. J. Appl. Physiol. 43:133-137.

SNEDECAR, G. W., and W. G. COCHRAN. 1967. Statistical methods(6th edition). Ames, Iowa, Iowa State University Press, 539p.