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Thermal sensations of secondary schoolchildren in summer

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SUMMARY

Summer thermal sensations of secondary schoolchildren in England are compared with those earlier published for winter. Heat stress, contrary to expectation, is seen to decrease during the warm months, and neutrality is found to increase by some 6° F. (3·5° C.) air temperature, which is more than double the increases observed for adults under similar circumstances.

INTRODUCTION

Seasonally varying thermal comfort requirements in England have been reported for adults (Hickish, 1955). Given that such differences also exist for other populations, such as schoolchildren, single yearly temperature recommendations may be misleading. Moreover, the prescription of minimum permissible thermal levels (Statutory Instruments, 1954) gives no indication of desirable conditions, particularly as relates to the warm months of the year.

Winter optima for schoolchildren were established earlier (Auliciems, 1969), showing thermal neutrality to occur in conditions very closely corresponding to those previously found for adults under similar rates of metabolic activity (Bedford, 1936), but being considerably in excess of legally required temperatures. The present report is designed to provide comparative information for the summer population of schoolchildren.

METHOD

Collection of data was identical with that previously reported for winter (Auliciems, 1969), but using children from 14 secondary schools in the Reading area. Atmospheric measurement included air temperature, radiation (globe thermometer), humidity (Assmann psychrometer) and rate of air movement (kata thermometer), while subjective thermal sensations were gained on a seven-point scale (see Table 1). Three separate measures of ambient warmth were employed for data analysis: dry-bulb temperature, corrected effective temperature (C.E.T.) and equivalent temperature (T_{eq}). The data were collected during late May and June in 1967.

RESULTS

The distribution of thermal sensations appears in Table 1, and the frequency of various degrees of warmth in Tables 2–4. As in the winter study, ventilation rates were very low despite frequently opened windows, with average air movement for

Table 1. *Distribution of thermal sensations*

Sensation	Numerical value	Frequency Boys	Girls	Total
Much too warm	+3	16	16	32
Too warm	+2	59	35	94
Comfortably warm	+1	112	58	170
Comfortable	0	132	52	184
Comfortably cool	−1	95	29	124
Too cool	−2	39	9	48
Much too cool	−3	11	2	13
Total		464	201	665

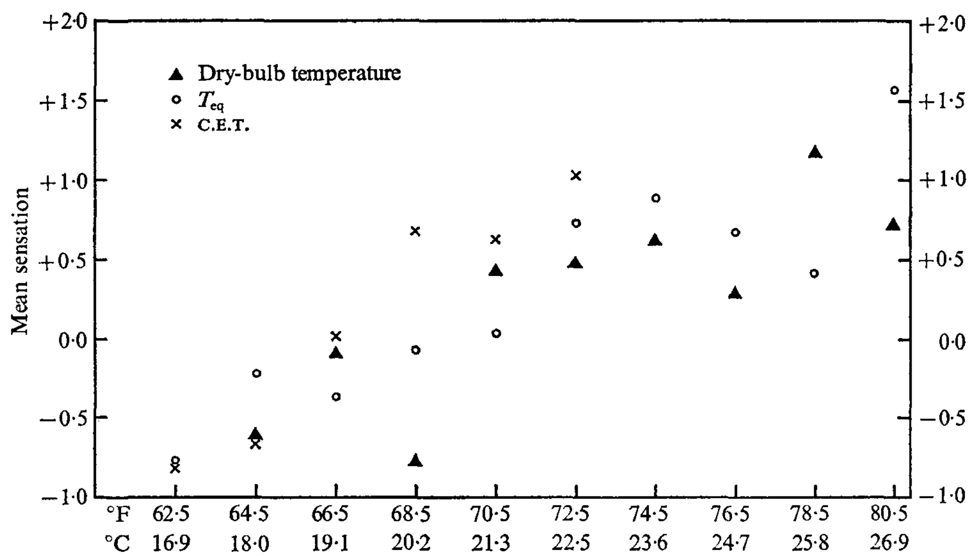

Fig. 1. Mean sensation against thermal levels.

the 36 sessions being 14 ft./min. (7 cm./sec.). Tables 2–4 also show the distribution of thermal sensations and means together with percentages of comfort for corresponding intervals of thermal levels.

Graphical representation of the sensation means against all three thermal measures is shown in Fig. 1. Regression analysis has been applied to individual scores and equations expressed in the form $Y = ax+b$, where Y is the thermal sensation, a and b constants and x thermal measure. The regression constants and the product moment correlation coefficients are shown in Table 5 and the optimum conditions (when $Y = 0$ or 'comfortable') in Table 6 together with those previously obtained for the children during winter and the earlier optima for light industrial workers.

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Table 2. *Distribution of sensations in relation to dry-bulb temperatures*

Dry-bulb		Frequency of observations	Frequency of sensations								Mean sensation	Percentage			
°F.	°C.		+3	+2	+1	0	−1	−2	−3	Total		Heat discomfort	Comfort	Comfort (pairs combined)	Cold discomfort
79·5–81·4	26·4–27·4	1	—	2	2	2	1	—	—	7	+0·71	29	71	59	0
77·5–79·4	25·3–26·3	2	8	12	13	6	7	—	—	46	+1·17	43	57		0
75·5–77·4	24·2–25·2	2	—	5	13	4	1	1	—	24	+0·83	21	75	69	4
73·5–75·4	23·1–24·1	1	2	4	3	5	3	—	1	18	+0·61	33	61		6
71·5–73·4	21·9–23·0	10	5	39	56	49	35	7	2	193	+0·49	23	72	75	5
69·5–71·4	20·8–21·8	12	14	25	68	65	40	11	1	224	+0·41	18	77		5
67·5–69·4	19·7–20·7	3	—	1	8	19	14	13	6	61	−0·79	2	67	69	31
65·5–67·4	18·6–19·6	2	2	4	4	15	10	3	2	40	−0·10	14	73		13
63·5–65·4	17·5–18·5	3	1	2	3	19	13	13	1	52	−0·62	6	67		27
Total		36	32	94	170	184	124	48	13	665		19	72		9

Table 3. *Distribution of sensations in relation to* T_{eq}

T_{eq} °F.	T_{eq} °C.	Frequency of observations	Frequency of sensations +3	+2	+1	0	−1	−2	−3	Total	Mean sensation	Percentage Heat discomfort	Comfort	Cold discomfort
79·5–81·4	26·4–27·4	2	8	11	7	3	3	—	—	32	+1·56	59	41 } 58	0
77·5–79·4	25·3–26·3	2	—	3	8	5	5	—	—	21	+0·43	14	86	0
75·5–77·4	24·2–25·3	2	—	5	16	7	3	1	—	32	+0·66	16	81 } 70	3
73·5–75·4	23·1–24·2	7	10	27	39	26	15	—	1	118	+0·89	31	68	1
71·5–73·4	21·9–12·0	6	7	27	29	24	19	2	1	109	+0·72	31	66 } 76	3
69·5–71·4	20·8–21·8	10	4	15	57	69	48	18	3	214	+0·03	9	81	10
67·5–69·4	19·7–20·7	1	—	—	3	5	2	1	—	11	−0·09	0	91 } 69	9
65·5–67·4	18·6–19·6	3	2	4	8	26	16	13	7	76	−0·37	8	66	26
63·5–65·4	17·5–18·5	2	1	1	1	13	6	7	—	29	−0·24	7	69 } 67	24
61·5–63·4	16·4–17·4	1	—	1	2	6	7	6	1	23	−0·78	4	65	31
Total		36	32	94	170	184	124	48	13	665		19	72	9

Table 4. *Distribution of sensations in relation to* C.E.T.

C.E.T. °F.	C.E.T. °C.	Frequency of observations	Frequency of sensations +3	+2	+1	0	−1	−2	−3	Total	Mean sensation	Percentage Heat discomfort	Comfort	Cold discomfort
71·5–73·4	21·9–23·0	5	8	19	28	12	9	1	—	77	+1·03	35	64	1
69·5–71·4	20·8–21·8	8	11	32	45	40	30	2	2	162	+0·63	27	71	2
67·5–69·4	19·7–20·7	7	6	28	41	32	18	3	1	129	+0·68	26	71	3
65·5–67·4	18·6–19·6	10	5	12	48	59	42	17	3	186	+0·01	9	80	11
63·5–65·4	17·5–18·5	5	2	2	6	35	18	19	6	88	−0·66	5	67	28
61·5–63·4	16·4–17·4	1		1	2	6	7	6	1	23	−0·78	4	66	30
Total		36	32	94	170	184	124	48	13	665		19	72	9

Table 5. *Regression constants and correlation coefficients*

Thermal measure	r	Constant a		Constant b	
		°F.	°C.	°F.	°C.
Dry-bulb	+0·32	0·125	0·225	−8·625	−4·614
T_{eq}	+0·40	0·133	0·240	−9·242	−4·976
G.E.T.	+0·39	0·194	0·350	−12·948	−6·731

Table 6. *Thermal optima*

	Schoolchildren					
	Summer		Winter (Auliciems, 1969)		Increase	
	°F.	°C.	°F.	°C.	°F.	°C.
Dry-bulb	69·0	20·6	62·7	17·1	6·3	3·5
T_{eq}	69·5	20·8	61·7	16·5	7·8	4·3
C.E.T.	66·7	19·3	60·8	16·0	5·9	3·3
	Adults					
	Summer (Hickish, 1955)		Winter (Bedford, 1936)		Increase	
	°F.	°C.	°F.	°C.	°F.	°C.
Dry-bulb	66·8	19·3	64·7	18·2	2·1	1·1
T_{eq}	65·9	18·8	62·3	16·8	3·6	2·0
G.E.T.	64·4	18·0	61·7	16·5	2·7	1·5

DISCUSSION

Perhaps the most significant result to emerge from the present analysis is that less heat discomfort is evident during the warm months than the cool ones. During the latter, fully 31 % of the subjects had reported being either 'much too warm' or 'too warm' (Auliciems, 1969), while in the summer heat discomfort was reduced to only 19 % (see Tables 2–4). The present data do not permit the establishment of a satisfactory comfort zone, but it would appear that the lower limits for approximately 70 % of the sample can be located above 65·5° F. (18·6° C.) with all three thermal measures, and the upper limits at 77·4° F. (25·2° C.) dry-bulb and T_{eq}, and 71·4° F. (21·8° C.) C.E.T. The previously employed comfort criterion of 60 % in winter was exceeded at almost all thermal levels and it must be concluded that the overall conditions in the schools were thermally preferable during summer.

Of particular interest also is the considerably greater increase of optima in comparison with those of adults (see Table 6). With all thermal measures the differences are at least double in magnitude, but the reasons are far from obvious. It may be suggested that children tend to wear more clothing during cold weather than adults, which removed in summer would lead to relatively greater increases in thermal requirements. If so, however, then being more heavily dressed, the children should have also preferred considerably lower temperatures in winter, particularly in view of their higher basal metabolic rates. Thus unless the metabolic heat production of adults had been higher owing to comparatively increased rates of activity at the time of testing, which does not appear to have been the case, the differential winter–summer increases must have resulted from some more subtle and less easily identifiable process of behavioural or physiological adaptation to seasonal changes.

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