PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

A Study of Temperature Regulation in Yemenite and Kurdish Jews in Israel

R. H. Fox, Z. Even-Paz, Patricia M. Woodward and J. W. Jack

Phil. Trans. R. Soc. Lond. B 1973 **266**, 149-168
doi: 10.1098/rstb.1973.0044

Phil. Trans. R. Soc. Lond. B. **266**, 149–168 (1973) [149]
Printed in Great Britain

VIII. A study of temperature regulation in Yemenite and Kurdish Jews in Israel

By R. H. Fox, Z. Even-Paz, Patricia M. Woodward and J. W. Jack
Division of Human Physiology, National Institute for Medical Research, Holly Hill, London N.W. 3 and *Department of Dermatology, Hadassah Hospital, Jerusalem, Israel*

(*Communicated by A. E. Mourant, F.R.S. – Received* 30 *March* 1972 – *Revised* 21 *December* 1972)

Temperature regulation has been studied in 34 Yemenite Jews and 33 Kurdish Jews, including both men and women, using a standard thermoregulatory function test based on an air conditioned bed. The subjects were first tested at the Negev Institute for Arid Zone Research in the hot summer of 1968 and a proportion were then retested 6 months later in the cooler winter weather.

The results reveal no differences between the Kurdish Jews and Yemenite Jews in thermoregulatory function. The women of both ethnic groups had much lower sweat rates, stored more heat before sweating was initiated and had higher skin temperatures at sweat onset than the men. These sex differences are discussed in relation to previous studies on the differences in temperature regulation between European men and women.

Both males and females sweated less in the winter than in the summer. In the summer experiments, sweating capacity corresponded to the level found in partially heat acclimatized Europeans, whereas in the winter experiments the level for the Israeli Jews was significantly lower than that for unacclimatized European controls tested in Britain.

Introduction

This study of temperature regulation constitutes one part of the joint United Kingdom-Israel multidisciplinary study in the Human Adaptability Section of the International Biological Programme.

The laboratory measurements took place at the Negev Institute for Arid Zone Research in two phases. The first series of tests (series 1) were completed during the hot summer months of June and July 1968, and the second series (series 2) during the cooler winter season in January and February 1969. The technique used to investigate thermoregulatory function was based on the controlled hyperthermia test described in the *I.B.P. Handbook* of methods (Weiner & Lourie 1969).

There were five principal aims: (1) To compare thermoregulatory function in the two ethnic groups of Kurdish and Yemenite Jews; (2) to study the differences in temperature regulation between the two sexes in these groups; (3) to look for a possible seasonal variation in the response to the test; (4) to compare the thermoregulatory response of the Israeli subjects with the results of similar tests on European subjects living in cooler climates; (5) to attempt to relate individual differences in thermoregulatory response to factors such as individual differences in the degree of exposure to environmental thermal stress, energy expenditure and physical working capacity.

Methods

Subjects

The physical characteristics of the subjects in series 1 and retested in series 2 are set out in table 1. In the first series of experiments, a total of 19 male and 15 female Yemenite Jews, together with 20 male and 13 female Kurdish Jews, were examined. In general, the Kurdish Jews were a little taller and rather heavier than the Yemenite Jews, which is in agreement with the anthropometric observations in the much larger study reported by Lourie (1973, this volume). In the second series, it proved possible to retest 16 Yemenite and 16 Kurdish male Jews, but only six Yemenite female Jews and four Kurdish female Jews. However, the average physical characteristics of the retested subjects were close to the mean values for the subjects of series 1.

Table 1. The physical characteristics of the male and female Kurdish and Yemenite Jews tested in series 1

Mean values, standard deviations and ranges are given for each group.

	n	age/years	height/cm	mass/kg	DuBois area/m²
Yemenite male Jews	19	25.7 ± 4.2 (21–34)	162.40 ± 5.25 (153.4–170.4)	61.49 ± 10.01 (49.49–81.85)	1.65 ± 0.13 (1.45–1.92)
Kurdish male Jews	20	26.1 ± 3.7 (18–31)	169.06 ± 6.58 (154.9–179.3)	64.25 ± 6.06 (54.33–75.90)	1.73 ± 0.10 (1.54–1.90)
Yemenite female Jews	15	24.6 ± 4.0 (19–29)	152.96 ± 6.39 (140.6–166.7)	50.34 ± 10.07 (36.60–67.50)	1.45 ± 0.14 (1.21–1.69)
Kurdish female Jews	13	25.2 ± 3.2 (20–29)	153.17 ± 4.50 (144.5–157.4)	57.15 ± 11.70 (37.90–70.25)	1.53 ± 0.17 (1.25–1.64)

It was originally intended to confine the tests to individuals in the 18 to 30 years range, but subsequently three Yemenite male Jews and two Kurdish male Jews were found to be over 30 years of age and their results have been included.

Experimental procedures

With the staff and equipment available, it was possible to test two subjects simultaneously and to have morning (a.m.) and afternoon (p.m.) sessions. The four subjects for a day's experiments were transported each morning to the laboratory from the villages by car, usually arriving some time between 09 h 00 and 10 h 00. The four subjects were then divided into two pairs, and while one pair was tested for temperature regulation, the other was tested for working capacity. At the end of the morning session, the subjects had a rest period with a meal and then the two pairs were reversed to complete the other test during the afternoon. Performing the two tests on one day undoubtedly proved rather tiring, especially for the women, and this was probably partly responsible for the unwillingness of some subjects to return for their retest in series 2.

In series 1, the two air-conditioned beds were set up in a large room which was also used for a number of other activities. The room was partially air conditioned but the air temperature frequently rose to between 25 and 30 °C. In series 2, the tests were conducted in a smaller room reserved for the purpose and with comfortable ambient air conditions. At the outset, the subjects were carefully instructed on the whole procedure for the test and were told that if they wished to discontinue at any time they were free to do so.

Thermoregulatory function test routine

The thermoregulatory function test is designed to measure the superficial and deep body temperature levels in a thermally neutral environment (neutral stage or neutral climate), the set point for sweat onset, and the efficiency of the main thermoregulatory mechanisms of heat transfer by the cardiovascular system and the sweating response during controlled hyperthermia with the deep body temperature raised to 38.0 °C.

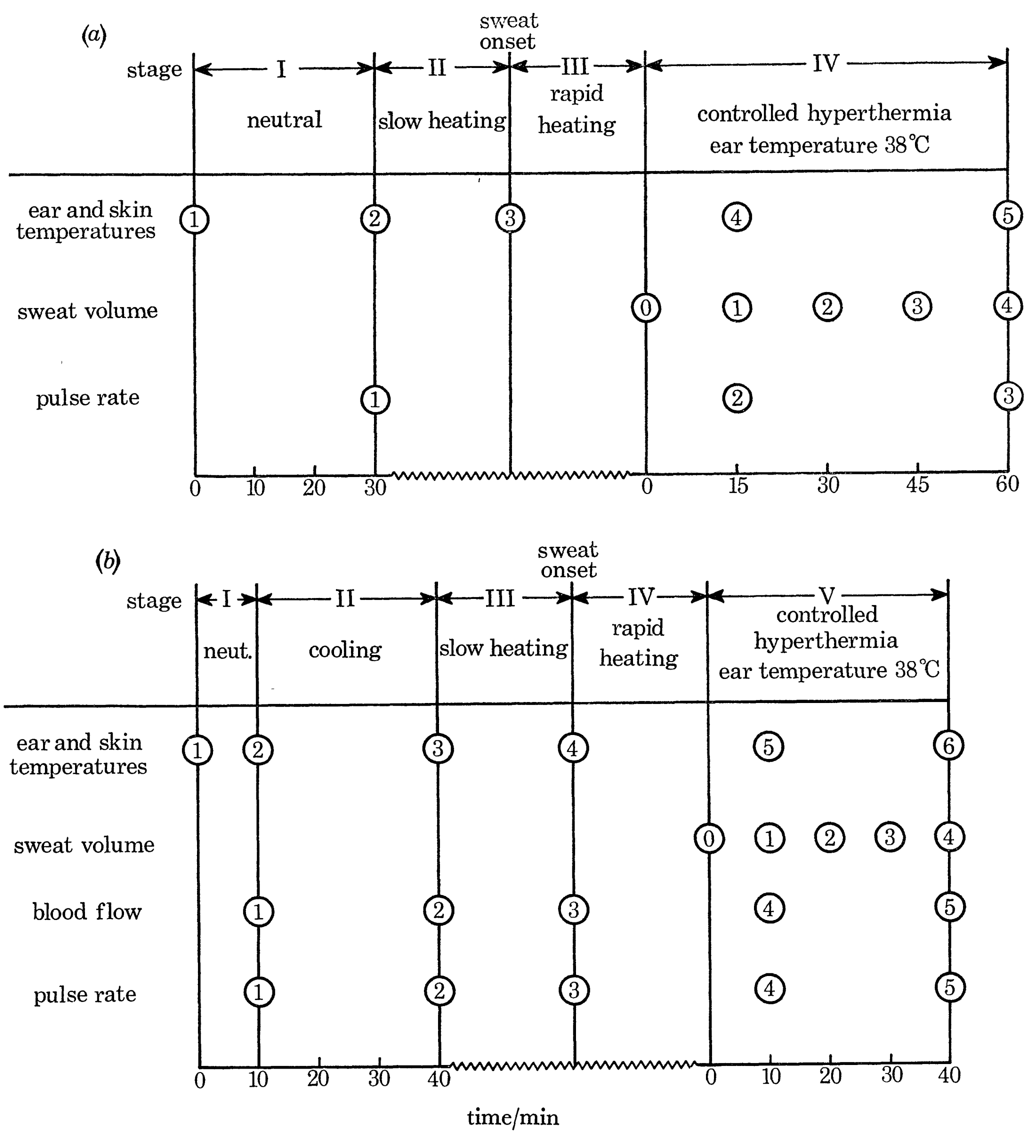

FIGURE 1. Experimental routines. (*a*) series 1, (*b*) series 2.

The test takes place in a specially designed air-conditioned bed which permits accurate control of the thermal microenvironment surrounding the subject over a wide temperature range. The subject is dressed in a plastic suit from which the secreted sweat can be drawn off and measured. Deep body temperature is measured in both external auditory meati using an insulated head technique and direct reading thermistor thermometers. The average skin

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

temperature is recorded from eight body sites using thermistor thermometers attached to the plastic suit which is drawn in contact with the body surface by suction. In the series 2 experiments, peripheral blood flow was also recorded from one hand by venous occlusion plethysmography. Using an automatic cuff inflating unit giving a 5 s inflow measurement every 15 s, blood flows were recorded continuously throughout the experiment. The plethysmograph temperature was maintained at 32 °C. Pulse volume amplitude changes were monitored with a photoelectric pulsimeter from the thumb of the other hand. In the series 1 experiments, heart rate was counted from e.c.g. recordings and in the series 2 experiments from the pulsimeter records.

The experimental routines used in series 1 and 2 are illustrated diagrammatically in figure 1. For the first series, the routine was as described in the *I.B.P. Handbook* no. 9 (Weiner & Lourie 1969). In the second series, the routine was modified by shortening the initial control period and the addition of 30 min of cooling with the bed air temperature at 15 °C. It also proved possible to shorten the period of controlled hyperthermia from 60 to 40 min (see p. 151).

Results

The detailed results are set out in tables in the appendix giving mean values and standard errors with tests of significance for relevant comparisons. In this section, the main points are summarized and illustrated following the order given for the aims in the Introduction.

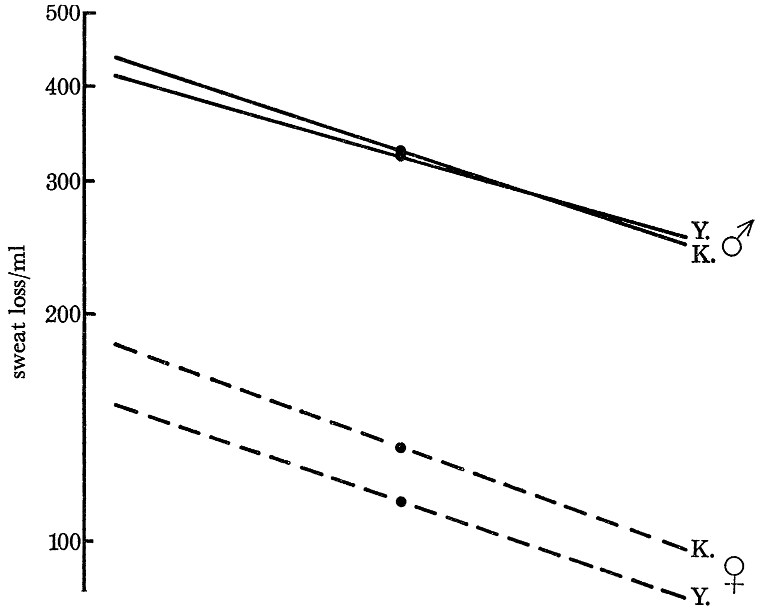

Figure 2. A comparison of the sweat losses during controlled hyperthermia in series 1 (summer) of the two ethnic groups. The mean half-hourly sweat loss (ml) is indicated by the closed circle and the rate of hydromeiosis by the slope of the line. Male (———); female (-----).

Comparison of Kurdish with Yemenite Jews in series 1

Body temperatures

There were no significant differences between the two male groups or between the two female groups in deep body temperature or skin temperature during the neutral stage or at sweat onset. Body temperatures measured in the afternoons usually tended to be a little higher than those measured in the morning experiments because of the effect of the diurnal rhythms, (see appendix, table A1).

Sweating response

The sweating responses of the two sexes in both groups for series 1 are illustrated in figure 2. The level of each line is a measure of sweating capacity and its slope gives the rate of hydromeiosis. There were no significant differences in response between the two groups of males or between the females (appendix, tables A2, A3).

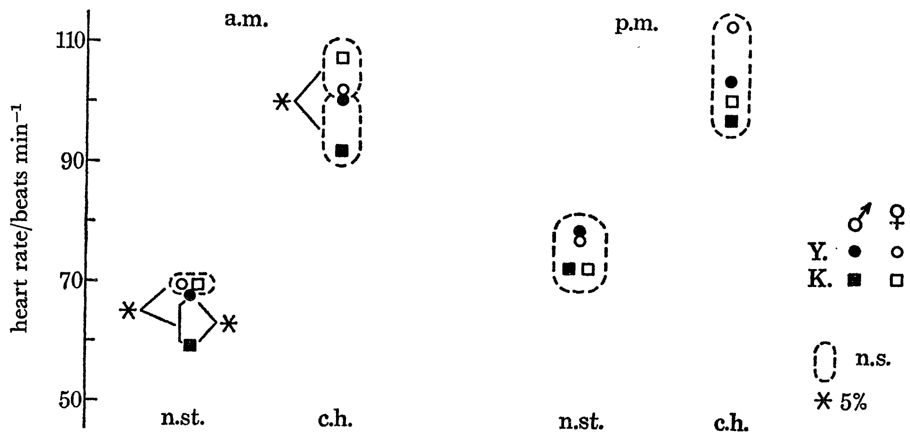

Figure 3. Heart rates measured in the neutral stage (n.st.) and during controlled hyperthermia (c.h.) in series 1 to illustrate the sex and ethnic comparisons. A dotted line encloses groups of values which are not significantly different.

Heart rates

The Yemenite male Jews tended to have higher heart rates than the Kurdish male Jews as shown in figure 3, and this difference was significant at the neutral stage of the morning experiments (appendix, table A5).

Comparison of sexes in series 1

Body temperatures

Since there were no differences between the two ethnic groups, the data from both were pooled for a more detailed comparison of the response by the sexes. The results for deep body temperatures are illustrated in figure 4 and for the skin temperature in figure 5. The deep body temperatures of the females were consistently higher both in the neutral stage and at sweat onset. Skin temperatures were not significantly different in the neutral stage, although the values for the females tended to be the lower, but the females did have significantly higher skin temperatures at sweat onset (appendix, table A1). The sex differences in reponse to the test are more clearly revealed by considering the temperature gradients between the core and surface of the body at each stage. For this comparison, any influence of diurnal rhythm can be ignored and the morning and afternoon experiments combined. The results are given in table 2 and show that women had the greater temperature difference in the neutral stage and the lesser difference at sweat onset. These sex differences in response are important because of their effects on the total heat storage required to initiate sweating. Estimates of the heat stored between the neutral stage and sweat onset were calculated for both sexes assuming that the skin and deep body temperatures are respectively representative of one-third and two-thirds

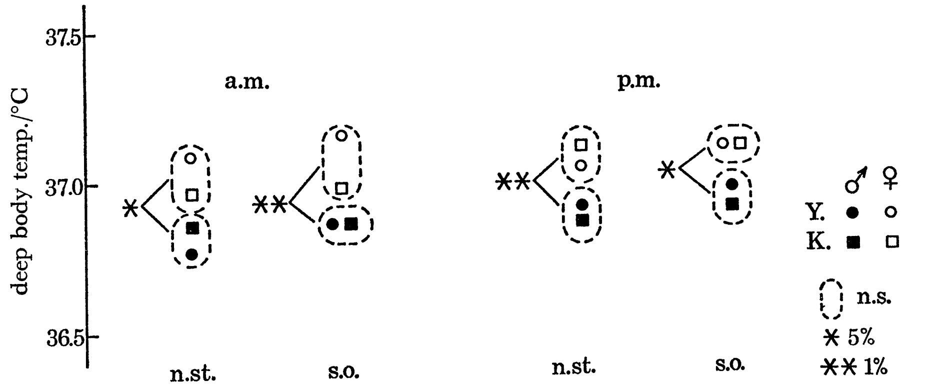

FIGURE 4. Deep body temperatures measured in the neutral stage (n.st.) and at sweat onset (s.o.) in series 1 to illustrate the differences between the 2 sexes.

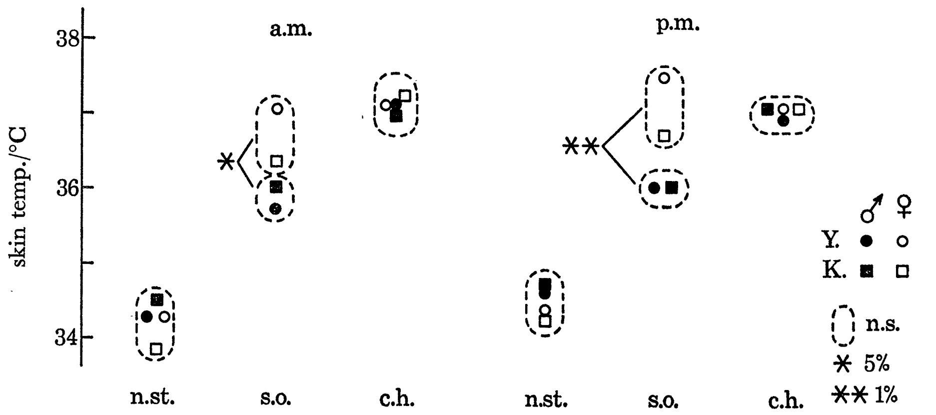

FIGURE 5. Skin temperatures measured in the neutral stage (n.st.) at sweat onset (s.o.) and during controlled hyperthermia (c.h.) in series 1 to illustrate the absence of ethnic and the presence of sex differences.

of the total body mass. The assumption will have tended to underestimate the difference between the sexes because of the greater skinfold thickness of the female. The specific heat of tissue was taken as 0.83. On this basis, the average heat storage by the females between the end of the neutral stage and the onset of sweating in series 1 was significantly greater ($P < 0.01$) at 42.00 ± 4.61 kcal (176 ± 19 kJ) than by the men 27.39 ± 3.20 kcal (115 ± 13 kJ). A similar trend was present in series 2 but with the smaller number of subjects it was not significant.

Heart rates

The females had significantly higher heart rates than the males at the neutral stage and during controlled hyperthermia in the a.m. experiments, but this was not present in the p.m. experiments, (see figure 3 (appendix, table A5)).

Sweat rates

The females of both ethnic groups had much lower sweat rates than the males ($P < 0.001$) as can be seen in figure 2.

Table 2. A comparison of the deep body less skin temperature differences (°C) for all experiments on the 2 sexes in series 1 at the neutral stage, sweat onset and during controlled hyperthermia

(Significance levels: $P > 0.05$, n.s. (not significant); $P < 0.01$, **; $P < 0.001$, ***.)

		neutral stage		sweat onset		controlled hyperthermia	
	n	mean s.e.	significance	mean s.e.	significance	mean s.e.	significance
males	39	2.32 ± 0.10 ***	***	0.96 ± 0.18 ***	**	1.00 ± 0.04 ***	n.s.
females	28	2.85 ± 0.12 ***		0.16 ± 0.21 n.s.		0.92 ± 0.04 ***	

Comparisons of ethnic and sex differences in series 2

Body temperatures, heart rates and sweat losses

The results of the body temperatures and pulse rate measurements in the neutral stage, at sweat onset and during controlled hyperthermia in the tests of series 2, are less clear cut than series 1 because of the smaller number of subjects, but in general they confirm the pattern of sex differences and the absence of ethnic differences revealed by series 1. The sweat rates are illustrated in figure 7 (appendix, tables A 6–9).

Hand blood flow

The hand blood flows are illustrated in figure 6 for the four stages during the test. The results show little difference between the four groups up to controlled hyperthermia where the women show a tendency to have lower blood flows than the men (appendix, table A 10).

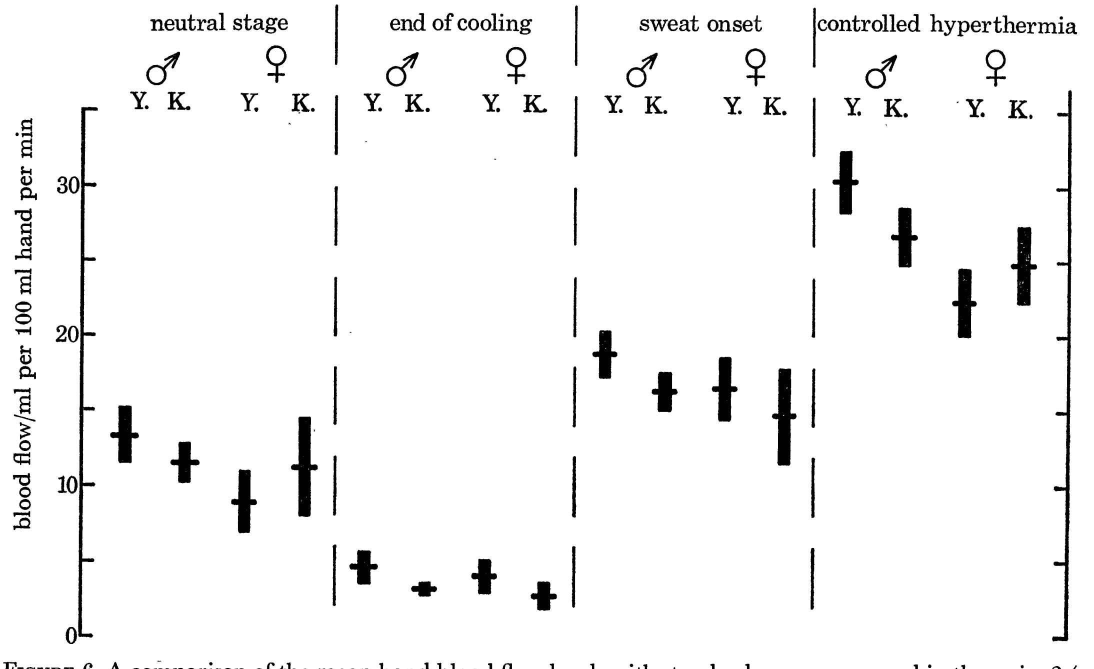

Figure 6. A comparison of the mean hand blood flow levels with standard errors measured in the series 2 (winter) in the neutral stage, at the end of cooling, sweat onset and during controlled hyperthermia.

Comparisons between series 1 and 2

Body temperatures and heart rates

Because of the changes in the experimental routine between series 1 and 2 and the small number of subjects tested in series 2, considerable caution is required in interpreting differences between the two seasons. The measurements in the neutral stage on both occasions are comparable and reveal no differences in deep body temperatures or pulse rates between the seasons. The

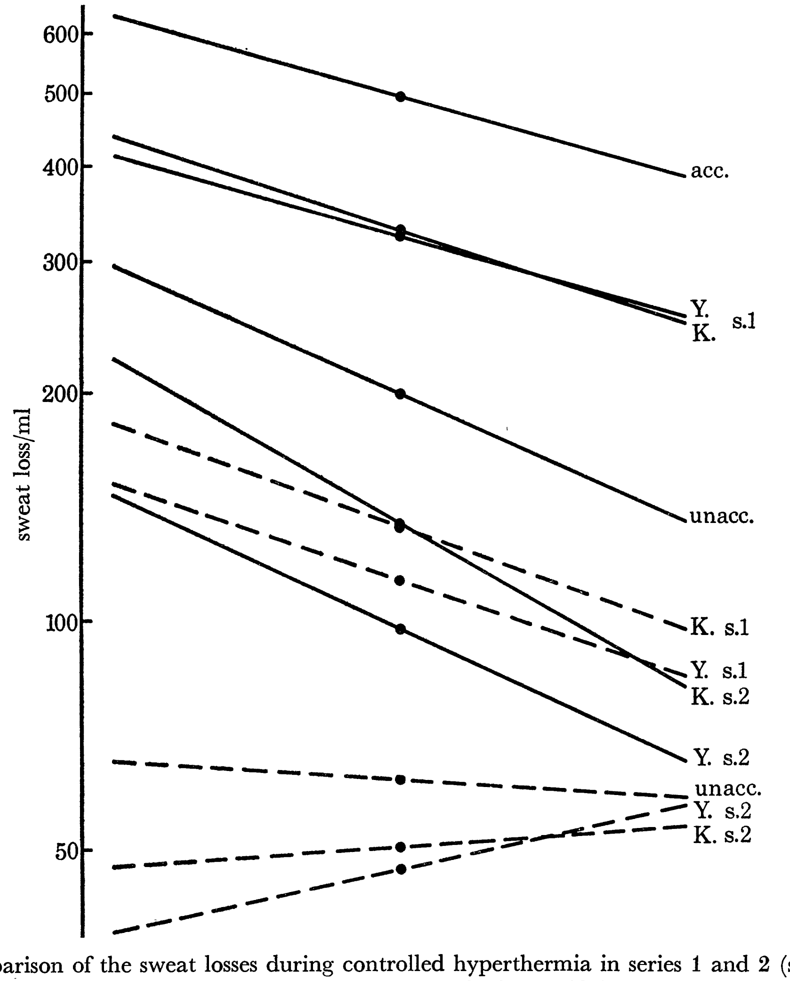

FIGURE 7. A comparison of the sweat losses during controlled hyperthermia in series 1 and 2 (s.1, s.2) in Israel with European control groups of male subjects before and after artificial heat acclimatization and unacclimatized females. The mean half-hourly sweat loss is indicated by the closed circle and the rate of hydromeiosis by the slope of the line. Male (———); female (-----).

lower skin temperatures in the winter probably reflect the reduced heat stress prior to the test. The winter trend of higher deep body temperatures and lower skin temperatures at sweat onset is attributed to the preceding period of cooling in series 2 which was not included for the tests in series 1. The higher winter skin temperatures during controlled hyperthermia are explained by the addition of the hand blood flow measurements in series 2. With maximum vasodilation in the hand and a plethysmograph temperature of 32.0 °C, considerable amounts of heat are removed and therefore a slightly higher body skin temperature is required to maintain the core temperature at 38.0 °C during controlled hyperthermia (appendix, table A 11).

Sweat rates

The measurements of the sweating response in series 1 and 2 are comparable and the a.m. and p.m. results could be pooled. The initial sweat losses and hydromeiosis for series 2 are illustrated in figure 7 and demonstrate a very striking and highly significant ($P < 0.001$) reduction in the sweating responses of both sexes (appendix, tables A 8, A 9).

Sweat electrolytes

Samples of sweat collected in both series 1 and 2 were analysed for electrolyte content. The sodium and chloride concentrations are illustrated as frequency distributions in figure 8. There was little difference between the groups except that the Yemenite female Jews tended to have the lowest values in the summer and the Kurdish female Jews in the winter tests. However, there was a definite seasonal change for all groups except the Kurdish female Jews, with the higher concentrations occurring in winter compared with summer. The normal ranges for sodium and chloride given by Eastham (1967) are also shown.

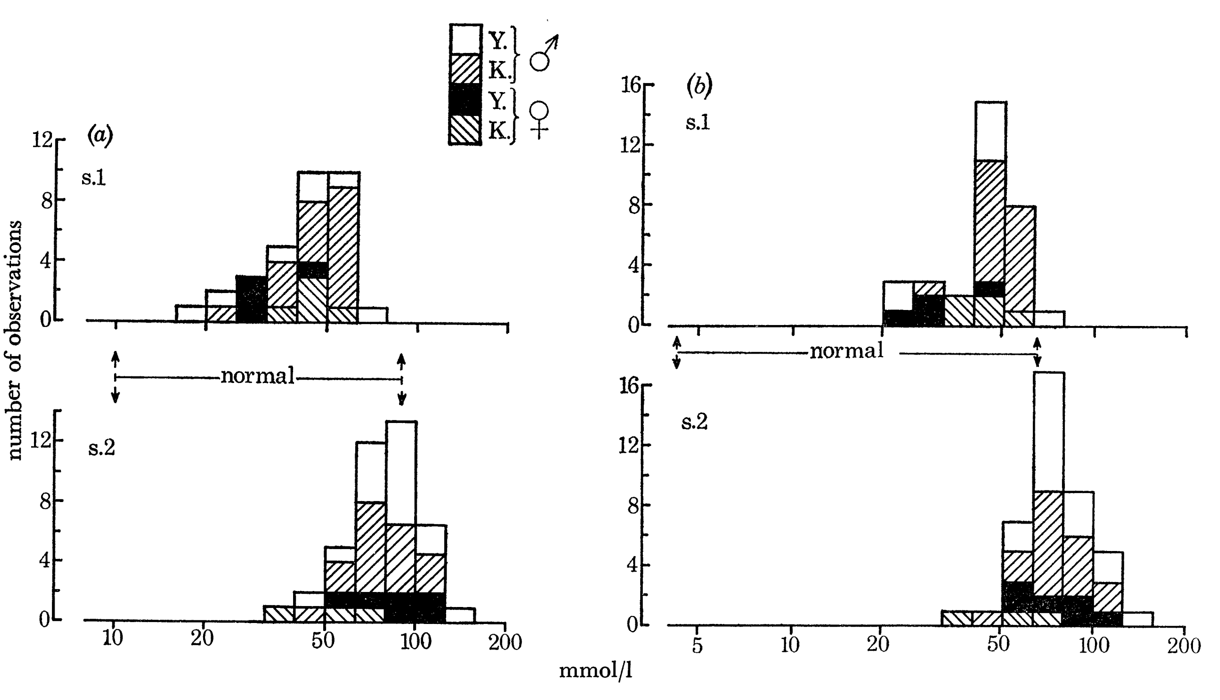

FIGURE 8. Frequency distributions for (*a*) sodium and (*b*) chloride in sweat collected in series 1 and 2 (s.1, s.2). Limits of normal range are shown.

Comparison with measurements on Europeans

The mean deep body temperatures of the Kurdish and Yemenite male Jewish subjects in the neutral stage and at sweat onset in the experiments of series 1 compared with similar measurements on European subjects tested before and again after artificial acclimatization to heat, are illustrated in figure 9. Artificial heat acclimatization is accompanied by a substantial decrease in deep body temperatures and it can be seen that the Israeli values fell midway between the pre- and post-acclimatization levels of the Europeans.

The mean skin temperatures of the Israeli subjects were also within the range found for pre- and post-acclimatization levels in the European.

Sweat rates

Sweat rates during controlled hyperthermia in series 1 and 2 for the male and female Kurdish Jews and Yemenite Jews are compared with the means for a control group of British males tested before and after heat acclimatization and an unacclimatized group of Swedish women (Fox *et al.* 1969) in figure 7. In the summer tests (series 1), the male Israeli subjects showed levels which were about midway between those of pre- and post-acclimatized British subjects, the differences from both being highly significant ($P < 0.001$). The female Israeli subjects in series 1 also had higher sweat rates than the unacclimatized female controls ($P < 0.001$).

In the winter tests (series 2), the male Israeli subjects had significantly lower sweat rates than the British unacclimatized subjects ($P < 0.05$), whereas the female Israeli subjects and female controls were not significantly different.

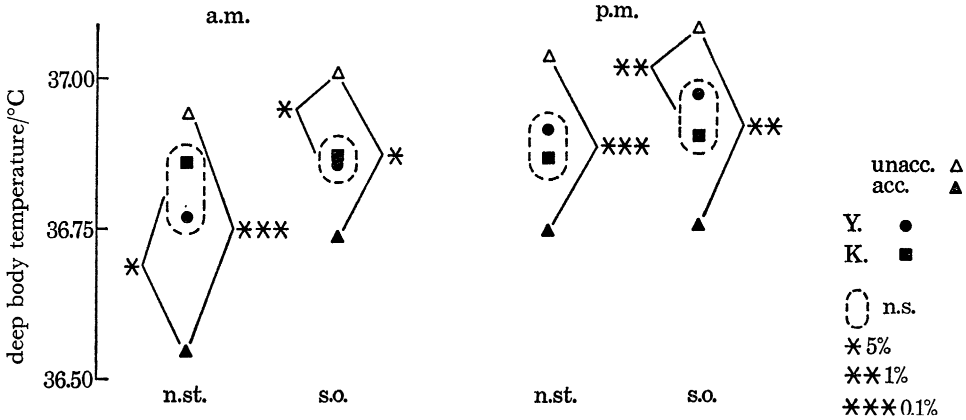

FIGURE 9. Deep body temperatures of the male Israeli subjects (series 1) in the neutral stage (n.st.) and at sweat onset (s.o.) compared with the values for a group of European males before and after artificial heat acclimatization.

DISCUSSION

Temperature regulation is of particular interest in the Human Adaptability Section of the International Biological Programme because in different parts of the world men live and are known to have lived for very long periods of time in widely differing thermal environments. During the course of many generations living in a hot climate, one might expect natural selection to have favoured individuals with a more efficient heat dissipating system, whereas in cold climates natural selection might be expected to have favoured individuals with a well-developed capacity to conserve body heat. Thus a comparison of temperature regulation in individuals living in hot and cold climates may help to determine whether man has the capacity to adapt his physiological mechanisms to meet the challenge of a hostile environment.

The Israeli project provided the opportunity to study two different ethnic groups who have been living and working in neighbouring villages in the Negev desert for the last 20 years, so that both had been exposed over this period to the same hot, dry climate (Edholm & Samueloff 1973, this volume). Before coming to Israel, it is probable that the Kurds in Kurdistan were living in a somewhat cooler climate than the Yemenites in the Yemen. The racial origins of the two groups are believed to be quite distinct and certainly they show many differences in anthropometry (Lourie 1973, this volume) and in blood genetic markers (Godber *et al.* 1973, this volume). It is therefore of some interest that the thermoregulatory response of these two groups have shown no differences and indeed could hardly have been more closely comparable.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

In contrast to the absence of any ethnic differences, there were clear-cut sex differences. The sweating responses of both Kurdish and Yemenite Jewish women were markedly lower than those of their male counterparts, both in the summer and winter studies. Although the Israeli women may have been somewhat less exposed to heat stress than the men, this finding is in agreement with the majority of previous studies in which the sexes have been compared (Hardy & DuBois 1940; Löfstedt 1966; Hardy, Milhorat & DuBois 1941; Morimoto, Slabochova, Naman & Sargent 1967; Kawahata 1960; McCance 1938; Wyndham, Morrison & Williams 1965; Fox *et al.* 1969), indeed only a few observers have failed to find a lower sweat rate in women. (Matsui 1955; Brouha, Smith, De Lanne & Maxfield 1960; Haslag & Hertzman 1965).

A difference between the sexes in the sweating response on exposure to heat has been recognized for many years but the cause is still a matter of controversy and speculation.

In a previous study (Fox *et al.* 1969) it was suggested that women have a smaller sweating capacity than men because they are able to maintain thermal equilibrium using vasomotor control over a wide range of thermal stress conditions. This in turn stems partly from their lower basal metabolic rate and partly from the possession of a larger heat sink in the body shell. With less frequent recourse to sweating than men, it follows that their sweating mechanism will be less trained or in other words acclimatized to heat (Fox, Goldsmith, Hampton & Lewis 1964; Fox, Goldsmith, Kidd & Lewis 1963). The present finding of a significantly larger storage of body heat before sweat onset by the women compared to the men gives further support to this hypothesis.

An alternative or additional explanation would be provided if women were able to increase their peripheral blood flow to higher levels than men. The results of the present study do not support this hypothesis and are in agreement with the conclusions of Hertig & Sargent (1963).

The results from series 1 do not indicate the presence of any sex difference in the rate of development of hydromeiosis and the apparently lower value for the women in series 2 as well as in the study by Fox *et al.* (1969) is almost certainly an artefact arising from the technical problems of measuring such small sweat rates.

Seasonal changes in the level of heat acclimatization have been detected previously (Wyndham *et al.* 1964) but the decline in the sweating capacity of the subjects in this study between the summer and winter measurements is much larger than any changes previously reported and is a striking finding. Although the environmental thermal stress was appreciably lower in the winter than in the summer, nevertheless a winter's day in the Negev is not unlike a summer's day in Britain (Edholm *et al.* 1973, this volume).

It is particularly striking to find the male Israeli sweat rates in the winter falling below the level for the unacclimatized European controls. A number of observers have found that the indigenous populations of hot countries are not usually fully acclimatized to heat as judged by their response to standard hot room tests (Ladell 1957; Weiner 1950; Hellon, Jones, Macpherson & Weiner 1956; Strydom & Wyndham 1963; Wyndham, Macpherson & Munro 1964). In general, it seems that in his natural setting and left to his own devices man does not normally choose to exert or expose himself sufficiently to develop his capacity for heat acclimatization to the full, just as most of us do not choose a way of life that will develop our physical prowess or muscular strength to the full (Fox 1965). However, the present findings suggest that this is not the whole story because in the winter measurements the Israeli subjects had an even smaller sweating response than the unacclimatized European controls. It is difficult to escape the

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

conclusion that there are important differences in the response patterns to short and long-term exposures to heat which at present we do not fully understand.

References

Brouha, L., Smith Jr., P. E., De Lanne, R. & Maxfield, M. E. 1960 Physiological reactions of men and women during muscular activity and recovery in various environments. *J. appl. Physiol.* **16**, 133–140.

Eastham, R. D. 1967 *Biochemical values in clinical medicine* (3rd ed.). Bristol: John Wright and Sons Ltd.

Edholm, O. G., Humphrey, J., Lourie, J. A., Tredre, B. E. & Brotherhood, J. 1973 Biological studies of Yemenite and Kurdish Jews in Israel and other groups in southwest Asia. VI. Energy expenditure and climatic exposure of Yemenite and Kurdish Jews in Israel. *Phil. Trans. R. Soc. Lond.* B **266**, 217–140.

Edholm, O. G. & Samueloff, S. 1973 Biological studies of Yemenite and Kurdish Jews in Israel and other groups in southwest Asia. I. Introduction, background and methods. *Phil. Trans. R. Soc. Lond.* B **266**, 85–95.

Fox, R. H. 1965 *Th physiology of human survival* (chap. 3). London: Academic Press.

Fox, R. H., Goldsmith, R., Hampton, I. F. C. & Lewis, H. E. 1964 The nature of the increase in sweating capacity produced by heat acclimatization. *J. Physiol.* **171**, 368–376.

Fox, R. H., Goldsmith, R., Kidd, D. J. & Lewis, H. E. 1963 Acclimatization to heat in man by controlled elevation of body temperature. *J. Physiol.* **166**, 530–547.

Fox, R. H., Löfstedt, B. E., Woodward, P. M., Eriksson, E. & Werkstrom, B. 1969 Comparison of thermoregulatory function in men and women. *J. appl. Physiol.* **26**, 444–453.

Godber, M. J., Kopeć, A. C., Mourant, A. E., Tills, D. & Lehmann, E. E. 1973 Biological studies of Yemenite and Kurdish Jews in Israel and other groups in southwest Asia. IX. Hereditary blood factors of the Yemenite and Kurdish Jews. *Phil. Trans. R. Soc. Lond.* B **266**, 169–184.

Hardy, J. D. & DuBois, E. F. 1940 Differences between men and women in their response to heat and cold. *Proc. natn. Acad. Sci., Wash.* **26**, 389–398.

Hardy, J. D., Milhorat, A. T. & DuBois, E. F. 1941 Basal metabolism and heat loss of young women at temperatures from 22 °C to 35 °C. *J. Nutr.* **21**, 383–404.

Haslag, W. M. & Hertzman, A. B. 1965 Temperature regulation in young women. *J. appl. Physiol.* **20**, 1283–1288.

Hellon, R. F., Jones, R. M., Macpherson, R. K. & Weiner, J. S. 1956 Natural and artificial acclimatization to hot environments. *J. Physiol.* **132**, 559–576.

Hertig, B. A. & Sargent, F. 1963 Acclimatization of women during work in hot environments. *Fedn. Proc.* **22**, 810–813.

Kawahata, A. 1960 *Sex differences in sweating. Essential problems in climatic physiology*, (ed. H. Yoshimura, K. Ogata and S. Itoh), pp. 169–195. Kyoto: Nankodo.

Ladell, W. S. S. 1957 Human and animal ecology. UNESCO Arid Zone Research VIII. *Paris: Reviews of Researches.*

Löfstedt, B. 1966 Human heat tolerance. Thesis. University of Lund, Sweden.

Lourie, J. A. 1973 Biological studies of Yemenite and Kurdish Jews in Israel and other groups in southwest Asia. III. Physical characteristics of Yemenite and Kurdish Jews in Israel. *Phil. Trans. R. Soc. Lond.* B **266**, 101–112.

Matsui, N. 1955 The ability to perspire in relation to sexuality. *Bull. Res. Inst. Diathetic Med. Kunamoto Univ.* **6**, 60–68.

McCance, R. A. 1938 Individual variations in response to high temperatures and to the production of experimental salt deficiency. *Lancet* ii, 190–191.

Morimoto, T., Slabochova, Z., Naman, R. K. & Sargent, F. 1967 Sex differences in physiological reactions to thermal stress. *J. appl. Physiol.* **22**, 526–532.

Strydom, N. B. & Wyndham, C. H. 1963 Natural state of heat acclimatization of different ethnic groups. *Fedn Proc.* **22**, 801–809.

Weiner, J. S. 1950 Observations on working ability of Bantu mineworkers with reference to acclimatization to hot humid conditions. *B. J. indust. Med.* **7**, 17–26.

Weiner, J. S. & Lourie, J. A. 1969 *Human biology; A guide to field methods.* I.B.P. Handbook no. 9. Oxford: Blackwell Scientific Publications.

Wyndham, C. H., Macpherson, R. K. & Munro, A. 1964 Reactions to heat of Aborigines and Caucasians. *J. appl. Physiol.* **19**, 1055–1058.

Wyndham, C. H., Morrison, J. F. & Williams, C. G. 1965 Heat reactions of male and female Caucasians. *J. appl. Physiol.* **20**, 357–364.

Wyndham, C. H., Strydom, N. B., Ward, J. S., Morrison, J. F., Williams, C. G., Bredell, G. A. G., von Rahden, M. J. E., Holdsworth, L. D., van Graan, C. H., van Rensburg, A. J. & Munro, A. 1964 Physiological reactions to heat of Bushmen and of unacclimatized and acclimatized Bantu. *J. appl. Physiol.* **19**, 885–888.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Appendix

Table A1. Series 1: deep body and skin temperatures (°C)

	n	neutral stage: Yemenite male Jews	neutral stage: Kurdish male Jews	neutral stage: Yemenite female Jews	neutral stage: Kurdish female Jews	sweat onset: Yemenite male Jews	sweat onset: Kurdish male Jews	sweat onset: Yemenite female Jews	sweat onset: Kurdish female Jews	controlled hyperthermia: Yemenite male Jews	controlled hyperthermia: Kurdish male Jews	controlled hyperthermia: Yemenite female Jews	controlled hyperthermia: Kurdish female Jews
ear temperature													
a.m.													
Yemenite male Jews	9	36.77 ± 0.07	n.s.	*	n.s.	36.86 ± 0.07	n.s.	*	n.s.	38.04 ± 0.01	—	—	—
Kurdish male Jews	10	—	36.86 ± 0.06	*	n.s.	—	36.87 ± 0.06	*	n.s.	—	38.04 ± 0.01	—	—
Yemenite female Jews	7	—	—	37.09 ± 0.08	n.s.	—	—	37.16 ± 0.09	n.s.	—	—	38.03 ± 0.02	—
Kurdish female Jews	6	—	—	—	36.97 ± 0.11	—	—	—	36.98 ± 0.10	—	—	—	38.03 ± 0.01
p.m.													
Yemenite male Jews	10	36.92 ± 0.08	n.s.	n.s.	n.s.	36.98 ± 0.08	n.s.	n.s.	n.s.	38.04 ± 0.01	—	—	—
Kurdish male Jews	10	—	36.87 ± 0.06	*	**	—	36.91 ± 0.05	*	*	—	38.04 ± 0.01	—	—
Yemenite female Jews	8	—	—	37.05 ± 0.05	n.s.	—	—	37.11 ± 0.05	n.s.	—	—	38.03 ± 0.02	—
Kurdish female Jews	7	—	—	—	37.11 ± 0.05	—	—	—	37.12 ± 0.05	—	—	—	38.01 ± 0.01
skin temperature													
a.m.													
Yemenite male Jews	9	34.29 ± 0.30	n.s.	n.s.	n.s.	35.72 ± 0.40	n.s.	*	n.s.	37.16 ± 0.07	n.s.	n.s.	n.s.
Kurdish male Jews	10	—	34.48 ± 0.17	n.s.	*	—	36.02 ± 0.28	n.s.	n.s.	—	36.99 ± 0.07	n.s.	*
Yemenite female Jews	7	—	—	34.31 ± 0.22	n.s.	—	—	37.07 ± 0.46	n.s.	—	—	37.12 ± 0.08	n.s.
Kurdish female Jews	6	—	—	—	33.84 ± 0.23	—	—	—	36.35 ± 0.42	—	—	—	37.20 ± 0.06
p.m.													
Yemenite male Jews	10	34.62 ± 0.17	n.s.	n.s.	n.s.	36.01 ± 0.31	n.s.	**	n.s.	36.93 ± 0.09	n.s.	n.s.	n.s.
Kurdish male Jews	10	—	34.72 ± 0.19	n.s.	n.s.	—	36.00 ± 0.41	**	n.s.	—	37.05 ± 0.04	n.s.	n.s.
Yemenite female Jews	8	—	—	34.39 ± 0.24	n.s.	—	—	37.49 ± 0.23	n.s.	—	—	37.07 ± 0.07	n.s.
Kurdish female Jews	7	—	—	—	34.20 ± 0.22	—	—	—	36.70 ± 0.49	—	—	—	37.03 ± 0.08

Values given are means and standard errors for each group.
Level of significance of difference between pairs of group means are also shown: n.s. (not significant), $P > 0.05$; *, $0.05 > P > 0.01$; **, $0.01 > P > 0.001$.

Table A2. Series 1: sweat rates (ml)

	mean	95% confidence limits
Yemenite male Jews	12.32	10.79–14.07
Kurdish male Jews	12.88	11.36–14.62
Yemenite female Jews	4.39	3.18– 6.08
Kurdish female Jews	5.32	4.12– 6.86

Means for Israeli males are significantly greater than for Israeli females.

Table A3. Series 1: hydromeiosis ratios

	mean	95% confidence limits
Yemenite male Jews	0.53	0.45–0.63
Kurdish male Jews	0.47	0.41–0.54
Yemenite female Jews	0.46	0.36–0.57
Kurdish female Jews	0.43	0.32–0.59

All mean ratios are significantly greater than 1.0, (1.0 represents no suppression).

There is no significant difference between the four means.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

TABLE A4. SERIES 1: DIFFERENCES BETWEEN DEEP BODY AND SKIN TEMPERATURE (°C)

		neutral stage				sweat onset				controlled hyperthermia			
	n	Yemenite male Jews	Kurdish male Jews	Yemenite female Jews	Kurdish female Jews	Yemenite male Jews	Kurdish male Jews	Yemenite female Jews	Kurdish female Jews	Yemenite male Jews	Kurdish male Jews	Yemenite female Jews	Kurdish female Jews
a.m.													
Yemenite male Jews	9	2.48*** ± 0.32	n.s.	n.s.	n.s.	1.14* ± 0.44	n.s.	n.s.	n.s.	0.88*** ± 0.06	n.s.	n.s.	n.s.
Kurdish male Jews	10	—	2.38*** ± 0.15	n.s.	*	—	0.85* ± 0.29	n.s.	n.s.	—	1.05*** ± 0.06	n.s.	*
Yemenite female Jews	7	—	—	2.78*** ± 0.28	n.s.	—	—	0.09 n.s. ± 0.45	n.s.	—	—	0.90*** ± 0.09	n.s.
Kurdish female Jews	6	—	—	—	3.13*** ± 0.22	—	—	—	0.63 n.s. ± 0.50	—	—	—	0.83*** ± 0.06
p.m.													
Yemenite male Jews	10	2.30*** ± 0.17	n.s.	n.s.	n.s.	0.98* ± 0.33	n.s.	**	n.s.	1.11*** ± 0.09	n.s.	n.s.	n.s.
Kurdish male Jews	10	—	2.14*** ± 0.16	n.s.	*	—	0.91 n.s. ± 0.41	*	n.s.	—	0.98*** ± 0.04	n.s.	n.s.
Yemenite female Jews	8	—	—	2.66*** ± 0.24	n.s.	—	—	0.38 n.s. ± 0.21	n.s.	—	—	0.96*** ± 0.06	n.s.
Kurdish female Jews	7	—	—	—	2.90*** ± 0.24	—	—	—	0.43 n.s. ± 0.49	—	—	—	0.99*** ± 0.09

Values given are means and standard errors for each group: n.s. (not significant), $P > 0.05$; *, $0.05 > P > 0.01$; **, $0.01 > P > 0.001$; ***, $P < 0.001$.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Table A 5. Series 1: heart rates (beats/min)

	n	neutral stage				controlled hyperthermia			
		Yemenite male Jews	Kurdish male Jews	Yemenite female Jews	Kurdish female Jews	Yemenite male Jews	Kurdish male Jews	Yemenite female Jews	Kurdish female Jews
a.m.									
Yemenite male Jews	9	68.00 ± 2.67	*	n.s.	n.s.	100.44 ± 3.89	n.s.	n.s.	n.s.
Kurdish male Jews	10	—	59.90 ± 1·88	*	**	—	92.00 ± 3.06	n.s.	**
Yemenite female Jews	7	—	—	69.71 ± 3.03	n.s.	—	—	101.86 ± 4.57	n.s.
Kurdish female Jews	6	—	—	—	69.67 ± 2.67	—	—	—	107.33 ± 3.85
p.m.									
Yemenite male Jews	10	78.80 ± 3.87	n.s.	n.s.	n.s.	104.00 ± 4.35	n.s.	n.s.	n.s.
Kurdish male Jews	10	—	72.30 ± 2.88	n.s.	n.s.	—	97.70 ± 3.57	*	n.s.
Yemenite female Jews	8	—	—	77.50 ± 3.47	n.s.	—	—	113.29 ± 4.59	n.s.
Kurdish female Jews	5	—	—	—	72.80 ± 5.17	—	—	—	101.20 ± 3.15

Values given are means and standard errors for each group: n.s. (not significant), $P > 0.05$; *, $0.05 > P > 0.01$; **, $0.01 > P > 0.001$.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Table A6. Series 2: deep body and skin temperatures (°C)

		neutral stage				sweat onset				controlled hypothermia			
	n	Yemenite male Jews	Kurdish male Jews	Yemenite female Jews	Kurdish female Jews	Yemenite male Jews	Kurdish male Jews	Yemenite female Jews	Kurdish female Jews	Yemenite male Jews	Kurdish male Jews	Yemenite female Jews	Kurdish female Jews
						ear temperature							
a.m.													
Yemenite male Jews	7	36.83 ± 0.13	n.s.	n.s.	n.s.	36.67 ± 0.08	n.s.	n.s.	n.s.	38.02 ± 0.01	—	—	—
Kurdish male Jews	8	—	36.87 ± 0.08	n.s.	n.s.	—	36.67 ± 0.11	n.s.	n.s.	—	38.02 ± 0.01	—	—
Yemenite female Jews	3	—	—	36.99 ± 0.16	n.s.	—	—	36.96 ± 0.05	n.s.	—	—	38.00 ± 0.01	—
Kurdish female Jews	4	—	—	—	36.84 ± 0.22	—	—	—	36.98 ± 0.16	—	—	—	37.98 ± 0.02
p.m.													
Yemenite male Jews	9	36.82 ± 0.08	n.s.	n.s.	—	36.74 ± 0.09	n.s.	*	—	38.05 ± 0.01	—	—	—
Kurdish male Jews	8	—	36.90 ± 0.05	n.s.	—	—	36.82 ± 0.06	**	—	—	38.05 ± 0.02	—	—
Yemenite female Jews	3	—	—	37.08 ± 0.16	—	—	—	37.24 ± 0.06	—	—	—	38.02 ± 0.02	—
Kurdish female Jews	0	—	—	—	—	—	—	—	—	—	—	—	—
						skin temperature							
a.m.													
Yemenite male Jews	7	32.13 ± 0.22	n.s.	n.s.	n.s.	37.01 ± 0.08	n.s.	*	n.s.	37.50 ± 0.08	n.s.	n.s.	n.s.
Kurdish male Jews	8	—	32.72 ± 0.16	n.s.	n.s.	—	37.03 ± 0.22	n.s.	n.s.	—	37.35 ± 0.08	n.s.	n.s.
Yemenite female Jews	3	—	—	32.19 ± 1.01	n.s.	—	—	37.57 ± 0.25	n.s.	—	—	37.25 ± 0.40	n.s.
Kurdish female Jews	4	—	—	—	33.02 ± 1.05	—	—	—	37.49 ± 0.27	—	—	—	37.61 ± 0.07
p.m.													
Yemenite male Jews	9	34.20 ± 0.42	n.s.	n.s.	—	36.81 ± 0.18	n.s.	**	—	37.37 ± 0.06	n.s.	n.s.	—
Kurdish male Jews	8	—	34.15 ± 0.42	n.s.	—	—	37.01 ± 0.25	n.s.	—	—	37.39 ± 0.07	n.s.	—
Yemenite female Jews	3	—	—	33.07 ± 0.29	—	—	—	37.88 ± 0.24	—	—	—	37.13 ± 0.21	—
Kurdish female Jews	0	—	—	—	—	—	—	—	—	—	—	—	—

Values given are mean and standard errors: n.s. (not significant), $P > 0.05$; *, $0.05 > P > 0.01$; **, $0.01 > P > 0.001$.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

TABLE A7. SERIES 2: HEART RATES (BEATS/min)

		neutral stage				controlled hyperthermia			
	n	Yemenite male Jews	Kurdish male Jews	Yemenite female Jews	Kurdish female Jews	Yemenite male Jews	Kurdish male Jews	Yemenite female Jews	Kurdish female Jews
a.m.									
Yemenite male Jews	7	70.43 ± 1.11	***	n.s.	n.s.	106.5 ± 5.10	n.s.	n.s.	n.s.
Kurdish male Jews	8	—	64.3 ± 3.6	n.s.	n.s.	—	98.0 ± 4.1	n.s.	n.s.
Yemenite female Jews	3	—	—	69.3 ± 5.5	n.s.	—	—	113.3 ± 10.9	n.s.
Kurdish female Jews	4	—	—	—	68.3 ± 3.5	—	—	—	107.3 ± 5.3
p.m.									
Yemenite male Jews	9	76.11 ± 4.08	n.s.	n.s.	—	104.89 ± 3.04	*	n.s.	—
Kurdish male Jews	8	—	69.9 ± 2.9	n.s.	—	—	95.3 ± 1.1	n.s.	—
Yemenite female Jews	3	—	—	80.0 ± 8.6	—	—	—	109.3 ± 9.8	—
Kurdish female Jews	0	—	—	—	—	—	—	—	—

Values given are mean and standard errors: n.s. (not significant), $P > 0.05$; *, $0.05 > P > 0.01$; ***, $P < 0.001$.

TABLE A8. SERIES 2: SWEAT RATES (ml)

	mean	95% confidence limits
Yemenite male Jews	4.25	2.84–6.36
Kurdish male Jews	6.11	4.56–8.20
Yemenite female Jews	0.75†	0.05–1.10
Kurdish female Jews	0.73†	0.22–2.47

† Estimated from the first collection only as no significant hydromeiosis. No significant difference between male responses.

TABLE A9. SERIES 2: HYDROMEIOSIS RATIOS

	mean	95% confidence limits
Yemenite male Jews	0.34	0.22–0.53
Kurdish male Jews	0.26	0.21–0.34
Yemenite female Jews	1.65†	0.32–8.59
Kurdish female Jews	1.17†	0.04–29.24

† No significant hydromeiosis $P > 0.05$. No significant difference between male responses.

TABLE A10. SERIES 2: HAND BLOOD FLOWS (ml/100 ml HAND TISSUE min^{-1})

	n	neutral stage	cooling	sweat onset	controlled hyperthermia
Yemenite male Jews	16	13.36 ± 1.81	4.59 ± 1.11	18.78 ± 1.55	30.26 ± 2.13
Kurdish male Jews	15	11.52 ± 1.33	3.23 ± 0.28	16.34 ± 1.31	26.68 ± 1.88
Yemenite female Jews	6	8.93 ± 1.96	3.97 ± 0.99	16.48 ± 2.03	22.34 ± 2.24
Kurdish female Jews	4	11.16 ± 3.18	2.66 ± 0.75	14.72 ± 3.14	24.80 ± 2.53

Values given are mean and standard errors.

Table A11. Series 1 and 2: within subject differences between series 1 and 2, body temperatures and heart rates

	n	neutral stage mean s.e.	neutral stage P	sweat onset mean s.e.	sweat onset P	controlled hyperthermia mean s.e.	controlled hyperthermia P
ear temperature							
Yemenite male Jews	8	0.07 ± 0.10	n.s.	0.22 ± 0.12	n.s.	n.a.	—
Kurdish male Jews	9	0.03 ± 0.07	n.s.	0.21 ± 0.08	*	n.a.	—
Yemenite female Jews	4	−0.28 −0.70, 0	n.s.	0.08 −0.23, +0.26	n.s.	n.a.	—
Kurdish female Jews	2	−0.02 −0.24, +0.20	n.a.	−0.22 −0.36, −0.08	n.a.	n.a.	—
skin temperature							
Yemenite male Jews	8	1.42 ± 0.61	n.s.	−1.25 ± 0.42	*	−0.51 ± 0.08	***
Kurdish male Jews	9	1.30 ± 0.33	**	−1.19 ± 0.36	*	−0.40 ± 0.13	*
Yemenite female Jews	4	0.63 0.16, 0.99	*	−0.45 −1.40, +0.25	n.s.	−0.26 −0.50, −0.02	n.s.
Kurdish female Jews	2	2.25 1.54, 2.95	n.a.	2.06 0.70, 3.42	n.a.	−0.39 −0.41, −0.36	n.a.
pulse							
Yemenite male Jews	8	3.00 ± 4.51	n.s.	n.a.	—	−4.5 ± 2.93	n.s.
Kurdish male Jews	9	−0.86 ± 2.73	n.s.	n.a.	—	−7.63 ± 2.20	*
Yemenite female Jews	4	−1.25 −9, +4	n.s.	n.a.	—	0 −8, +11	n.s.
Kurdish female Jews	2	−9 −12, −6	n.a.	n.a.	—	−8 −11, −5	n.a.

Mean values given are the differences of series 1–series 2.
Ranges are given for female groups in lieu of standard error.
(n.s. (not significant), $P > 0.05$; *, $0.05 > P > 0.01$; **, $0.01 > P > 0.001$; ***, $P < 0.001$; n.a., not applicable.)

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES