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**U. S. ARMY
MEDICAL
RESEARCH &
NUTRITION
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**ENVIRONMENTAL TEMPERATURE
AND ENERGY EXPENDITURE**

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**UNITED STATES ARMY
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US ARMY MEDICAL RESEARCH AND NUTRITION LABORATORY
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Report No. 267

2 April 1962

Report of
ENVIRONMENTAL TEMPERATURE
AND ENERGY EXPENDITURE

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Report No. 267
Project No. 6X60-11-001
Nutrition
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ENVIRONMENTAL TEMPERATURE AND ENERGY EXPENDITURE

OBJECT:

The object of this study was to measure the metabolic rates of young men performing three levels of physical activity at three different environmental temperatures.

SUMMARY:

This study indicates that as the environmental temperature increases there is also an increase in metabolic rate of men performing a fixed activity. There was a significantly higher metabolic rate for men working at 100°F than at 85° and 70°F. Body temperatures also were significantly higher at 100°F than at 85° and 70°F environments.

These data again suggest that there is an increase in energy requirements for men living and working in the heat.

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ENVIRONMENTAL TEMPERATURE AND ENERGY EXPENDITURE

BACKGROUND

Recent work completed by this Laboratory shows that there is a definite increase in the energy requirements of men living and working in extreme heat (1, 2, 3). This increase is due primarily to the heat load imposed on the body by solar radiation and the extreme environmental heat. The increased energy expenditure is a result of the increased action of the blood in heat transport, increased action of the sweat glands, increased caloric loss due to sweat vaporization, and to increased body temperature (1).

Some of the main unanswered questions from these studies were whether the subjects were fully acclimated to the heat and whether the increase in energy requirements was due to insufficient training prior to the beginning of these experiments. In the present study the metabolic rate was measured under three strictly controlled levels of temperature and humidity, replicated 4 times in a random order. The plan would permit the calculation of a factor for the increased metabolic rate due to each 15°F increment in environmental temperature. Comparisons could be made between the rate of sweating and increased metabolic rate. Other measurements to be computed included nitrogen and water balance, diurnal changes in sweat rates, body weights and changes in body temperature.

EXPERIMENTAL DESIGN

This study was divided into three separate phases at temperatures of 70°, 85° and 100°F (21.2°, 29.4° and 37.7°C), each of 4 days' duration. Each phase was repeated 4 times randomly for a total of 48 days from July to September 1960. The test group consisted of 8 healthy men from the Metabolic Ward between the ages of 19 and 25. The men were exposed to the 3 temperatures for 7½ hours a day and were allowed to eat their noon meal outside the chamber each day. One man dropped out because of an accident so the final data cover only 7 men. The daily activity of the men during all the test periods was controlled at a constant level and measurement of the metabolic rates was performed at three activity levels:

- (a) Fairly heavy activity, Ergostat (bicycle ergometer), 50 minutes per day.
- (b) Moderate activity, Exercycle, 50 minutes per day.
- (c) Resting activity, lying down.

Once the men left the test area (evenings) no moderate or heavy type activities were permitted. A diary record of all after-hour activities was also maintained by each subject.

Experimental Procedures

All phases of this study were performed in the environmental chamber on the Metabolic Ward which was controlled as follows:

Phase A, average daily temperature 70°F with a 30% humidity.
 Phase B " " " 85°F " " "
 Phase C " " " 100°F " " "

Each phase was performed 4 times during the test for a total of 12 periods. These phases were randomly distributed as follows:

Period 1 Phase B	Period 2 Phase C	Period 3 Phase A
Period 4 Phase C	Period 5 Phase A	Period 6 Phase B
Period 7 Phase A	Period 8 Phase B	Period 9 Phase C
Period 10 Phase C	Period 11 Phase B	Period 12 Phase A

Food

The food menus were prepared by the dietitians on the Metabolic Ward and consisted of 4 daily menus that were rotated during the experiment. Food was issued and consumed at a constant daily level of 3283 Calories, including 93.3 gm of protein, 171.1 gm of fat, 328.7 gm of carbohydrate. All of the food was consumed daily and no extra food was permitted. One subject who was unable to consume this quantity of food offered, was placed on a constant intake of 2951 Calories per day. Cool distilled water (in a weighed plastic bottle) was supplied ad libitum for drinking purposes and the fluid intake was recorded for each man daily.

Triplicate composites of each of the 4 menus were taken and analyzed for nitrogen, fat, moisture, ash, and for total energy using bomb calorimetry.

Sweat

Sweat rates, including water from the skin and lungs were measured, using the method of Adolph, et al. ('47) (4). These were determined by measuring weight changes during the morning and afternoon periods. The differences in body weight were then corrected for water intake, urinary output and defecation. (Gaseous exchanges of respiration contribute a small quantity, which usually constitute less than 1% of the observed decrease in body weight.) Sweat samples during rest and exercise were collected in polyethylene bags that covered one whole arm for 3½ hours in the morning and 4 hours in the afternoon daily throughout the 3 phases.

The arm and bags were rinsed with distilled water and dried before each collection period began. The question that comes to mind is whether the arm sweat is representative of the sweat from the whole body. Mitchell, et al.(5) reports that the daily chloride and nitrogen in hand sweat represents reasonably, the concentration of the total body sweat. So one might assume that calcium may be in the same category.

Water Balance

In computing water balance for each subject, water gain and water loss from all sources were considered. Water gain can be determined from several factors, some that can be measured directly and others that can be calculated. The factors that may be measured directly are fluid water consumed, and water preformed in food. The factor that must be calculated is the water derived from the metabolism of foodstuffs and from the breakdown of tissue in the body. Metabolic water can be determined by using the factors of Newburgh, et al. ('45) (6) and assuming 100% oxidation of the ingested foodstuffs:

Protein	= 0.41 x gm protein
Carbohydrate	= 0.6 x gm carbohydrate
Fat	= 1.07 x gm fat

Water loss can be determined by weighing a man at the beginning and at the end of a specific period of time, and then considering the various losses during this period. They include the urinary output, total insensible water loss both from the lungs and the skin, water loss in the feces, and the water loss from the sweat as sensible perspiration. Insensible water loss and sweat cannot be separated easily.

Body Weights

Each subject was weighed daily in the morning before breakfast and after voiding. This was always done in the nude state, using the Plima balance, which is accurate to ± 10 grams. Other weighings for measuring sweat rates were performed before entering the environmental chamber at 8 a.m., before lunch at 11:30 a.m., after lunch at 12:30 p.m., and before the evening meal at 4:30 p.m.

Body Temperature

Rectal temperatures were taken at the end of each day's activity (4:30 p.m.) just before leaving the chamber.

Meteorological Data in the Chamber

Weather data was recorded daily at one hour intervals from 7:30 a.m. to 4:30 p.m. This data included temperature, relative humidity and barometric pressure.

Energy Expenditure

Energy expenditure was measured on all the designated activities every other day by means of indirect calorimetry using the Muller-Franz portable metabolimeter (Insull, et al. '53) (7). The energy cost of each activity

was measured after the subject had participated in the activity for 15 minutes. Aliquots of expired air were collected for a total of 10 minutes after the warm-up period during exercise and for 20 minutes during the resting period. On alternate days, metabolic rate samples were taken while the individuals were at rest, lying on the bed. The aliquots of expired air were analyzed for carbon dioxide and oxygen by means of the Haldane and Beckman gas analyzers, respectively. Evening activities were recorded by diary and used for the determination of total daily energy expenditure. Metabolic rates were also measured and recorded directly on a continuous carbon dioxide and oxygen analyzer for comparative purposes.

Urine and Fecal Collection

Urines were collected on a 24-hour basis on each of the 8 men. At the end of each day the volumes were measured, the specific gravity recorded and a 10% aliquot saved, which was pooled at the end of each period for each man. Urine aliquots for each period were analyzed for moisture, ash and nitrogen.

Fecal collections were also made by periods. At the beginning of each period, carmine and charcoal were alternately consumed by each of the test subjects. The sample collection for the period began at the first appearance of the carmine or charcoal in the stool. The stools were collected in plastic buckets, and immediately frozen. At the end of each period, the combined samples of each man were weighed and recorded. Each sample was then diluted with 500 gm of distilled water, homogenized in a blender and two aliquots saved (in 8 oz. bottles) for the subsequent chemical analysis of moisture, ash, fat, nitrogen, and total energy.

RESULTS

The average daily temperature for each 4-day testing period is presented in Table I. With the exception of the first period, most of the temperatures were in the designated temperature range assigned to each period. This was also true for the average relative humidity which stayed fairly close to 30% after the first period (Table II).

The body weight changes were slight for all periods, never changing more than 100 gm/man/day for each of the three phases. The body weight changes for all of the 12 days at each temperature, averaged a +9.2 gm/day for the 100°F, +71 gm/day for the 85°F and -30 gm/day for the 70°F periods (Table III).

Body temperatures, taken at the end of each work day, were significantly higher during the 100°F phase than during the 85° and 70°F test periods (Table IV).

Energy expenditure values for the light, moderate and heavy activities, performed by each man during each period and a summary are presented in Tables V to VIII. Energy expenditures averaged 0.304, 0.282 and 0.273 liters of oxygen used/minute for the low activity, 0.590, 0.525 and 0.521

for the moderate work, and 1.570, 1.404 and 1.422 liters/minute of oxygen used for the heavy work, for the 100°, 85° and 70°F test periods, respectively. Values for the 100°F phase are significantly higher than those for the 85° and 70°F phases.

The chemical composition of the 4 menus is shown in Table IX. The food issued each man daily averaged 3280 Calories, with 93.3 gm of protein, 177.1 gm of fat and 328.7 gm of carbohydrate. Six of the subjects consumed all the food offered daily but subject C, a small young man, could consume only 2957 Calories/day.

Table X shows the sweat rates during the three test phases. They averaged 2248, 1298 and 708 gm/day for the 100°, 85° and 70°F periods.

The water balance for each period is presented in Table XI. The mean balance averaged +114 gm for the 100°F, 59 gm for the 85°F and 32 gm/man/day for the 70°F periods.

DISCUSSION

A recent study (1) by this Laboratory suggested that an increase in metabolic rate was one of the factors related to increased energy requirements of men working and living in the heat. This suggested a reevaluation of the recommendations of the National Research Council's Food and Nutrition Board (8), and the United Nations' Food and Agriculture Organization (9), that there is a decrease of energy requirements in the heat. These organizations recommended a 5% decrease in requirements for every 10°C increase in environmental temperature. Since this has been a very controversial subject it seemed desirable to perform another study designed to rule out the effects, if any, of acclimatization to the heat and the effects of training on the metabolic rate.

In the present study a significant increase in metabolic rate in the heat was observed in the three activities studied. The energy expenditure at 100°F was significantly higher than in the 85°F phase for all three levels of activity. It is of interest to note that for each man the average at 100°F was higher than his average at 85°F. This consistency of results may be of biological interest because it showed up even though there was a considerable variation among the men at a common temperature and activity level. It had been our original concept that the metabolic rate gradually increased in environmental temperatures above 70°F but no significant difference was observed in metabolic rates between the 70° and 85°F temperatures. This means that the significant threshold increase in metabolic rate must occur in temperatures above 85°F.

Increases in metabolic rate averaged 11.4% for the light, 13.3% for the moderate and 11.7% for the heavier activity. It is felt that these results are very important since they have shown that neither acclimatization nor training were factors for the increased metabolism and subsequent energy requirements in the heat. These values are in agreement

with Consolazio, et al. (1), Welch, et al. (10) and Shapiro, et al. (11) who also observed increases in metabolic rates of humans in the heat. Herrington (12) working with small animals has also observed increases in metabolic rates in the heat.

The average increase in body temperature of 0.5°F at 100°F was significant even though it may seem low. Work by Eichna, et al. (13) and Christensen (14) have shown that there is an approximate increase of 11.6% in the metabolic rate for every degree centigrade rise in body temperature. On this basis, the increase in body temperature observed in this study could account for only about half of the metabolic rate increase. Other factors such as increased action of the blood in heat transport and increased actions of the sweat glands might account for much of the rest of the increase.

Sweat rates averaged 708, 1298 and 2248 gm/day for the cool to hot periods, which was equivalent to approximately 51 gm of sweat for each 1°F increment of environmental temperature. The sweat rates comparing the 4 periods for any given temperature (Table X), decreased during the course of the experiment which is in agreement with Mitchell, et al. (5)

Water balance changes showed an increase in fluid retention with an increase in environmental temperature, from +32 gm at 70°F to 113 gm at 100°F. This means that the men lost more weight (fat, protein) during the hot periods at 100°F than at 70°F on the same constant daily intake.

The findings of this study indicate that the metabolic rate of a designated physical activity is increased in the heat and that this increase is not due to the fact that the men were not acclimated, or that the men were not in training. This in turn suggests that the increased metabolism leads to an increase in energy requirements of men living and working in the heat. In the light of this study and that of Consolazio, et al. (1) it is again suggested that the recommendation for decreased dietary allowances in heat, made by the Food and Nutrition Board of the National Research Council and the Food and Agriculture Organization of the United Nations be reevaluated.

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LITERATURE CITED

1. Consolazio, C. F., Shapiro, R., Masterson, J. E. and McKinzie, P. S. L.: Energy Requirements of Men in Extreme Heat. *J. Nutrition* 73:2, February 1961.
2. Consolazio, C. F., Konishi, F., Ciccolini, R. V., Jamison, J. M., Sheehan, C. F. and Steffen, W. F.: Food Consumption of Military Personnel Performing Light Activities in a Hot Desert Environment. *Metabolism* 9:5, May 1960.
3. Shapiro, R. and Consolazio, C. F.: Energy Requirements of Men Exposed to Solar Radiation and Heat. USAMRNL Report No. 240, July 1959.
4. Adolph, E. F. and Associates: *Physiology of Man in the Desert*. Interscience Publishers, Inc., New York, 1947.
5. Mitchell, H. H. and Hamilton, T. S.: The Dermal Excretion Under Controlled Environmental Conditions of Nitrogen and Minerals in Human Subjects, with Particular Reference to Calcium and Iron. *J. Biol. Chem.* 178: 345-361, 1949.
6. Newburgh, C. H., Johnston, M. W. and Newburgh, J. D.: *Some Fundamental Principles of Metabolism*. Lithoprinted by Edwards Brothers, Inc., Ann Arbor, Michigan, 1945.
7. Insull, W. Jr.: Indirect Calorimetry by New Technique. A Description and Evaluation. USAMRNL Report No. 146, December 1954.
8. National Research Council: *Recommended Dietary Allowances*. Revised 1958. Publication 589, Washington, D. C., 1958.
9. Food and Agriculture Organization of the United Nations: *Calorie Requirements*. No. 15, Rome, Italy, 1957.
10. Welch, B. E., Buskirk, E. R. and Iampietro, P. F.: The Relation of Climate and Temperature to Food and Water Intake in Man. *Metabolism* 7: 141, 1958.
11. Shapiro, R. and Consolazio, C. F.: Energy Requirements of Men Exposed to Solar Radiation and Heat. *Fed. Proc.* 18: 546, 1959.
12. Herrington, L. P.: Heat Regulation of Small Laboratory Animals at Various Environmental Temperatures. *Am. J. Physiol.* 129: 123, 1940.
13. Eichna, L. W., Park, C. R., Nelson, N., Horvath, S. M. and Palmes, E. D.: Thermal Regulation During Acclimatization in a Hot, Dry (Desert Type) Environment. *Am. J. Physiol.* 163: 585-597, 1950.
14. Christensen, E. H.: *The Physiology of Severe Muscular Work*. IX. Hyperthermy and Rest Metabolism. *Arbeits.* 7: 120-126, 1933.

TABLE I

Mean Daily Temperatures of Experimental Chamber, in °F

Periods	1	2	3	4	5	6	7	8	9	10	11	12
Day 1	86.1	97.5	70.4	100.5	70.3	84.8	69.4	85.8	100.0	99.9	83.6	69.6
2	88.9	99.2	71.1	100.0	70.0	84.9	69.9	85.2	100.1	100.4	84.9	68.8
3	89.3	98.7	70.5	100.1	69.6	84.9	70.9	84.8	100.0	100.0	84.6	70.8
4	89.5	100.4	70.4	100.1	70.2	85.1	70.7	86.5	99.4	95.5	84.6	71.8

TABLE II

Mean Daily Relative Humidity, %

Periods	1	2	3	4	5	6	7	8	9	10	11	12
Day 1	-	29.5	29.4	29.4	29.5	29.8	29.0	30.5	33.4	29.9	29.4	31.0
2	16.0	27.0	29.6	27.9	28.5	28.6	29.0	30.3	33.8	30.1	31.2	31.7
3	28.3	27.0	29.5	28.6	29.0	28.0	28.8	29.3	32.9	30.3	31.0	29.0
4	29.3	28.6	29.0	30.5	26.2	31.0	29.3	30.9	25.3	31.2	31.3	29.4

TABLE III

Body Weight Changes in kg/Period

Subj	Initial Weight	Periods												
		1	2	3	4	5	6	7	8	9	10	11	12	
	Phase	B	C	A	C	A	B	A	B	C	C	C	B	A
A	98.20	-0.42	-0.39	+0.20	+0.14	-0.34	+0.51	-0.23	+0.20	-0.64	+0.18	-0.92	-0.92	9.00
B	71.78	+0.48	-0.25	+0.21	-0.01	-0.37	+0.17	-0.25	+0.41	-0.36	-0.66	-0.28	-0.28	+0.38
C	55.36	+0.82	-0.36	-0.82	+0.67	-0.57	+0.37	-0.32	+0.30	+0.04	-0.09	-0.18	-0.18	+0.28
D	62.33	+0.38	+0.18	+0.39	+0.21	-0.09	+0.46	+0.55	+0.45	-0.29	+0.58	+0.05	+0.05	-0.05
F	76.57	+0.01	+0.44	-0.68	0.00	-0.23	-0.01	-0.14	-0.36	+0.28	+0.06	-	-	-0.20
G	72.95	+0.22	-0.07	-0.06	+0.87	-0.10	+0.96	-0.33	+0.30	0.00	-0.42	-0.90	-0.90	+0.09
H	77.51	+1.00	-0.33	+1.00	+0.50	+0.41	+0.38	-0.95	+1.40	+0.79	-0.53	+0.07	+0.07	-0.23
Mean	73.23	+0.36	+0.03	-0.05	+0.38	-0.15	+0.41	-0.24	+0.39	+0.08	-0.13	-0.31	-0.31	+0.04

TABLE IV

Average Body Temperatures At Various
Environmental Temperatures, In °F

100°	99.6°*
85°	99.1°
70°	99.1°

* Significantly higher than body
temperatures at 85° or 70°F.
(P < .005)

TABLE V

Mean Energy Expenditure During Light ActivityIn Room Temperatures of 70°, 85° and 100°F*

(Liters of Oxygen Used/Minute)

~~PERIODS~~

Temp.	100°F	70°F	85°F	70°F	85°F	100°F	100°F	70°F	85°F
Subj A	0.349	0.305	0.350	0.277	0.280	0.357	0.326	0.256	0.308
B	0.274	0.270	0.256	0.260	0.324	0.279	0.276	0.310	0.210
C	0.274	0.250	0.235	0.263	0.257	0.245	0.260	0.195	0.199
D	0.242	0.290	0.260	0.275	0.280	0.343	0.287	0.243	0.295
F	0.311	0.320	0.335	0.293	0.322	0.407	0.282	0.274	0.309
G	0.276	0.290	0.310	0.286	0.250	0.294	0.330	0.313	0.269
H	<u>0.325</u>	<u>0.240</u>	<u>0.295</u>	<u>0.255</u>	<u>0.295</u>	<u>0.318</u>	<u>0.322</u>	<u>0.276</u>	<u>0.295</u>
Mean	0.293	0.281	0.291	0.273	0.288	0.320	0.293	0.267	0.271

* Each temperature period is listed in the order that the men experienced them. Periods 1, 2 and 3 not shown, were training periods, so no metabolic rates were collected.

TABLE VI

Mean Energy Expenditure During Heavy ActivityIn Room Temperatures of 70°, 85° and 100°F*

(Liters of Oxygen Used/Minute)

PERIODS

Temp.	100°F	70°F	85°F	70°F	85°F	100°F	100°F	70°F	85°F
Subj A	1.728	1.665	1.545	1.415	1.657	2.091	1.687	1.784	1.837
B	1.819	1.530	1.400	1.370	1.510	1.771	1.761	1.558	1.622
C	1.266	1.167	1.010	1.102	1.060	1.445	1.292	1.088	1.035
D	1.526	1.430	1.573	1.980	1.770	1.337	1.521	1.540	1.378
F	1.567	1.300	1.435	1.240	1.644	1.874	1.675	1.602	1.658
G	1.506	1.430	1.200	1.390	1.440	1.712	1.540	1.307	1.353
H	<u>1.427</u>	<u>1.366</u>	<u>1.318</u>	<u>1.350</u>	<u>0.934</u>	<u>1.071</u>	<u>1.355</u>	<u>1.252</u>	<u>1.095</u>
Mean	1.548	1.413	1.355	1.407	1.431	1.613	1.547	1.447	1.418

* Each temperature period is listed in the order that the men experienced them. Periods 1, 2 and 3 not shown, were training periods, so no metabolic rates were collected.

TABLE VII

Mean Energy Expenditure During Moderate ActivityIn Room Temperatures of 70°, 85° and 100°F*

(Liters of Oxygen Used/Minute)

PERIODS

Temp.	100°F	70°F	85°F	70°F	85°F	100°F	100°F	70°F	85°F
Subj A	0.793	0.590	0.780	0.760	0.668	0.735	0.734	0.672	0.625
B	0.685	0.436	0.590	0.460	0.535	0.633	0.554	0.518	0.563
C	0.560	0.383	0.430	0.473	0.335	0.361	0.415	0.358	0.403
D	0.500	0.510	0.400	0.460	0.477	0.731	0.454	0.334	0.421
F	0.758	0.641	0.610	0.593	0.652	0.557	0.732	0.561	0.528
G	0.570	0.703	0.570	0.673	0.540	0.648	0.458	0.360	0.482
H	<u>0.510</u>	<u>0.505</u>	<u>0.420</u>	<u>0.550</u>	<u>-</u>	<u>0.497</u>	<u>0.507</u>	<u>0.397</u>	<u>0.519</u>
Mean	0.625	0.538	0.543	0.567	0.534	0.595	0.551	0.457	0.506

* Each temperature period is listed in the order that the men experienced them. Periods 1, 2 and 3 not shown, were training periods, so no metabolic rates were collected.

TABLE VIII

Summary of Mean Energy Expenditure During Light, Moderate
And Heavy Activity At Temperatures of 70°, 85° and 100°F
(Liters of Oxygen Used/Minute)

Temp.	Light Activity			Moderate Activity			Heavy Activity		
	100°F	85°F	70°F	100°F	85°F	70°F	100°F	85°F	70°F
Subj A	0.344	0.313	0.279	0.754	0.691	0.674	1.835	1.680	1.621
B	0.276	0.263	0.280	0.624	0.563	0.471	1.784	1.511	1.486
C	0.260	0.230	0.236	0.445	0.389	0.405	1.334	1.035	1.119
D	0.291	0.278	0.269	0.562	0.433	0.435	1.461	1.574	1.650
F	0.333	0.322	0.296	0.682	0.597	0.598	1.705	1.579	1.381
G	0.300	0.276	0.296	0.559	0.531	0.579	1.586	1.331	1.376
H	<u>0.322</u>	<u>0.295</u>	<u>0.257</u>	<u>0.505</u>	<u>0.470</u>	<u>0.484</u>	<u>1.284</u>	<u>1.116</u>	<u>1.323</u>
Mean	0.304	0.282	0.273	0.590	0.525	0.521	1.570	1.404	1.422

TABLE IX

Composition of Average Daily Food Intake, By Menus*Analysis of the Menus

(Food Consumed/Man/Day*)

Menu	Calories	Protein gm	Fat gm	Carbohydrate gm	Water gm
1	3122	93.2	168.0	309.0	1656
2	3316	92.3	187.3	314.9	1592
3	3377	83.5	182.3	350.2	1460
4	<u>3318</u>	<u>104.3</u>	<u>170.8</u>	<u>340.7</u>	<u>1695</u>
Mean	3283	93.3	177.1	328.7	1601

* One subject, a very small man, consumed 332 Calories/day less than the other men.

TABLE X

Average Daily Sweat Rates By Room
Temperature and Period*
(In gm/Man)

PERIODS**	70°F	85°F	100°F
Period I	710	1513	2368
Period II	826	1372	2443
Period III	687	1180	2040
Period IV	<u>609</u>	<u>1026</u>	<u>2140</u>
Mean	708	1298	2248

* Sweat produced during the 7½ hours in the environmental chamber each day.

** These periods refer to the 1st, 2nd, 3rd and 4th time each man experienced a given temperature.

TABLE XI

Average Daily Fluid Intake, Output,
And Balance, By Periods
(In grams)

	Periods												
	1	2	3	4	5	6	7	8	9	10	11	12	
<u>Intake</u>													
Fluid Intake	1606	2208	997	2285	805	1371	815	1272	2140	2145	1034	562	
Fluid in Food	1578	1578	1578	1578	1578	1578	1578	1578	1578	1578	1578	1578	
Water of Oxidation	<u>421</u>	<u>421</u>	<u>421</u>	<u>421</u>	<u>421</u>	<u>421</u>	<u>421</u>	<u>421</u>	<u>421</u>	<u>421</u>	<u>421</u>	<u>421</u>	
Total	3605	4207	2996	4284	2804	3370	2814	3271	3139	4244	3033	2561	
<u>Output</u>													
Urinary Output	813	782	1133	872	1191	928	1128	1118	918	915	1022	1143	
Fecal Water	83	87	89	60	92	82	94	109	91	95	82	82	
Sweat, Insensible Water Loss*	<u>2473</u>	<u>3228</u>	<u>1570</u>	<u>3303</u>	<u>1686</u>	<u>2232</u>	<u>1547</u>	<u>2040</u>	<u>2900</u>	<u>3000</u>	<u>1886</u>	<u>1469</u>	
Total	3369	4097	2792	4235	2969	3242	2769	3267	3089	4010	2990	2694	
Balance	+236	-110	+204	+49	-165	+128	+45	+4	+50	+134	+43	-133	

* Constant values for insensible water loss assumed for all periods.

Mean weight change, 100°F - +113 gm
 " " 85°F - +59 gm
 " " 70°F - +32 gm

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