R57-17

Variations in Resting Metabolism with Changes in Food, Exercise and Climate

By E. R. Buskirk, P. F. Iampietro and B. E. Welch

Reprinted from Metabolism
Vol. VI, No. 2, March, 1957
Printed in U.S.A.

Reprinted from METABOLISM
Vol. VI, No. 2, March, 1957
Printed in U.S.A.

Variations in Resting Metabolism with Changes in Food, Exercise and Climate

By E. R. BUSKIRK, P. F. IAMPIETRO AND B. E. WELCH

WHAT changes in metabolic pattern occur during the day when food and exercise are taken as usual? How do variations in food intake and exercise alter this metabolic pattern? Does climate have an impact on this pattern? The present study was designed to furnish information to answer these and related questions as part of a continuing effort to establish meaningful caloric recommendations for men stationed in various climates.

Numerous studies have been conducted in an effort to clarify the impact of climate *per se* on basal metabolic rate.[1-4] Such impact has not been clearly established although a correction has been frequently made for temperature.[1] Temperature corrections have also been applied in establishing daily caloric recommendations.[5,6] The basal metabolic rate (BMR) applies to a narrow range of time under post-prandial conditions. Since these conditions do not accurately reflect metabolic events during the day, it was decided to compare resting metabolism of soldiers living in different climates at specific times during the day. It was conceivable that the extra work performed in the arctic to travel a given distance and the resultant higher caloric intake would elevate man's resting metabolism at other hours of the day more in the arctic than in other climates. If this occurred the relationship previously reported between caloric intake and mean daily outdoor temperature would be explained in part.

Food intake has been shown to vary between climates and may in itself alter the caloric requirement. Specific dynamic action (SDA) is known to elevate metabolic rate.[7] A correction is frequently made for SDA, of approximately 6 to 10 per cent of the ingested calories, when daily energy expenditure is calculated.[8-10] This figure has been established largely on the basis of results from single meal experiment.[11, 12] If the SDA effect is cumulative with regular meals, it is possible that 6 to 10 per cent is too low an estimate. In addition, a small diurnal metabolic cycle may occur independent of food and exercise[13] which would influence the magnitude of the SDA elevation.

MATERIALS AND METHODS

The experiment can be divided into three phases: 1. study of factors associated with an elevation in metabolic rate during the day, 2. study of specific dynamic action (SDA) during the periods between regular meals and 3. study of the impact of environment on the daily pattern of metabolism when regular meals were eaten and moderate exercise was performed between meals.

Oxygen consumption ($\dot{V}_{O_2}$) was measured with a closed system. Duplicate determinations were made when possible. The subjects rested quietly in bed for 30 to 40 minutes before each measurement. They wore only underwear and used a blanket only when necessary for thermal comfort. All records were analyzed by the same individuals in order to

From the Quartermaster Research and Development Command, Natick, Massachusetts, and Medical Nutrition Laboratory, Denver, Colorado.

TABLE 1.—*Daily Schedule*

Reveille	In Bed	Determination	Meals	Activity
0645 (urinate and weighed)	0700	0740	0800	0830
	1120	1200	1220	1250
	1540	1620	1640	
	2000	2040		
	2300			

avoid personnel differences in methods of analysis. Each test subject was given at least ten practice trials in order to minimize training effects.

Body weights were measured each morning. The subjects arose, voided, were weighed on scales sensitive to 30 Gm. and then returned to bed.

In each study the men subsisted on Army 5-in-1 rations. Although the caloric intake varied with different climates (3,000–3,600 kcal./man/day), no difference was apparent when caloric intake was calculated as kcal./Kg./day. Meal patterns were also similar in the various climates. Eighty per cent of the daily calories were taken at breakfast and supper. Lunch was always light (600 kcal.). A daily schedule of meal times, activities and times of measurement is given in table 1.

Phase I. The effect of exercise and food on resting metabolism. This experiment was conducted at Mt. Washington, New Hampshire, on eight men during December 1954. The daily schedule of activities and diet was arranged so that each man was exposed to a combination of exercise or no exercise, and food or no food in a random order. On days of no exercise the men reclined in bed all day.

Phase II. Specific dynamic action of food. A group of three men was studied at Mt. Washington during December 1954. Measurements were made at 20 minute intervals on these men for approximately 13 hours during the day (0740 to 2040 hours). They were confined to bed at all times and sat up only to eat meals or void.

Phase III. The impact of environment of basal metabolic rate and resting metabolism during the day. Three groups of eight men each were studied in three environments. One group was studied at Ft. Churchill, Canada, during January 1955. The second group was studied at Yuma, Arizona during July 1955 and the third group was studied at Natick, Massachusetts during September 1955. Some characteristics of each man are shown in table 2. The weather data for the three environments (and Mt. Washington, N. H.) are shown in table 3. Each group lived in a given climate for at least one month. Outdoor activities consisted on walking 9 to 10 miles each day over the surrounding terrain. Standard army issue clothing for the particular environment was worn.

Phase I. Resting $\dot{V}_{O_2}$ throughout the day is shown as the curve labeled "eat, exercise" in figure 1. The 0800 hours (prebreakfast) determination was accomplished under "basal" conditions and was consistently lower than the $\dot{V}_{O_2}$ for any later hour. The values for 1200 (prelunch) and 1600 (presupper) hours were significantly different from each other and from the 0800 value. The 2000 hours (postsupper) value was consistently higher than for any earlier hour. Thus, a continual and gradual elevation in metabolism occurred throughout the day when measurements were made at four hour intervals.

To evaluate the effect of food intake and/or exercise on the change in metabolism during the day, a latin square design was used with exercise, no exercise, food as normal, and fasting as the variables. The data are shown in figure 1; all possible combinations are plotted for ease of interpretation. There was a small elevation in $\dot{V}_{O_2}$ which was independent of food and exercise. Taking food definitely increased the metabolic rate, not only above the basal level, but also

TABLE 2.—*Characteristics of Test Subjects on First Day Studied*

No.	Age* (years)	Height (cm.)	Weight (Kg.)	Surface Area (M.²)	BMR†
(Fort Churchill)					
1	21	173.5	76.0	1.94	−18
2	22	168.0	66.4	1.77	−5
3	22	171.8	77.3	1.93	+3
4	20	171.4	69.8	1.83	−18
5	19	172.6	64.1	1.76	−9
6	21	171.7	73.2	1.87	−15
7	19	171.6	86.4	2.01	−15
8	22	180.3	84.4	2.05	−18
$\bar{x}$	21	172.6	74.7	1.89	−12
(Natick)					
1	20	170.2	55.7	1.63	−7
2	17	167.6	59.7	1.68	−10
3	19	177.8	63.4	1.78	−10
4	22	166.4	63.2	1.71	0
5	20	172.7	59.8	1.70	−12
6	23	170.2	64.1	1.78	−14
7	19	170.2	61.5	1.71	−11
8	24	175.3	46.9	1.55	−10
$\bar{x}$	20	171.3	59.2	1.69	−9
(Yuma)					
1	20	170.2	62.6	1.74	−6
2	19	170.2	52.2	1.60	+1
3	20	175.3	62.4	1.76	−9
4	20	180.3	69.9	1.90	−22
5	19	172.7	63.7	1.77	−7
6	17	167.6	60.0	1.68	−13
7	23	170.2	58.3	1.78	−10
8	20	177.8	77.0	1.96	−9
$\bar{x}$	20	173.0	63.3	1.77	−9
(Mt. Washington)					
1	22	168.2	70.7	1.83	+4
2	18	178.8	70.6	1.87	−3
3	26	171.0	48.3	1.55	−9
4	19	169.5	61.1	1.70	−5
5	18	178.8	73.7	1.91	−6
6	18	181.0	81.0	2.00	−8
7	24	167.5	65.7	1.73	−12
8	20	186.0	89.1	2.13	−14
$\bar{x}$	20	175.1	70.0	1.84	−7

* Age to nearest birthday.
† % deviation from standards in Sanborn Manual.

above the small elevation associated with fasting. Moderate exercise (a 4.5 to 5 mile walk or sled-pull per exercise period) appeared to produce no additional elevation.

Planimetric measurement of the curves in figure 1 showed that the total area under the "eat, exercise" curve was 20 per cent greater than the total area under the "fast, exercise" curve. A similar difference between eating and fasting was found when exercise was not performed. A difference in area of 20 per cent means a $\dot{V}_{O_2}$ of approximately 2.5 cc./Kg.$^{0.7}$/min. or 50 cc./min.

TABLE 3.—*Weather Data*

Site	Outdoor Ambient Temperature, °C. (°F.)	Room Temperature, °C. (°F.)	Relative Humidity, %	Winchill, kcal./M.²/hr.
Ft. Churchill	−25(−15)*	22(71)*	40*	1000*
	−16(−13) to −38(−36)†	15(59) to 25(77)†	25 to 60†	
Yuma	34(94)	34(94)(Tent)	39	—
	27(81) to 43(110)	27(81) to 43(110)	18 to 81	
Natick	22(72)	22(72)	70	—
	18(65) to 27(81)	18(65) to 27(81)	46 to 95	
Mt. Washington	−4(25)	23(74)	45	—
	−4(25) to 4(40)	20(68) to 31(88)	30 to 70	

* Mean.
† Range.

The effect of exercise was negligible. When the men ate and exercised there was no difference in area as compared to eating with no exercise. The same was true when the men were fasting. Since the values obtained for resting metabolism can be considered to be on a daily curve of specific dynamic action (SDA), the percentages given above are unrealistic because they do not represent the "true" difference in metabolic rate but only a minimal difference. The peak portions of the SDA curves were not included in estimation of the percentage difference in area.

Phase II. To obtain information concerning the "true" difference, three men were studied while resting quietly in bed under both fasting and nonfasting conditions. $\dot{V}_{O_2}$ was measured every 20 minutes from 0740 until 2040 hours. The respective curves for each man are shown in figure 2. A distinct elevation in $\dot{V}_{O_2}$ occurred after each meal, while transient changes and perhaps a slight overall elevation occurred on those days when food was not taken. These changes were within the error of measurement.

Two baselines may be used to evaluate SDA. The first is the basal metabolic rate, which is the base most commonly used. The second is the curve in metabolism which is independent of food intake and exercise. The results, while not conclusive, suggest that a fasting pattern may exist. (fig 1).

The elevation in metabolism was calculated using both baselines. When basal $\dot{V}_{O_2}$ was used, the elevation in metabolism for the 12 hour experimental period averaged 88 cc. O_2/min. or 38 per cent above the basal $\dot{V}_{O_2}$. When the fasting curve of $\dot{V}_{O_2}$ was subtracted from the SDA curve the mean difference was 51 cc. O_2/min. or 22 per cent above the mean fasting $\dot{V}_{O_2}$. The magnitude of these differences over a 12 hour period was not large. When the caloric expenditure was computed for the 12 hour period, it was found that the basal expenditure was 718 kcal./man/12 hours and the average basal plus fasting plus SDA was 999 kcal./man/12 hours. In our men, who consumed approximately 3,200 kcal./day, the difference, 281 kcal./12 hours, amounted to 8.8 per cent of the daily caloric intake. There is evidence that SDA continues for longer than four hours after a meal.[11] The last measurement of $\dot{V}_{O_2}$ in the evening was never later than five hours after the meal. Thus, our results are in agreement with the commonly used value for elevation of metabolism due to SDA (10 per cent).

Considerable variability is shown among the patterns for the three individuals,

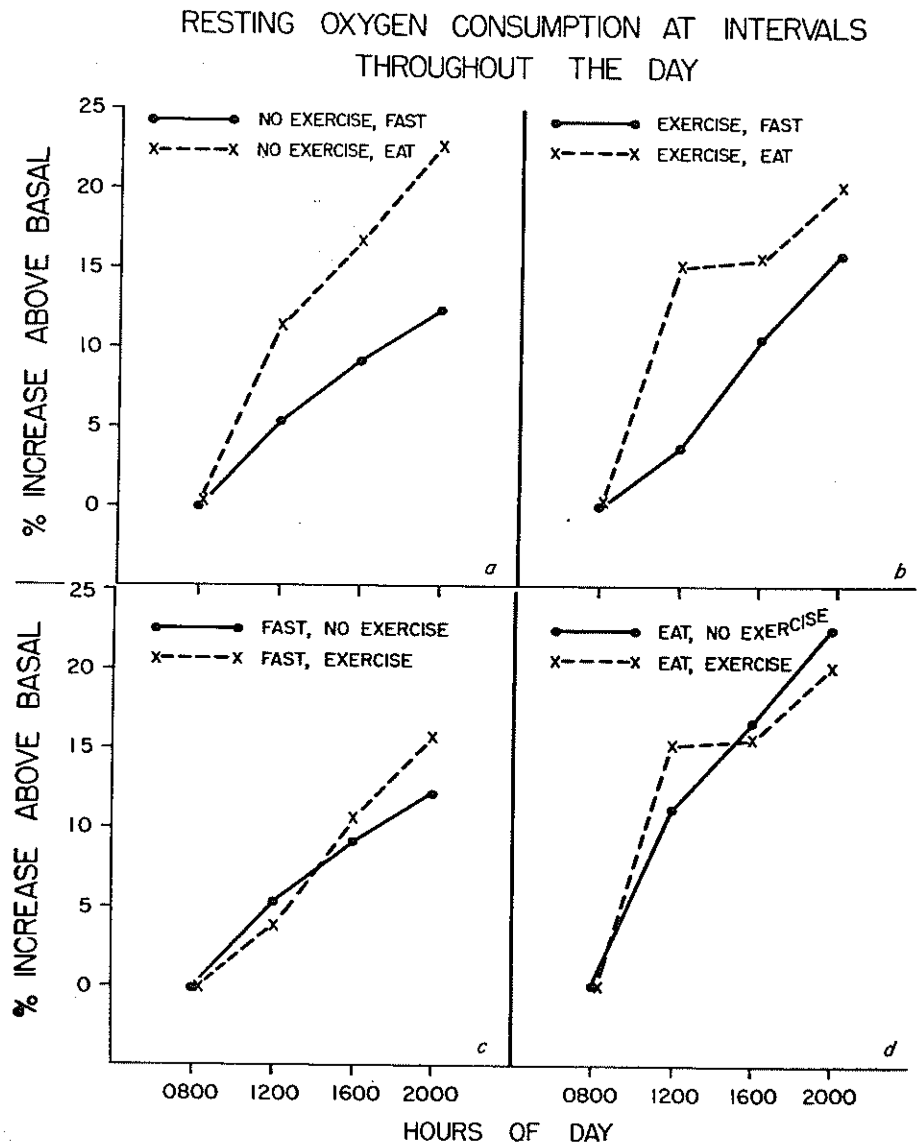

FIG. 1.—Resting oxygen consumption ($\dot{V}_{O_2}$) at intervals throughout the day.

although the peak metabolic rate usually occurred within one hour after the meal was eaten (fig. 2). The fluctuations in the fasting curves of subjects Cla and Tom were relatively large. A clear-cut fasting pattern was not apparent in these individuals. In regard to this variability, analysis of all duplicate determinations in phases I and II of the study yielded a mean difference of 4.8 per cent of the mean daily $\dot{V}_{O_2}$. At least 95 per cent of the differences between two observations would be less than 27.6 cc. O_2/min. This statement can be made with 95 per cent confidence. Following the peak, metabolic rate decreased in a variable manner. An average curve for the three men followed the equation for a sigmoid curve

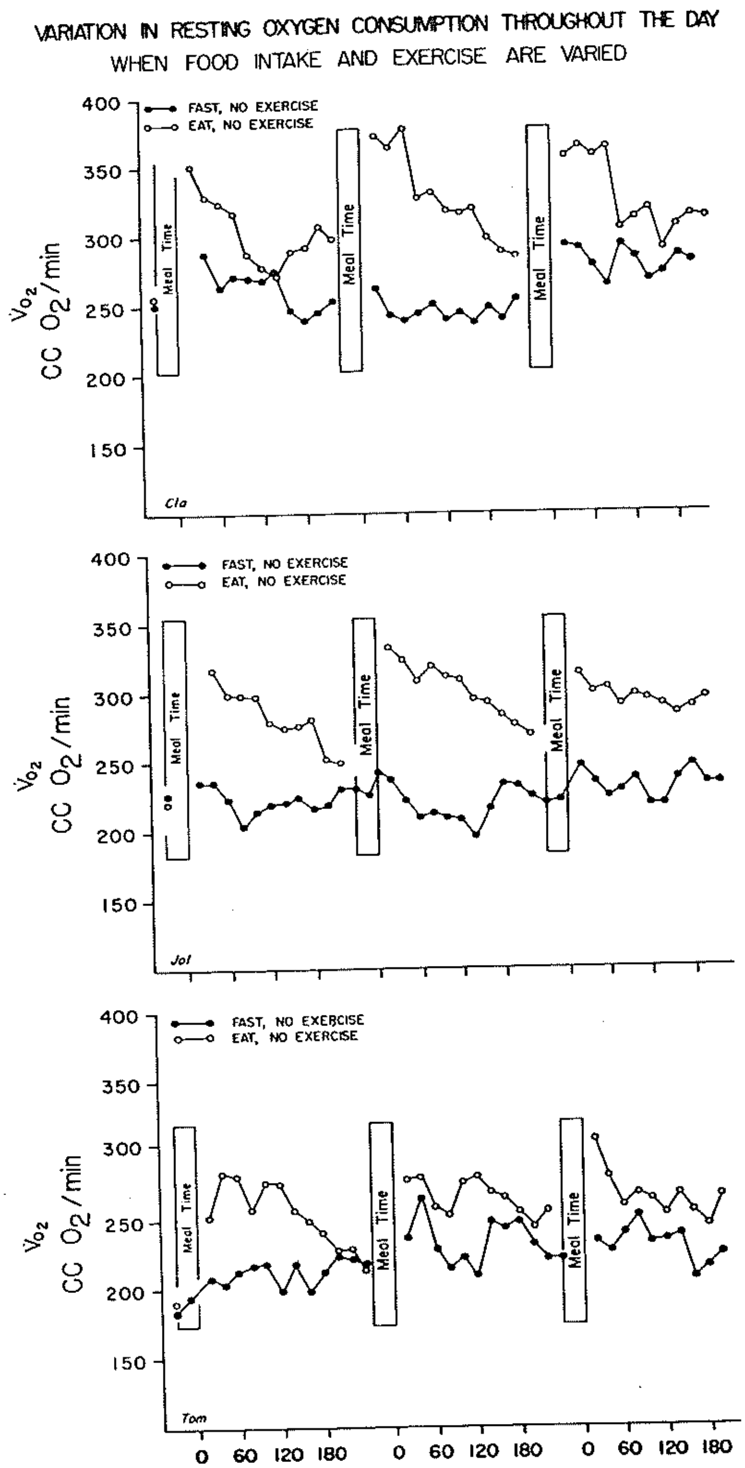

FIG. 2.—Variation in resting oxygen consumption ($\dot{V}_{O_2}$) throughout the day when food intake and exercise are varied. Abscissa—Time in min. after meal.

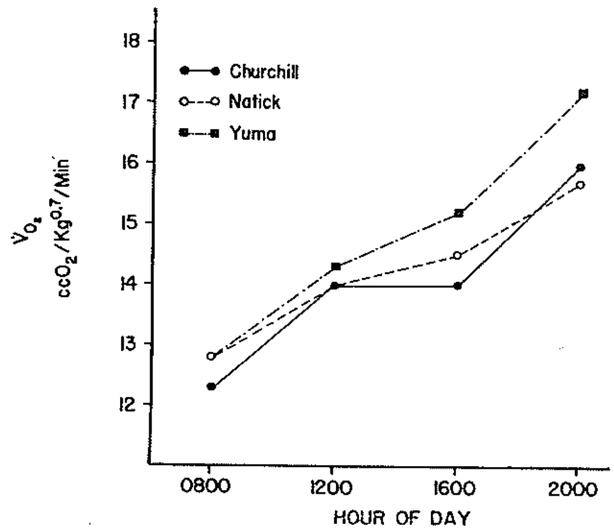

FIG. 3.—Change in resting oxygen consumption ($\dot{V}_{O_2}$) throughout the day in three different climates.

described by Glickman et al.[11] In connection with this sigmoid curve, Mitchell and Edman point out that "The accumulation of extra calories above basal beyond the point of inflection was very well described by the curve of self-inhibiting growth (the law of diminishing returns as formulated by Brody (1927).[14]

Phase III. The pattern of metabolism throughout the day for three different climates is shown in figure 3. $\dot{V}_{O_2}$ at 2000 hours obtained at Yuma was significantly higher than any other 2000 hours $\dot{V}_{O_2}$. A difference in basal $\dot{V}_{O_2}$ between environments was not found. The above findings were surprising in that a larger elevation in resting metabolism during the day might be expected in the cold area because 600 kcal. more food/man/day was eaten and the men worked harder per unit of distance traveled. It is not so surprising, however, if one takes into account the following: (a) When expressed as kcal./Kg./day, the caloric intake was the same for both groups. (b) The proportion of foodstuffs was 14 per cent protein, 38 per cent fat and 48 per cent carbohydrate for both groups.

The plane of nutrition is known to alter SDA.[15, 16] A small weight loss was common to each experiment but was slightly greater in the cold-dry climate. The weight loss was 0.18 Kg./man/day at Ft. Churchill and 0.10 Kg./man/day at Yuma and Natick. Thus, a real climatic impact may have been masked by the greater negative caloric balance in the cold-dry climate.

DISCUSSION

The results suggest that the major factor in the elevation of resting metabolism during the day is the specific dynamic action of food (SDA). In addition, there was a suggestive smaller and more variable elevation which occurred with fasting. Moderate physical activity failed to alter the pattern of metabolism during the day (fig. 2). Living in various environments had no observed effect on basal metabolism and did not importantly influence the pattern of metabolism throughout the day.

The term basal metabolism can apply to the metabolic rate only during a small daily interval of time. Thus, the basal $\dot{V}_{O_2}$ represents a reproducible but perhaps fictitious baseline for computing daily energy expenditure. Oxygen consumption, throughout a given day under fasting conditions, increased slightly, independent of food and exercise. Benedict[17] has described this small elevation and divided it into three distinct planes: (a) asleep, (b) awake in morning and (c) awake in afternoon. Each plane was higher than the preceding one. A similar change has been observed for rectal temperature.[18] It would seem that a fasting "diurnal" increase in metabolism does exist although the cause remains obscure. The elevation obtained with fasting may reflect SDA of body stores. This effect could conceivably be disguised or depressed by the general state of nutriture with conditions of starvation. A depression of basal $\dot{V}_{O_2}$ is commonly observed with fasts or conditions of semistarvation lasting more than 24 hours. The "diurnal" pattern might be assessed by subjecting individuals to a controlled series of tests where mealtime is changed by one hour intervals and $\dot{V}_{O_2}$ is routinely measured 14 hours later.

The question of how to express energy expenditure has long been a problem. Passmore and Durnin[19] suggest that gross values are more directly useful than "net" values. This statement can be true only in certain situations. "Net" $\dot{V}_{O_2}$ will vary, depending on the baseline the investigator selects. Total $\dot{V}_{O_2}$ for most activities will be relatively constant if measurements are made at fixed times after meals of similar composition and amount. In this instance SDA and "diurnal" changes are included in total $\dot{V}_{O_2}$. When $\dot{V}_{O_2}$ associated with SDA is included in total $\dot{V}_{O_2}$ for mild activities such as standing, sitting, etc., appreciable variation in total $\dot{V}_{O_2}$ may result simply because of variation in SDA if measurements are made at various times after meals[20]. Thus, the investigator is faced with a choice between making metabolic measurements for light activity at several times during the day to obtain representative values, controlling meals and time of measurement, or being content with the variation that will result if total $\dot{V}_{O_2}$ measurements are used indiscriminately.

The situation for severe exercise is not as critical because $\dot{V}_{O_2}$ associated with SDA comprises only a small fraction of the total $\dot{V}_{O_2}$. In this instance total $\dot{V}_{O_2}$ is highly reproducible[21] and "net" $\dot{V}_{O_2}$ is largely dependent on total $\dot{V}_{O_2}$. However, most of the average man's activities are of a mild or moderate nature.

It should be remembered that in certain instances attempts to allow for SDA may lead to a fictitious impression of accuracy. The SDA of food varies with meal composition and amount.[22-25] In addition, the extent to which energy associated with SDA may be used in muscular work has not been clearly established.[26-32] In this experiment a relatively fixed diet and meal pattern was used. Thus errors of interpretation in regard to "net" energy expenditure were minimized.

The influence of climate *per se* on resting metabolism during the day has not been previously assessed although the impact of climate and seasons on the basal metabolic rate has been studied extensively and reviewed.[4, 23, 33, 34] Many of these investigations are included in the statistical study of Quenouille[1] who concluded, from multiple correlation analysis, that a one degree deviation from the base mean annual temperature of 70 F. would produce a 4 kcal. change in basal metabolic rate. This large difference in basal metabolic rate between climates was not found in the present study, nor has it been found in other studies where diet was reasonably constant in amount and composition.[35, 36] Variations in diet between seasons and climate may explain many of the results imputed to climate.

Since different groups of subjects were used in each climate, largely because of attritional factors associated with military service and not by choice, the unit of reference for metabolism becomes important. A function of body weight was routinely used ($Kg.^{0.7}$). A recalculation of the data using body surface (M^2) yielded the same results, i.e. no significant differences between climates. With the latter unit of reference, $\dot{V}_{O_2}$ was, in general, slightly lower in the temperate climate than during corresponding hours in the cold or hot climates.

Summary

Basal oxygen consumption (basal $\dot{V}_{O_2}$) and resting $\dot{V}_{O_2}$ measured at four hour intervals was studied in four groups of eight men in an attempt to describe the effects of specific dynamic action (SDA) and exercise and the impact of climate on metabolism.

The elevation in $\dot{V}_{O_2}$ that occurred throughout the day was largely explained by the change in $\dot{V}_{O_2}$ associated with SDA. Moderate exercise alone did not alter resting $\dot{V}_{O_2}$. A small "diurnal" elevation in $\dot{V}_{O_2}$ occurred during fasting, with or without exercise.

Climate *per se* did not appear to influence basal $\dot{V}_{O_2}$ or the pattern of resting metabolism during the day with the exception that the $\dot{V}_{O_2}$ at 2000 hours in the hot-dry climate was significantly higher than the 2000 hours values in other climates.

Peak $\dot{V}_{O_2}$ associated with SDA can amount to 1.5 to 2.0 times basal $\dot{V}_{O_2}$. Thus, when total $\dot{V}_{O_2}$ (gross oxygen consumption) is used as an expression of energy expenditure for mild or light physical work, considerable variation may result unless measurements are made under well controlled conditions with respect to food intake and time after meals.

REFERENCES

[1] Quenouille, M. H. et al.: Statistical studies of recorded energy expenditure of man. Commonwealth Bureau of Animal Nutrition. Technical Communication No. 17, Dec. 1951.

[2] Ames, A., III and Goldthwait, D. A.: Influence of cold climate on basal metabolism. QM Climatic Research Laboratory, Lawrence, Mass. Report No. 136, 1948.

[3] Mason, E. D.: The basal metabolism of European women in South India and the effect of change of climate on European and South Indian women. J. Nutrition *8:* 695, 1934.

[4] Galvao, E. G.: Human heat production in relation to body weight and body surface. J. Appl. Physiol. *3:* 21, 1950.

[5] Food and Agricultural Organization of the United Nations: Calorie requirements. Report of the Committee on Calorie Requirements, Washington, D. C. Published June, 1950.

[6] Johnson, R. E. and Kark, R. M.: Environment and food intake in man. Science *105:* 378, 1947.

[7] Lusk, G.: Science of Nutrition. Philadelphia, W. B. Saunders Co., 1923.

[8] KEYS, A.: Caloric requirement of adult man. Nutrition Abstr. & Rev. *19:* 1, 1949–50.

[9] STARE, F. J. (Ed.): Present Knowledge in Nutrition. New York, Nutrition Foundation, Inc., 1956.

[10] SWIFT, R. W. AND FRENCH, C. E.: Energy Metabolism and Nutrition. New Brunswick, N. J., Scarecrow Press, 1954.

[11] GLICKMAN, N., MITCHELL, H. H., LAMBERT, E. H. AND KEETON, R. W.: The total specific dynamic action of high protein and high carbohydrate diets on human subjects. J. Nutrition *36:* 41, 1948.

[12] KEETON, R. W., LAMBERT, E. H., GLICKMAN, N., MITCHELL, H. H., LAST, J. H. AND FAHNESTOCK, M. K.: The tolerance of man to cold as affected by dietary modifications: protein versus carbohydrates, and the effect of variable protective clothing. Am. J. Physiol. *146:* 66, 1946.

[13] BENEDICT, F. G. AND CARPENTER, T. M.: The metabolism and energy transformations of healthy man during rest. Washington, D. C., Carnegie Institute of Washington, Publication No. 126, 1910.

[14] MITCHELL, H. H. AND EDMAN, M.: Nutrition and climatic stress with particular reference to man. Springfield, Ill., Charles C Thomas, 1951.

[15] SWIFT, R. W.: The importance of fat in the diet. Ann. New York Acad. Sc. *56:* 4, 1952.

[16] FORBES, E. B. AND VORIS, L.: Energy metabolism. Ann. Rev. Physiol. *5:* 105, 1943.

[17] BENEDICT, F. G.: Factors affecting basal metabolism. J. Biol. Chem. *20:* 263, 1915.

[18] BUSKIRK, E. R., ET AL.: Caloric intake and energy expenditure in a sub-arctic environment. QM R&D Command, Natick, Mass. Report No. EP-33, 1956.

[19] PASSMORE, R. AND DURNIN, J. V. G. A.: Human energy expenditure. Physiol. Rev. *35:* 801, 1955.

[20] BALDWIN, F. M. AND SHAW, R. J.: Relation between BMR and SDA of proteins. Proc. Soc. Exper. Biol. & Med. *37:* 705, 1938.

[21] TAYLOR, H. L., BUSKIRK, E. AND HENSCHEL, A.: Maximal oxygen intake as an objective measure of cardio-respiratory performance. J. Appl. Physiol. *8:* 73, 1955.

[22] FORBES, E. B. AND SWIFT, R. W.: Associative dynamic effects of protein carbohydrate and fat. J. Nutrition *27:* 453, 1944.

[23] DUBOIS, E. F.: Basal Metabolism in Health and Disease. Philadelphia, Lea & Febiger, 1936.

[24] MCCLELLAN, W. S., SPENCER, H. J. AND FALK, E.: Clinical calorimetry. XLVII. Prolonged meat diets with a study of the respiratory metabolism. J. Biol. Chem. *93:* 419, 1931.

[25] SODERSTROM, G. F., BARR, D. P. AND DUBOIS, E. F.: Clinical calorimetry XXVI. The effect of a small breakfast on heat production. Arch. Int. Med. *21:* 613, 1918.

[26] GIUSTINA, G., MESCHIA, G. AND SETNIKAR, I.: Azione dinamica specifica delle proteine nel lavoro muscalare. Arch. Sc. biol. Bologna *37:* 44, 1953.

[27] RAPPORT, D.: The nature of the foodstuffs oxidized to provide energy in muscular exercise. Am. J. Physiol. *91:* 238, 1929.

[28] ORR, J. B. AND KINLOCK, J. P.: Note on the influence of diet on the energy expenditure in work. J. Roy. Army M. Corps *36:* 81, 1921.

[29] COURTICE, F. C. AND DOUGLAS, C. G.: The effects of prolonged muscular exercise on the metabolism. Proc. Roy. Soc., London s.B. *119:* 381, 1936.

[30] BAHN, K.: Zur Frage der spezifisch-dynamishen Eweisswerkung und ihres Verhaltens bei Muskelarbeit. Deutsches Arch. Klin. Med. *156:* 67, 1927.

[31] KAPLAN, P. M.: Die spezifish-dynamische Wirking der gemischten Kost. Arbeitsphysiologie *6:* 411, 1933.

[32] PITTS, G. C., CONSOLAZIO, F. C. AND JOHNSON, R. E.: Dietary protein and physical fitness in temperate and hot environments. J. Nutrition *27:* 497, 1944.

[33] MILLS, C. A.: Vitamin requirements in hot climates (*in* Nutrition under Climatic Stress). QM F&CI, Chicago, May 1954.

[34] LINDHARD, J.: III Contribution to the physiology of respiration under the arctic climate. Medelelser om Grønland *44a:* 77, 1910.

[35] RODAHL, K.: Basal metabolism of the Eskimo. J. Nutrition *48:* 359, 1952.

[36] ——: Nutritional requirements in cold climates. J. Nutrition *53:* 575, 1954.