BODY TEMPERATURE AND ITS RELATIONSHIP TO DEMOGRAPHIC AND CARDIOVASCULAR RISK FACTORS IN A NATIONAL SAMPLE OF CHILDREN AND ADOLESCENTS

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The association of body temperature with demographic, maturational, constitutional, and cardiovascular risk variables was investigated in a large, representative sample of US children and adolescents in the Health Examination Survey. While body temperatures in children ages 6 to 11 years were not related to demographic variables, temperatures in children ages 12 to 17 were lower at older ages, higher in females than males, and higher in whites than blacks. In multiple regression analyses, demographic variables, maturational variables, and variables related to heat production or loss explained less than 10% of the variation in body temperature. Body temperature was a significant independent correlate of resting heart rate and systolic blood pressure at ages 6 to 11 and 12 to 17. Body temperature showed weak tracking over a follow-up interval averaging 44 months. (*J Natl Med Assoc.* 1992;84:591-599.)

Key words • body temperature • Health Examination Survey • US children • US adolescents

The regulation of body temperature is achieved through complex mechanisms involving multiple body systems including the circulatory system.[1] Body temperature in turn affects the functioning of these systems. Although body temperature has been easily measured throughout this century,[2,3] it has been given little attention in population surveys. This article describes the associations of body temperature with demographic, maturational, and constitutional variables, and with cardiovascular risk variables in US children and adolescents.

METHODS

The second cycle of the Health Examination Survey (HES) was conducted on a nationwide multistage probability sample of 7417 US children (excluding children residing in Hawaii and Alaska) between 6 and 11 years of age. The survey started in July 1963 and was completed in December 1965. Of the 7417 children selected for the sample, 7119 (96%) were examined. There were 6100 whites, 987 blacks, and 32 others. Details of the plan, sampling, operation, and response have been published elsewhere as have procedures used to obtain informed consent and maintain confidentiality.[4] This article focuses on black and white children with complete data on body temperature and cardiovascular risk variables.

Demographic and medical history information was collected during a household interview prior to the examination. Oral temperatures were taken shortly after the arrival of subjects at the examination site. Before the standardized examination was begun, the physician examined any child whose temperature was 37.8°C (100°F) or over. If the physician determined that the child was too sick to be examined further or if a contagious disease was suspected, the child was sent home without further examination, and the examination was rescheduled for another date.

A team of examiners including a pediatrician

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examined each child in a mobile examination center. The pediatrician's examination included assessment of breast development in girls, male genital development, and the presence of axillary hair. The nurse took two blood pressure readings in the right arm supine with a mercury sphygmomanometer as described elsewhere.[5] The average of these readings was used in the present analysis. Diastolic pressure was defined as the complete cessation of sounds. If the sounds failed to disappear, the pressure at which muffling occurred was used. A pediatric or adult cuff was used as appropriate. Heart rate was measured from a 10-lead electrocardiogram. Technicians measured height to the nearest millimeter, weight to the nearest half pound, and a series of body measurements including standing waist and hip girths and triceps, subscapular, and lateral chest wall skinfold thickness to the nearest millimeter using methods detailed elsewhere.[6] A radiograph of the right hand and wrist was taken for determination of skeletal age as described elsewhere.[7]

The third cycle of the Health Examination Survey was conducted on a nationwide multistage probability sample of 7514 US youths between the ages of 12 and 17 years. This survey started in March 1966 and was completed in March 1970. Of the 7514 youths selected for the sample, 6768 (90%) were examined. There were 5735 whites, 999 blacks, and 34 others. Details of the plan, sampling, response, and operation were published previously.[8] This article is limited to white and black children with complete data on body temperature and cardiovascular risk variables.

Demographic, medical history, and behavioral information was collected during a household interview and from self-administered questionnaires prior to the examination. Shortly after arrival at the examination center, body temperature was measured to the nearest 0.1°F with an oral thermometer. Any subject with a temperature of ≥100°F (37.8°C) was sent home and rescheduled for another date at the physician's discretion.

The physical examination was conducted in a mobile center and included a pediatrician's assessment of breast development in girls, genital development in boys, and pubic hair stage in both sexes.[9] A nurse measured blood pressure supine at the beginning and end of the physician's examination using a mercury sphygmomanometer as described elsewhere.[10] The average of these readings was used in the present analysis. Diastolic pressure was defined as the complete cessation of sounds. If sounds failed to disappear, the pressure at which muffling occurred was used. A pediatric or adult cuff was used as appropriate.

A blood sample was taken and sent to the laboratories of the Center for Communicable Diseases in Atlanta, Georgia for analyses of levels of serum total cholesterol by the Abell-Kendall method and serum uric acid by the Technicon Auto Analyzer-1 (Technicon Instruments Corp, Tarrytown, New York) (N-136) method, and for protein-bound iodine concentration as described elsewhere.[11-13] A radiograph of the hand and wrist was taken for assessment of skeletal age, weight was measured to the nearest pound, standing height to the nearest centimeter, and waist and hip girth and subscapular skinfold thickness to the nearest millimeter.[14]

Exercise tolerance was measured by the use of a 5-minute submaximal treadmill exercise test. The test consisted of a 5-minute walk at a speed of 3.5 mph. The grade of the incline during the first 2 minutes was 0 after which it was raised to a 10% grade for the remaining 3 minutes. Baseline resting heart rate was measured from an electrocardiogram monitor strip containing 15 to 20 clear complexes taken with the subject standing quietly immediately prior to the exercise test. Heart rate measurements were repeated after 5 minutes of exercise. The subject was instructed to walk naturally with hips straight, head up, and arms swinging. Room temperature was maintained at 21.1°C to 23.3°C (70°F to 74°F) and relative humidity was maintained at 50% to 60% during the exercise test.

The Health Examination Survey Cycle III of youths was based on the same sample design as the previous survey of children aged 6 to 11. Because the same sampling areas were used, nearly one third of the youths examined in Cycle III had also been examined in the earlier Cycle II survey of children. The time lapse between the two examinations of the same sample persons ranged from 28 months to 5 years. In the longitudinal analyses presented here, only subjects with follow-up times of 23 to 53 months (median: 44 months) are included.

Population estimates for many of the variables have been published by the National Center for Health Statistics in the form of Series 11 reports.[5-7,10-12,14] Data in this article were not weighted to give precise estimates for the US population aged 6 to 17. However, the samples were large and similar to the population in most demographic characteristics.[4,8] Furthermore, the subsample examined two times resembles the overall sample for most characteristics as described elsewhere.[15] All descriptive statistics were computed by standard methods using unweighted data. Numbers of children in some analyses may vary because of missing

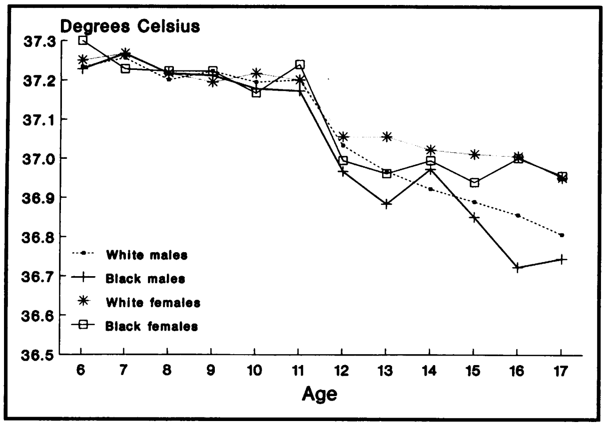

Figure 1. Mean oral body temperature of children and adolescents ages 6 to 17 years.

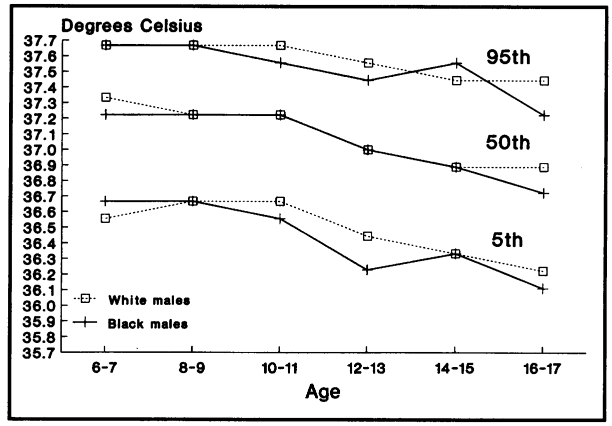

Figure 2. Selected percentiles (95th, 50th, and 5th) of body temperature in male children and adolescents ages 6 to 17 years.

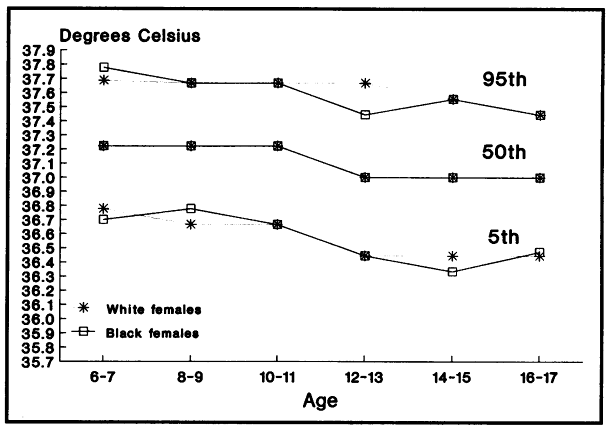

Figure 3. Selected percentiles (95th, 50th, and 5th) of body temperature in female children and adolescents ages 6 to 17 years.

data. Pearson product moment correlation was used to assess the association of body temperature with other continuous variables. Kendall's nonparametric rank correlation was used to assess the association of body temperature with ordinal variables and selected other variables.[16] Stepwise linear multiple regression analysis (SAS Forward) was used to develop models for predicting body temperature for each age, sex, and race group in Cycle III from Cycle II measurements.[17] Only variables with statistically significant bivariate correlation coefficients were eligible to enter the regression models. In view of the large number of tests performed, $P<.01$ was required for statistical significance.

RESULTS

Age, Sex, and Race

Figures 1, 2, and 3 show that body temperature was unrelated to age in 6 to 11 year olds. Six to 8 year olds were scheduled in the morning and 9 to 11 year olds in the afternoon; no trend with age was apparent within these subgroups. However, in 12 to 17 year olds, mean body temperature fell with increasing age, especially in males. In 6 to 11 year olds, there was no sex difference except slightly lower means in older white males. In 12 to 17 year olds, females had higher mean body temperature than males except at ages 16 to 17. Figures 2 and 3 show that distributions were symmetrical for all groups. Standard deviations ranged from 0.28°C to 0.34°C in children and from 0.29°C to 0.37°C in youths. The entire distribution of body temperature in 12 to 17 year olds seemed shifted downward in relation to 6 to 11 year olds with a marked discontinuity between survey cycles. This was probably the result of systematic measurement changes that caused the temperatures in the two survey cycles not to be comparable, for example, the practice of scheduling all 9 to 11 year olds in the afternoon in HES Cycle II. Thus, age trends were assessed only within survey cycle. Blacks tended to have slightly lower mean body temperatures than whites at ages 12 to 17 (Figures 1, 2, and 3), with the greatest difference in males. This was true within each geographic region.

In adolescents, mean body temperature was slightly higher in the South than in other regions at each age in both sexes and races. In children, no consistent regional differences in mean body temperature were seen. In children, temperature showed no consistent association with family income or parental education across age, sex, and race groups. In adolescents, there were only weak negative associations with these variables, some of which reached statistical significance (Table 1). In children, no consistent seasonal differences in tempera-

TABLE 1. CORRELATION OF SEXUAL AND SKELETAL MATURITY AND OTHER VARIABLES WITH BODY TEMPERATURE

	Sex, Age, Race							
	Males						Females	
	12 to 13		14 to 15		16 to 17		12 to 13	
Variable	White	Black	White	Black	White	Black	White	Black
Pubic hair stage	−0.08*	−0.07	−0.08*	−0.21*	−0.10*	−0.03	−0.03	0.03
Right breast stage	—	—	—	—	—	—	−0.01	−0.04
Left breast stage	—	—	—	—	—	—	0	−0.04
Male genital stage	−0.10*	−0.06	−0.07	−0.18*	−0.07	0.01	—	—
Bone age	−0.10*	−0.04	−0.05	−0.17*	−0.01	0.13	−0.02	−0.07
Smoking status	−0.08*	0.06	−0.02	−0.09	−0.04	−0.10	−0.04	0.01
TV viewing hours	−0.03	−0.01	0.06	0.04	0.03	0.10	0.03	0.07
Family income	−0.04	0.07	−0.07*	0.08	−0.11*	−0.01	−0.03	−0.10
Mother's education	−0.02	0.03	−0.08*	−0.11	−0.06	0	−0.07*	−0.06

*$P<.01$.

TABLE 2. CORRELATION OF BODY TEMPERATURE WITH SELECTED VARIABLES IN CHILDREN

	Sex, Age, Race							
	Males						Females	
	6 to 7		8 to 9		10 to 11		6 to 7	
Variable	White	Black	White	Black	White	Black	White	Black
Age (months)	0.04	0.04	0	0.01	−0.03	−0.03	0.02	−0.15
Height	0.01	−0.05	0	−0.11	−0.01	0	−0.03	−0.22*
Weight	0.04	−0.07	0.03	0.04	−0.03	0.08	−0.03	−0.19
Ponderal Index	−0.05	0.03	−0.03	−0.20	0.02	−0.09	0.01	−0.06
Body mass index	0.04	−0.07	0.04	0.14	−0.03	0.09	−0.02	−0.07
Tricep skinfold	0.01	−0.13	0.03	0.05	−0.01	−0.01	−0.02	−0.02
Subscapular skinfold	0.01	−0.08	0.05	0.06	−0.02	0	−0.01	−0.08
Waist-to-hip ratio	0.03	0.06	0.05	0.10	0.04	0.15	0.09*	0.10
Systolic blood pressure	0.09*	0.12	0.07	0.17	0.10*	−0.07	0.13*	0.02
Diastolic blood pressure	0.04	0.17	0.04	0.08	0.11*	0.01	0.06	0.14
Resting heart rate	0.13*	0.31*	0.16*	0.24*	0.15	0.12	0.17*	0.35*
N	1035	162	1059	153	1051	148	972	165

*$P<.01$.

ture were observed within age, sex, or race group. In adolescents, temperature was highest in winter in males with no consistent pattern during other seasons. In females, no consistent seasonal variation was observed.

Maturation

In girls aged 10 and 11 years, the presence of axillary hair or breast development or menstrual periods was not associated with body temperature. Temperature was not significantly correlated with skeletal age except in girls aged 10 to 11 years (whites, $R=-.07$, $P=.003$; blacks, $R=-.13$, $P=.016$). In adolescents, body temperature was significantly related to sexual maturation stage and to skeletal age within 2-year age groups in males but not females (Table 1). However, the relationship was weak even in males. In 12- to 13-year-old and 14- to 15-year-old females, body temperature was not related to the presence of menstrual periods.

Cardiovascular Risk Variables

In children, body temperature was not significantly correlated with height, weight, ponderal index, body

Sex, Age, Race			
Females			
14 to 15		16 to 17	
White	Black	White	Black
−0.06	−0.07	−0.03	−0.01
0.03	0	−0.02	−0.06
0.03	−0.02	−0.02	−0.06
—	—	—	—
−0.02	0	0.01	0.02
−0.12*	−0.04	−0.06	−0.05
0.05	−0.01	0.13	0.05
−0.08*	0.02	−0.11*	−0.07
−0.09*	0.01	−0.12*	0.13

Sex, Age, Race			
Females			
8 to 9		10 to 11	
White	Black	White	Black
−0.07	0	−0.06	0.04
−0.10*	−0.02	−0.10*	−0.12
−0.06	−0.04	−0.07	−0.09
−0.02	0.06	0	0.03
−0.02	−0.04	−0.03	−0.05
−0.05	−0.09	−0.03	−0.02
−0.01	−0.06	−0.05	−0.03
0.08	0.04	0.07	0.17
0.12*	0.12	0.07	0.11
0.07	0.12	0.09*	0.12
0.22*	0.08	0.09*	0.14
992	197	978	161

mass index, triceps skinfold, subscapular skinfold, or waist-to-hip ratio except for a negative correlation with height in 8- to 11-year-old white girls ($R=-.10$, $P=.002$) (Table 2). In adolescents, subscapular skinfold, triceps skinfold, and waist-to-hip ratio were significantly correlated with body temperature in older males (Table 3). However, neither weight nor body mass index was significantly related to temperature.

In children, systolic blood pressure was significantly correlated with body temperature in four of six age sex groups in whites with sample correlation coefficients ranging from 0.07 to 0.13 in whites and from 0.02 to 0.17 in blacks (Table 2). Diastolic blood pressure was significantly correlated with body temperature in 10- to 11-year-old white boys and girls. Resting heart rate was significantly correlated in most groups (Table 2).

In children, no hematological or biochemical determinations were made. In adolescents, neither serum cholesterol nor serum uric acid was significantly correlated with body temperature. Serum protein-bound iodine concentration was not significantly correlated with body temperature. Hematocrit was significantly correlated with temperature in males only (Table 3). In 16- to 17-year-old white males, current smokers had slightly lower body temperature than nonsmokers (98.24°F versus 98.33°F), probably partly because of an age effect; this was not observed at 14 to 15 years of age. A similar trend was observed in 14- to 15-year-old and 16- to 17-year-old white females but was unlikely the result of age because temperature changed little with increasing age in white females. Smokers' temperatures were about 0.11°C (0.2°F) lower than those of nonsmokers. No consistent variation of body temperature with ABO blood type was noted.

In children, stepwise multiple regression analysis was performed with body temperature as the dependent variable and height, skeletal age, systolic blood pressure, resting heart rate, height × systolic blood pressure, and height × resting heart rate as independent variables. In males, resting heart rate was the only variable that was significantly related to body temperature independent of the other variables within each age, sex and race group. However, the multiple correlation coefficient with only pulse in the model was about 2%. In females, pulse entered the model first and remained significantly associated with temperature after entry of other variables. Systolic blood pressure was also significantly independently associated with body temperature entering the model after pulse in most subgroups. The exception to this was 10- to 11-year-old girls in whom height and systolic blood pressure entered the model before pulse, which was not an independent correlate. Thus, the associations of body temperature with heart rate in both sexes and with systolic blood pressure in girls seem independent of age, growth, and development in whites. Similar results were obtained for blacks.

In adolescents, stepwise multiple regression analysis was performed with temperature as the dependent variable and age in months (forced to enter first), subscapular skinfold, waist-to-hip ratio, skeletal age, pubic hair stage, age × subscapular skinfold, age ×

TABLE 3. CORRELATION OF BODY TEMPERATURE WITH SELECTED VARIABLES IN ADOLESCENTS

	Sex, Age, Race							
	Males						Females	
	12 to 13		14 to 15		16 to 17		12 to 13	
Variable	**White**	**Black**	**White**	**Black**	**White**	**Black**	**White**	**Black**
Age (months)	−0.10*	−0.06	−0.10*	−0.17	−0.06	0	−0.03	−0.03
Height	−0.10*	−0.12	−0.07	−0.25*	−0.09*	−0.11	−0.05	−0.02
Weight	−0.04	0.04	0.01	−0.17	0.01	0.12	0.04	−0.05
Ponderal Index	−0.06	−0.20*	−0.07	0.02	−0.09*	−0.22	−0.08	0.06
Body mass index	0.01	0.14	0.05	−0.08	0.06	0.20	0.07	−0.04
Triceps skinfold	0.06	0.17	0.10*	0.05	0.10*	0.24*	0.07	−0.02
Subscapular skinfold	0.04	0.21*	0.11*	0.04	0.09*	0.24*	0.05	0.01
Waist-to-hip ratio	0.11*	0.20*	0.12*	0.19	0.10*	0.13	0.03	0.15
Systolic blood pressure	0.06	0.04	0.07*	0.03	0.13*	0.27*	0.15*	0.06
Diastolic blood pressure	0	−0.03	−0.08*	−0.09	0.03	0.16	0.08	0.01
Serum cholesterol	0.07	0.08	0.09*	−0.16	0.05	0.07	−0.01	−0.10
Serum uric acid	−0.05	−0.04	−0.02	−0.03	0.05	0.12	−0.01	−0.01
Protein-bound iodine	0.04	0.21	0	−0.02	0.12*	0.09	0.01	0.03
Hematocrit	−0.18*	−0.30*	−0.13*	−0.22*	−0.06	0.12	−0.06	−0.08
Estimated VO_2	−0.11*	−0.25*	−0.17*	−0.24*	−0.19*	−0.22	−0.15*	−0.10
Exercise heart rate	0.13*	0.20*	0.17*	0.24*	0.20*	0.24	0.14*	0.18
Resting heart rate	0.15*	0.23*	0.11*	0.25*	0.18*	0.25*	0.19*	0.39*
N	1075	180	1046	171	906	126	938	176

*$P<.01$.

waist-to-hip ratio, family income, season, region, and season × region as independent variables. In whites, significant independent variables explain less than 6% of the variation and all entered variables less than 7% of the variation in body temperature (Tables 4 and 5). Region was an independent predictor in three of six subgroups. In blacks, significant independent variables explained as much as 15% of the variation in body temperature (Tables 4 and 5). Region was an independent predictor in four of six subgroups.

To test the hypothesis that race was an independent predictor of body temperature in adolescents, the stepwise multiple regression was repeated with race forced to enter the model first for males and females separately. Race was a significant predictor ($P<.01$) of body temperature only in 16- to 17-year-old males and 12- to 13-year-old females after controlling for the other predictors mentioned above.

In adolescents, body temperature remained a significant independent predictor of systolic blood pressure in 12- to 13-year-old and 16- to 17-year-old white males, and 12- to 13-year-old and 14- to 15-year-old white females but not in blacks after controlling for age, subscapular skinfold, waist-to-hip ratio, resting heart rate, season, region, and sexual development stage. Temperature was an independent predictor of resting heart rate in 12- to 13-year-old and 16- to 17-year-old white males, 14- to 15-year-old black males, white females in each age group, and 12- to 13-year-old and 14- to 15-year-old black females. It was an independent predictor of exercise heart rate in 12- to 13-year-old and 16- to 17-year-old white males and 12- to 13-year-old white females. It was an independent predictor of hematocrit in 12- to 13-year-old and 14- to 15-year-old white males, 12- to 13-year-old blacks males, and 12- to 13-year-old and 14- to 15-year-old white females after controlling for the same variables mentioned above.

Tracking

Tracking of body temperature over a 44-month follow-up period was poor although generally statistically significant as measured by rank correlation coefficients. Among sex race groups, the coefficients were: white males, 0.14; black males, 0.13; white females, 0.09; and black females, 0.05 (not significant). The results were essentially unchanged after stratifica-

Sex, Age, Race			
Females			
14 to 15		16 to 17	
White	Black	White	Black
−0.03	−0.07	−0.13*	−0.04
−0.03	−0.09	−0.04	0.08
0.06	−0.08	0.09*	0.02
−0.07	0.05	−0.10	0.01
0.08	−0.05	0.12	0
0.09*	0	0.07	0.02
0.08	−0.03	0.11*	−0.04
0.11*	0.05	0.04	−0.11
0.17*	0.06	0.15*	0.11
0.02	0.02	0.05	0.08
0.01	−0.06	0.04	−0.19
−0.03	0.01	0.03	−0.11
0	−0.02	0.01	−0.03
−0.16*	−0.14	−0.05	−0.13
−0.14*	−0.13	−0.13*	−0.04
0.12*	0.16	0.10*	0.09
0.19*	0.37*	0.13*	0.24*
905	172	828	164

TABLE 4. SIGNIFICANT INDEPENDENT PREDICTORS OF BODY TEMPERATURE IN WHITE ADOLESCENTS*

Age	Male	Female
12 to 13	Age (months)†	Age (months)†
	R^2 = .01	R^2 = 0
	R^2 (7 variables) = .03	R^2 (5 variables) = .01
14 to 15	Age (months)	Age (months)†
	Region	Region
	Age × subscapular skinfold	R^2 = .01
	R^2 = .04	R^2 (6 variables) = .03
	R^2 (6 variables) = .05	
16 to 17	Age (months)†	Age (months)
	Family income	Subscapular skinfold
	Region	Family income
	Pubic hair stage	R^2 = .04
	R^2 = .05	
	R^2 (8 variables) = .06	R^2 (5 variables) = .05

*Predictors were variables that added at least .009 to R^2 and whose regression coefficients were significant at $P < .01$. Entry of variables into the model stopped when the .50 significance level for entry was no longer met.

†Age (months) was not a significant independent predictor but was forced to enter the model first.

tion into the younger group examined in the morning and the older group examined in the afternoon in Cycle II. Coefficients were no higher for those followed ≤44 months compared with those followed >44 months. Coefficients for height were 0.67, 0.63, 0.58, and 0.42, respectively, for these groups.

DISCUSSION

While body temperatures at ages 6 to 11 were not related to demographic variables, body temperatures of adolescents were lower at more advanced ages, higher in females than in males, and higher in whites than in blacks. In multiple regression analysis, demographic variables, maturational variables, and variables related to heat production or loss explain little of the variation in body temperature. However, body temperature was a significant if weak independent predictor of systolic blood pressure and resting heart rate in children and adolescents, and exercise heart rate and hematocrit in adolescents. Body temperature showed a weak tracking over a 44-month period.

A physiologic model guided these analyses.[1] Decreasing levels of strenuous physical activity might be related to some of the decrease in body temperature with age in adolescents.[18] Also, basal metabolic rate decreases with age from childhood to adulthood with an acceleration at puberty as the result of slower growth of high energy-producing organs relative to total body weight.[19] However, body temperature is not related to body size among species of homeotherms.[19,20]

Racial and sexual variations may be caused by genetically determined mechanisms of body temperature control. Unlike body temperature in this survey, basal metabolic rate is about 10% lower in females than males at each age.[19] Greater insulating subcutaneous fat as reflected by skinfold thickness would tend to diminish heat loss and might be related to sex and race differences, with males and blacks having less subcutaneous fat.[6,14]

Regional and seasonal variations might be the result of environmental conditions, especially an indoor environment that may be cooler in summer than in winter because of air conditioning.[18] Basal metabolic rate is lowest in inhabitants of tropical zones, higher in

TABLE 5. SIGNIFICANT INDEPENDENT PREDICTORS OF BODY TEMPERATURE IN BLACK ADOLESCENTS*

Age	Male	Female
12 to 13	Age (months)† Subscapular skinfold Region Waist-to-hip ratio Family income $R^2 = .15$ R^2 (6 variables) = .15	Age (months)† Family income $R^2 = .02$ R^2 (4 variables) = .05
14 to 15	Age (months) Region Pubic hair stage $R^2 = .12$ R^2 (8 variables) = .18	Age (months)† Region $R^2 = .01$ R^2 (6 variables) = .03
16 to 17	Age (months)† Subscapular skinfold Skeletal age Pubic hair stage $R^2 = .13$ R^2 (6 variables) = .15	Age (months)† Region $R^2 = .03$ R^2 (3 variables) = .04

*Predictors were variables that added at least .009 to R^2 and whose regression coefficients were significant at $P<.05$. Entry of variables into the model stopped when the .50 significance level for entry was no longer met.
†Age (months) was not a significant independent predictor but was forced to enter the model first.

those of temperate zones, and highest in Eskimos.[18,21] Higher basal metabolic rate, serum protein-bound iodine, plasma thyroxine levels, and lower serum cholesterol were found in winter, and the opposite changes were found in summer.[19] Increased fat intake in winter may be a factor related to basal metabolic rate and lipid changes with season.[19] The inverse relationship of family income to body temperature in adolescents could reflect an increased prevalence of recent upper respiratory infections in lower socioeconomic status adolescents.[18] However, one would have expected such a relationship to be stronger in children.

The relationship of body temperature to heart rate is by a direct effect on cardiac tissue.[1] Statistically, the blood pressure effect was not entirely secondary to the heart rate effect but its mechanisms are unclear. Increased peripheral resistance caused by cutaneous vasoconstriction might tend to raise both body temperature and blood pressure. The mechanism of the association of body temperature with hematocrit is also unclear.

The discontinuity of mean body temperatures between Cycle II and III examinations suggest some source of measurement bias between the surveys. A difference in the practice of sending home children with temperatures greater than 100°F seems unlikely since both low and high percentiles are affected (Figures 2 and 3). The greater frequency of upper respiratory infections and greater physical activity in younger children compared with adolescents probably explains only a little of the difference. The most likely explanation is a difference in measurement technique or instruments. Information to support this was found in HES field manuals. In HES II, bias may have risen from the practice of scheduling 6 to 8 year olds in the morning and 9 to 11 year olds in the afternoon, as afternoon temperatures are generally higher. This could obscure any decline with age in 6 to 11 year olds. However, no significant associations with age were seen in 6 to 7 year olds or 10 to 11 year olds (Table 2 and Figures 1, 2, and 3). Because 12 year olds in HES III were examined both in the morning and afternoon, this bias also could explain the apparent discontinuity between surveys, at least in part.

When tested, 18% of glass thermometers showed errors of greater than 0.28°C (0.5°F) in one study, a magnitude similar to the discrepancy between Cycle II and III.[3] A systematic difference in duration of recording time is another possibility, the optimal time being 8 to 9 minutes, with clinical practice often being only 3 to 5 minutes.[3] This might be especially important at lower environmental temperatures when the time required is increased.[3] This also might influence seasonal variations. In any event, all analyses were conducted within each survey except for the tracking analysis. The rank order correlation should not be biased by a uniform shift of the entire distribution. No attempt was made to assess absolute change in body temperature between childhood and adolescence.

Although there was no indication of such bias, measurement errors related to other variables could cause bias in measures of an association of body temperature with these variables. Unfortunately, data were lacking in these surveys on many sources of body temperature variation such as daily and monthly biological rhythms,[22] familial aggregation of body temperature, time of last meal, recent upper respiratory infections, drugs, and environmental conditions. These could be sources of random variation or possible confounders. Random variation would bias correlation coefficients toward the null. The lack of such data reflects the nature of this general epidemiologic survey, which did not focus on body temperature.

No other comparable large epidemiologic surveys of body temperature in children and adolescents were found in the literature for comparison. However, the HES data are generally consistent with those from clinical settings.[23] An exception to this is the failure of body temperature to fall with increasing age in 6 to 11 year olds in HES.[23] In a sample of middle-aged men in Sweden, body temperature was related positively to height, weight, body mass index, and body fat. Physically active men had higher body temperatures than sedentary men but not independent of body fat. Body temperature was higher in the winter and in individuals with a history of upper respiratory infection during the preceding 14 days. Although not directly comparable, the present findings in adolescents are generally consistent with these findings.

Ambient temperature in the examination room has been reported to be inversely related to systolic blood pressure in children but body temperature was not reported.[24] The present findings indicate that just as various environmental variables may be controlled in studies of blood pressure, heart rate, and exercise performance, body temperature might be an important potential confounder to be controlled. This could be accomplished by rescheduling febrile subjects for reexamination after 2 or more weeks and by using body temperature as a control variable in statistical analyses.

CONCLUSION

Body temperature should be examined in other general population samples to shed further light on the relationship of body temperature with variables of interest in epidemiologic surveys. Measurement variation might be reduced by attention to standardization, quality control, and use of rapid-reading digital thermometers. Time of day should be recorded. Laboratory and longitudinal studies may investigate the mechanisms for observed associations of body temperature with blood pressure, hematocrit, body fat, and the apparent low levels of tracking.

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