Effect of a Step Change in Temperature on Skin Temperature and Blood Flow.* (29574)

T. Sasaki and L. D. Carlson
Department of Physiology and Biophysics, University of Kentucky, Lexington

The effect of local temperature on skin temperature and blood flow are intimately related to internal body temperature or to body thermal state(1). A significant circadian change in internal body temperature occurs with the lower period early in the morning, the rise to a peak occurring during the day. These tests were conducted to determine if the circadian shift in internal temperature alters the response to a step change in temperature.

Methods. The subjects were seated in a calorimeter(2). Heat loss and heat production were measured in a manner already described(2). Body and skin temperatures were recorded with thermistors (YSI thermal underwear suit). Peripheral blood flow was estimated from the change in volume per beat determined by Whitney mercury in rubber gauges(3). Measurements were made on 4 subjects over a time period of 3 hours. Experiments were initiated at 0630 with the subject basal and at 1330 with a controlled intake at 1200. An initial period of 90 minutes at 30°C was followed by a period of 60 minutes at 25°C. The 5°C temperature shift was accomplished in one minute.

The data recorded from these tests, Tables I, II and III, have been analyzed in several ways and 3 salient features appear. First

TABLE I. Average Skin Temperature.

	LDC		WVJ		TS		AH	
	AM	PM	AM	PM	AM	PM	AM	PM
5	33.34	33.90	32.63	33.17	33.20	33.85	33.33	33.37
10	.41	34.05	32.61	.17	.32	33.88	.30	.47
	.44	.12		.27	.46	34.21	.42	.52
20	.62	.17	32.87	.21	.59	.08	.41	.85
	.74	34.07	.80	.30	.51	.21	.41	.76
30	.68	33.88	32.86	.42	.43	.15	.67	.73
	.75	34.13	33.00	33.48	.51	.26	.52	.89
40	.71	.13	33.09		.49	.15	.54	.66
	.83	.23	32.98	33.40	.54	.09	.60	.65
50	.81	.39	.89	.37	.55	.25	.78	.84
	.83	.53	32.85	.43	.53	.24	.79	.97
60	.62	.38	33.02	.35	.59	.25	.90	.87
	.65	.37	.10	.40	.56	.30	.84	.85
70	33.61	34.37	33.03	33.35	34.70	33.45	33.77	33.79
	.53	.47	.02	.34	.79	.56	.78	.84
80	.34	.52	33.04	.26	.74	.28	.85	.77
	.39	.39	32.99	.18	.69	.18	.67	.89
90	33.50	34.26	33.05	33.15	33.71	34.32	33.80	33.99
	32.95	33.67	32.30	32.61	33.32	33.65	33.12	33.38
100	.81	.29	31.94	.28	32.98	.38	32.98	33.06
	.76	.04	.76	.17	.66	33.15	.76	32.71
110	.46	.02	.74	32.04	.46	32.95	.72	.65
	.24	.04	.71	31.78	.48	.86	.61	.51
120	.25	33.06	.75	.75	.58	.84	.44	.43
	.28	32.88	.56	.75	.46	.93	.49	.48
130	.29	.73	.70	.62	.18	.83	.43	.46
	32.22	.64	.71	.61	.05	.68	.37	.34
140	31.87	.45	.40	.50	32.05	.59	32.18	.22
	.92	.46	.33	.52	31.96	.59	31.90	.28
150	31.94	32.41	31.26	31.47	32.14	32.48	31.85	32.37

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TABLE II. Finger Temperature and Blood Flow.

		LDC				WVJ				TS				AH			
		AM	% V beat	PM	% V beat	AM	% V beat	PM	% V beat	AM	% V beat	PM	% V beat	AM	% V beat	PM	% V beat
5		34.9		33.8		34.6		35.3		35.0		35.8		34.8		34.9	
10	0- 10	34.9	1.109	34.0	1.390	34.4	.980	35.3	.766	35.0	1.437	36.0	1.598	34.6	.968	35.3	1.253
		35.0		34.1				35.2		35.2		36.0		34.7		**35.1**	
20	10- 20	35.2	1.039	34.5	1.323	34.8	.945	35.1	.706	35.6	1.710	36.0	1.765	34.7	.979	35.3	1.070
		35.1		34.6		34.3		35.2		35.0		35.8		34.6		35.0	
30	20- 30	34.3	.893	34.8	1.279	34.5	.780	35.4	.650	35.2	1.608	36.0	1.701	34.8	.938	35.0	.945
		35.2		34.9		34.3		35.4		35.2		36.0		34.7		35.1	
40	30- 40	35.1	1.140	34.9	1.382	34.7	.900		.665	35.3	1.595	36.0	1.621	34.4	1.003	35.0	1.178
		35.0		34.9		35.0		35.1		35.5		36.0		34.3		35.0	
50	40- 50	34.9	1.289	35.0	1.264	34.4	.960	34.8	.543	35.2	1.180	36.1	1.422	34.1	.951	35.0	1.010
		35.1		35.0		34.6		34.9		35.3		35.6		34.1		35.0	
60	50- 60	34.7	1.125	35.0	1.245	34.7	.800	35.2	.537	35.0	1.485	36.0	1.696	34.3	.951	34.9	.888
		35.0		35.0		34.8		35.0		35.2		36.0		34.3		35.0	
70	60- 70	35.0	1.120	34.8	1.163	34.5	.785	35.1	.587	35.2	1.205	35.9	1.667	34.7	1.014	35.0	.948
		35.0		34.8		34.8		35.0		35.1		35.9		34.5		34.9	
80	70- 80	34.3	1.162	34.8	1.191	34.9	.905	35.2	.597	35.1	1.515	35.9	1.468	34.9	.948	35.0	.953
		35.1		34.5		34.8		35.1		35.0		36.0		34.3		35.0	
90	80- 90	34.9	1.085	34.2	1.077	34.9	.760	35.2	.621	35.2	1.110	36.0	1.637	34.6	.960	35.1	.921
		34.1		34.0		33.6		34.2		35.0		35.3		33.8		34.4	
100	90-100	34.0	1.093	33.6	1.066	33.2	.650	34.1	.505	34.2	1.100	35.0	1.361	33.6	.790	34.1	.765
		34.0		33.3		33.0		34.1		34.0		34.8		33.4		34.0	
110	100-110	33.1	.816	33.2	1.066	33.4	.419	34.1	.408	34.0	.990	34.4	.886	33.5	.791	33.9	.670
		33.0		33.2		33.5		33.3		33.8		34.9		33.1		33.8	
120	110-120	34.2	.867	33.0	.958	34.0	.690	33.5	.432	33.8	1.095	34.7	1.050	33.0	.791	33.8	.623
		34.1		33.0		33.8		33.9		34.3		34.1		33.1		34.0	
130	120-130	34.0	.924	32.9	.897	33.8	.655	33.7	.427	34.1	1.200	33.9	.663	33.3	.886	34.2	.749
		34.0		32.7		33.8		33.8		33.4		34.1		33.1		33.9	
140	130-140	33.2	.842	32.6	.864	33.3	.650	33.3	.432	33.3	.930	34.3	.695	32.9	.853	33.7	.686
		33.2		33.3		33.0		33.8		33.4		34.1		32.7		33.7	
150	140-150	33.4	.775	32.2	.893	32.6	.505	33.7	.430	33.3	.855	33.5	.739	32.5	.753	33.7	.716

TABLE III. Toe Temperature and Blood Flow.

		LDC				WVJ				TS				AH			
		AM	% V beat	PM	% V beat	AM	% V beat	PM	% V beat	AM	% V beat	PM	% V beat	AM	% V beat	PM	% V beat
5		29.9		29.5		32.3		31.2		31.5		32.0		33.5		33.3	
10	0- 10	30.0	.320	29.6	.277	32.2	.406	31.6	.608	31.8	.336	32.3	.465	33.5	.548	33.9	.872
		30.0		29.8				32.6		32.0		33.0		33.9		34.0	
20	10- 20	30.0	.307	29.7	.354	32.0	.319	31.9	.653	32.1	.408	33.0	.637	33.9	.564	34.1	.723
		29.9		29.8		31.8		31.9		32.0		33.3		34.0		34.0	
30	20- 30	29.7	.353	30.0	.385	31.7	.336	32.0	.540	32.0	.384	33.3	.604	34.0	.593	34.1	.758
		30.0		30.2		31.8		32.1		32.2		33.7		34.0		34.3	
40	30- 40	30.0	.288	30.5	.413	31.7	.418		.533	32.2	.377	33.8	.543	34.0	.587	34.3	.743
		29.8		30.9		31.9		32.1		32.4		33.5		34.0		34.1	
50	40- 50	29.8	.278	31.3	.448	31.9	.479	31.9	.473	32.1	.336	33.7	.519	34.0	.580	34.2	.776
		29.8		31.8		31.8		31.7		32.2		33.9		34.0		34.2	
60	50- 60	29.7	.267	31.9	.500	31.9	.400	31.8	.435	32.3	.396	34.0	.561	33.9	.574	34.1	.759
		29.6		32.3		31.9		31.9		32.4		33.9		33.9		34.1	
70	60- 70	29.6	.278	32.4	.528	31.8	.383	31.8	.522	32.3	.360	34.1	.557	33.9	.551	34.0	.667
		29.5		32.8		32.0		31.9		32.3		34.3		33.9		34.0	
80	70- 80	29.4	.266	32.8	.471	32.0	.423	31.9	.555	32.2	.364	34.0	.566	34.1	.555	34.1	.696
		29.6		32.8		31.9		31.7		32.1		34.1		34.0		34.1	
90	80- 90	29.4	.289	32.8	.448	31.9	.348	31.2	.548	32.2	.280	34.3	.587	34.0	.555	34.0	.704
		28.4		32.0		30.1		30.0		31.5		33.9		32.6		32.8	
100	90-100	28.2	.174	31.7	.356	29.4	.307	29.3	.473	31.0	.346	33.5	.470	32.5	.413	32.3	.551
		28.1		31.2		29.0		28.9		30.5		33.1		32.0		31.8	
110	100-110	28.0	.112	31.0	.292	28.9	.284	28.0	.323	30.1	.264	31.4	.347	31.9	.448	31.7	.449
		27.8		31.0		28.5		28.0		30.0		32.0		31.7		31.0	
120	110-120	27.8	.118	30.6	.244	28.2	.261	27.9	.272	30.0	.260	31.6	.411	31.7	.407	30.9	.375
		27.8		30.3		28.0		27.7		30.0		31.6		31.7		31.0	
130	120-130	27.7	.095	30.0	.220	28.0	.244	27.4	.284	29.7	.244	31.7	.279	31.0	.455	30.9	.467
		27.4		30.0		27.9		27.3		29.5		31.2		31.0		30.3	
140	130-140	27.0	.095	30.1	.211	27.5	.226	27.0	.278	29.8	.212	30.0	.282	30.8	.413	30.3	.382
		27.0		30.0		27.2		26.9		29.5		30.0		30.0		30.2	
150	140-150	27.0	.105	29.8	.185	27.2	.197	26.8	.263	29.0	.228	29.9	.312	29.9	.325	30.0	.406

TABLE IVa. Estimates of Average Time Constants for Toe, Finger, and Average Skin Temperature Changes.

Site	Estimated time constant ± S.E.	
Toe	13.84	±.34
Finger	4.85	
Avg skin	6.04	

TABLE IVb. Analysis of Variance of Time Constants.

	d.f.	Sum of squares	Mean square	
Subjects	3	1.091		
Time of day	1	.805	.805	F = 8.30
Error	3	.290	.097	
Sites	2	11.636	5.818	F = 27.53*
Sites × time of day	2	.763	.381	F = 1.80
Error	12	2.536	.2113	

* Site difference significant beyond the .1% level.

TABLE Va. Estimates of Average Time Constants for Toe and Finger Changes in Blood Flow.

Site	Estimated time constant ± S.E.	
Toe	1.51	±.28
Finger	1.98	

TABLE Vb. Analysis of Variance.

	d.f.	Mean square	
Subjects	3	.074	
Time of day	1	.043	F = 4.62
Error	3	.0093	
Sites	1	.0042	F = 1
Site × time of day	1	.0023	
Error	6	.0148	

there is a difference in the initial skin and rectal temperatures upon which the step change is imposed, secondly the pattern and extent of the change is similar and finally in the sitting position the toe response is different from that of finger and mean body skin.

Body heat content as reflected in rectal temperature and mean skin temperature increased during the period from morning to early afternoon. Average rectal temperature increased from 36.6°C to 37.1°C and mean skin temperature rose from 33.5°C to 33.9°C in the subjects tested. Approximating body heat content from the equation of $0.65\ T_b + 0.35\ T_s$ the change was 24 Kcal for a 70 Kg man. It is of interest to note that during a 3 to 4 hr test initiated at 6:30 A.M. the rectal temperature did not rise as would be anticipated but remained at the initial level. This effect of the experimental situation deserves further study.

The skin temperature from toe, finger, and the mean skin temperature were analyzed with the assumption of a "strength duration" relationship of the form $\Delta T = a/t + b$ where ΔT is change in surface temperature, t is time in minutes and a and b are constants. The model is not entirely adequate since there appears to be a tendency for step changes rather than smooth transition. This deviation is greatest in the morning experiments. Despite these deviations the model was effective for significant portions of the variation and its simplicity permits comparison of the rate of change by least squares estimates of the single parameter *a*.

Formally, the analysis of the time constant (a's) was regarded as a replicated experiment, with the subjects forming the replicates and with the main effects due to site (toe, finger, average skin) differences and time of day difference. ("Split plot" design). Differences among sites were highly significant; a major portion of the variance was due to the high value for the toe relative to finger and mean temperature. Estimates of the average time constants are given in Table IV and the analysis of variance is given in Table V.†

Under the conditions of the experiment the toe is operating separately from finger or other skin sites (Fig. 1).

Combination of the model discussed above

† Dr. Alan Ross, of Behavioral Analysis, made the statistical evaluation.

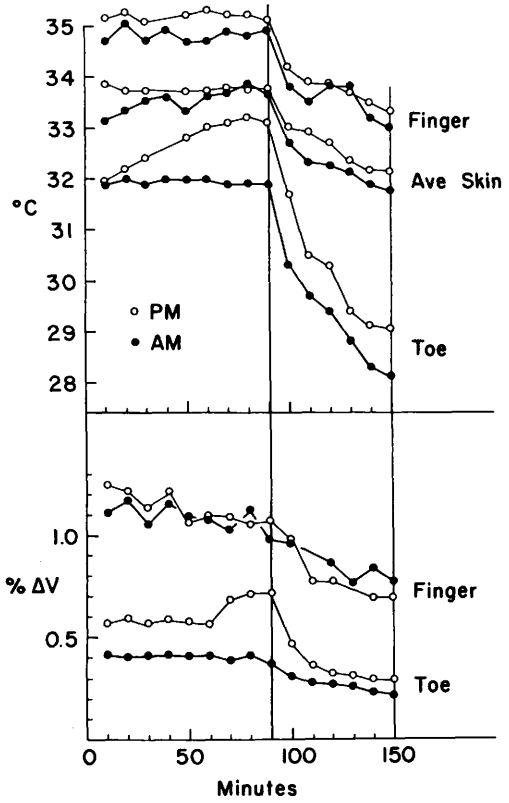

FIG. 1. Temperature and digital pulse during exposure at 30°C (first 90 minutes) and at 25°C (following 90 minutes). Open circles are data from afternoon experiments, closed circles are morning experiments.

with Newton's Law of cooling ($H = K(T_s - T_a)$ where H is the heat lost, T_s skin temperature and T_a the ambient temperature, the conclusion might be drawn that the shift in T_s should be the same as the shift in T_a (*i.e.* 5°C) since K should not change and H might be assumed to be constant. That this is not the case is readily apparent and since T_s does not change by 5°C, H must be altered by an internal mechanism.

When the finger blood flow, as indicated by the %ΔV/beat(4), is plotted against mean skin temperature the values show the tendency for the morning and afternoon values to be displaced, the afternoon values being higher. The slope however is not different. A similar plot for the toe blood flow suggests a slope change.

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Relationship of Interferon Production to Virus Growth *in vivo*. (29575)

SAMUEL BARON, HERMAN G. DU BUY, CHARLES E. BUCKLER AND MARTIN L. JOHNSON

U. S. Department of HEW, USPHS, Nat. Institutes of Health, National Institute of Allergy and Infectious Diseases, Laboratory of Biology Viruses, Bethesda, Md.

Interferon has been implicated as an important host factor which contributes towards recovery of animals from virus infection(1, 2). Early studies of interferon production in infected organs indicated a close correlation with virus growth(3,4,5). The present study was undertaken to compare the relationship of interferon production with virus growth during infection of mice with various viruses. The results indicate that interferon production may decline during the later stages of certain virus infections despite continued growth of virus.

Materials and methods. Interferon was assayed as described previously(6). It was characterized through its activity against heterologous virus, by: lack of activity in host cells from heterologous species, inactivation