

# Relation between Caloric Intake, Body Weight, and Physical Work:

## STUDIES IN AN INDUSTRIAL MALE POPULATION IN WEST BENGAL

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IT HAS been stated—or implied—by many workers that the regulation of food intake functions with such flexibility that an increase in energy output due to exercise is automatically followed by an equivalent increase in caloric intake. This view, usually accompanied by a minimization of the energy expenditure due to exercise, has often led to the disparagement of physical activity as a factor in weight control. The fallacies inherent in such an attitude have been discussed previously.<sup>1,2</sup> It has been shown that when rats are exercised for increasing durations on a treadmill, intakes vary linearly with exercise only within certain limits of activity.<sup>3</sup> Below this level, in what can be termed the “sedentary” range, a further decrease in activity is not followed by a decrease in food intake but, on the contrary, by a slight but significant increase. The animals increase both their weight and fat content. Enforced total inactivity in the rat can even lead to a considerable degree of obesity.<sup>4</sup> It has also been shown that spontaneous inactivity is a major factor in the development of genetic obesity in the mouse.<sup>5</sup> Enforced exercise decreases weight gain even when food

is available *ad libitum* in other types of animal obesity.<sup>6,7</sup> These findings appear related to the well-known practice among farmers to restrict the activity of animals (e.g., hogs, geese) which they want to fatten.

It appeared of interest to see whether these experimental results could be extended to man. The availability for study of a large population of male subjects demonstrating extreme differences of physical activity made it possible to attempt to correlate work with food intakes and body weight.

### SUBJECTS

The subjects constituted a sample of 213 workers out of a total of 800 on whom height and weight data were obtained. All were employees (or, in the case of the “stall holders” or bazaar shopkeepers, licensees) of the Ludlow Jute Co., Ltd., at Chengail, West Bengal. The mill is situated on the Hooghly (Ganges) about 20 miles south of Calcutta, and it and the “labor lines” (workers’ quarters) have been described by Chernin<sup>8</sup> on the occasion of his studies of parasitic infestations in the population of this mill. The total number of workers is in the neighborhood of 7,000.

The study was carried out on individuals 5 feet 2 inches to 5 feet 4 inches tall, the most usual range among the male workers of the mill. They were reasonably healthy individuals, free of obvious signs of malnutrition, of which those most frequently encountered in this population were anemia, angular stomatitis and other riboflavin deficiency symptoms, and ocular and skin anomalies probably referable in part to vitamin A deficiency.

The subjects, some 50 per cent of whom were

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indigenous Bengalis, also included persons from other parts of India as well, in particular Orissa, Madras, Bilaspuri (Central Province), Bihar and United Province. Bengalis, although almost equally divided between Hindus and Moslems in the workers' population as a whole, were preponderantly Hindu in this sample, as were workers from other provinces. These men were engaged in 16 occupations, which involved varying degrees of physical activity. In addition, the large clerical group was split into 4 subgroups depending essentially on the distance from their homes to the mill. Unemployment is widespread among people of this degree of education in Bengal and, as a result, "babus" (clerks) will commute considerable distances to a place of work—in this case, because of the lack of roads fit for buses, on foot and more exceptionally on bicycles.

#### METHODS

Food intakes were obtained by exhaustive dietary interviews using a pre-established questionnaire based on cross checks (by meals and by foodstuffs). The interviews were generally conducted in Bengali or Hindustani. In a few cases, interviews were conducted in English or by way of a reliable interpreter with individuals who spoke Telegu. Because most individuals interviewed lived away from their families, had little facility for storing food, and had a very uniform diet, additional checks could be obtained by questions on the amounts of food bought daily and weekly and on the amount of money spent on edibles (lists and prices of foods locally purchasable in one bazaar and in the village were obtained and checked). Repeated interviews and cross checks on individuals chosen at random, conducted at several weeks' intervals gave good agreement. A few random checks by direct weighing also confirmed the general reliability of the data; in fact, the extraordinary uniformity of the diet from day to day, and the monotony of living conditions gave a much higher degree of reproducibility than could be obtained in a Western population.

The results were analyzed using the Indian Food Composition Table established by the Coonoor Nutrition Laboratory,<sup>9</sup> and the fol-

lowing values calculated for each individual and averaged for each group (with standard deviations): animal protein, vegetable protein, total protein, fat, carbohydrate, calories, thiamine, riboflavin, niacin, and vitamin C. Activity was evaluated by a combination of methods. A detailed observation of each occupation was undertaken, with particular care given to "micro-schedule" (pauses, intervals between movements, etc.). Secondly, a thorough analysis conducted by an efficiency engineers' firm was available.

In this survey, "physical demand" was characterized on the following basis: "Physical demand is defined as the amount and continuity of physical endurance needed and for which allowances must be made to compensate for the degree of fatigue involved. Work necessitating awkward bending, stretching, reaching and other unusual postures must be recognized and rewarded. Also, the muscular effort required in excessive walking, standing on hard floors... must receive rating attention." A number of examples were used to illustrate the attribution of ratings: e.g., hand lifting weight up to 10 lb—infrequently, none, frequently, very low; up to 50 lb—infrequently, low, frequently, medium; up to 75 lb—infrequently, high, frequently, very high. Eighty-one occupations were analyzed in this fashion.

Oxygen consumption and carbon dioxide production data pertaining to a number of occupations in the jute industry as obtained by Sen, Gupta, and Ferris<sup>10</sup> were also available. While it was obviously impossible to calculate energy expended as work as such, the foregoing information seemed to permit a classification of the occupations in order of increasing caloric cost. At any rate, broad classes of activity could be differentiated with a reasonable certainty as to differences in energy cost. The following classes and groups were studied (ranged in order of increasing activity):

1st Class: *sedentary*. Thirteen *stall holders*, constituting a group of extraordinarily inert mode of life, who sat at their shop all day, except for one day a week and on occasional buying forays; 8 *supervisors* who lived on company premises and who either sat at desks or confined their walking to the precincts of one department; 22 *clerks* (called clerks I in Table I) who lived on company premises and who did not engage in any sport.



Their walking was confined, during most of the week, to company premises.

2nd Class: *light work*. Three groups of *clerks*, 13 in group II and 10 in group III, who were differentiated by the fact that group II and III lived outside of the mill compound, with group II commuting at least 3 miles and group III at least 6 miles. Group IV engaged in athletic activities (soccer) besides commuting. There was also a group of 22 *mechanics*, whose job was relatively standard except inasmuch as they did not have many power aids at their disposal.

3rd Class: *medium work*. *Drivers* (10 men) drove either electric tractors or steam locomotives, and did some coupling and uncoupling of wagons. The other groups, 10 *winders*, 10 *weavers*, and 10 *bagging twisters*, were composed of individuals driven at a steady pace by the nature of the machines they were operating. A number of operations involving some strength (lifting of rolls, pushing on large levers, etc.) were involved.

4th Class: *heavy work*. Eleven *mill waste carriers* who carried small bales of 50 to 75 lb. The work of *pilers* (10 men) and *selectors* (10 men) involved the handling of heavy bales (150 to 200 lb) at intervals and on relatively short stretches, as well as the opening of bales, lifting of fractions thereof, etc.

5th Class: *very heavy work*. *Ashmen* and *coalmen* (15 men) shoveled ashes and coal in tending furnaces. The work of *blacksmiths* corresponded to the classic occupation without power aids (15 men). *Cutters* (10 men) swung heavy cleavers and hacked steadily at jute fibers, a particularly hard and tiring procedure. Finally, 19 carriers were divided between 9 *Bojha carriers* (190 lb per man) and 10 *bale carriers* (400 lb for 3 men).

Additional information which was obtained included: height and weight (by means of portable scales and height-measure with sliding headpiece), religion and caste, income, numbers of dependents, regular payments on loans, amount of money sent home weekly, amount of money spent on items other than food, and educational level. Age had to be estimated, from questions and from physical appearance, as the absence of a system of registration of births results in a general ignorance of one's own age, even among clerks and supervisors.

#### RESULTS

The relation of caloric intake to physical activity is given in Figure 1. Differences in caloric intakes between classes were statistically significant; differences between groups within classes generally were not. Caloric intakes were adequate to satisfy hunger, and for the "light work" and more active classes

agreed well with the caloric requirements which could be calculated on the basis of the FAO Committee report.<sup>11</sup> The major proportion of calories was derived from carbohydrates in all groups, with an increasing proportion of fat in the higher intake groups (stall holders and supervisors, pilers, selectors, and "very heavy work" class), all of which consumed more than 50 g of fat per day (Table I). Protein intakes were at or above 70 g per day, but the major part of the protein (at least three-fourths) was derived from vegetable sources. Only two men were total vegetarians, but the amount of animal products generally consumed was so low that for several groups (mill waste carriers, winders, weavers, mechanics) the daily intake of animal protein was on the average of less than 10 g. It may be noted that the weavers and mechanics were among the better paid groups, so that their lower animal protein intake did not represent a more stringent economic necessity. Weavers were predominantly Moslems, so that religious practices were not involved in this avoidance of animal products. Clerks had on the whole the largest intake in animal proteins, in spite of their being predominantly Hindu with an appreciable proportion of Brahmins among them.

Daily thiamine intakes were adequate (above 1.4 mg on the average for all groups, and generally in the 1.6-1.9 mg range, as were niacin (above 12 mg) and vitamin C (30-60 mg range), but riboflavin intakes were very low (generally in the 0.6-1 mg range) (Table I). Carotene-vitamin A and calcium levels were low but were difficult to estimate on a group basis because of the widespread practice of chewing lime-treated green leaves wrapped around betel nuts.

Caloric intakes were not correlated with income (clerks, mechanics and weavers had higher incomes than men in the "heavy work" and "very heavy work" categories); nor were caloric intakes correlated with religion or caste. The differences in religion had, as a matter of fact, very little correlation with nutrient intakes, except as regards the source of animal proteins. Similarly, age did not appear to be a factor in the differences in intake noted between groups. As regards physical status, the

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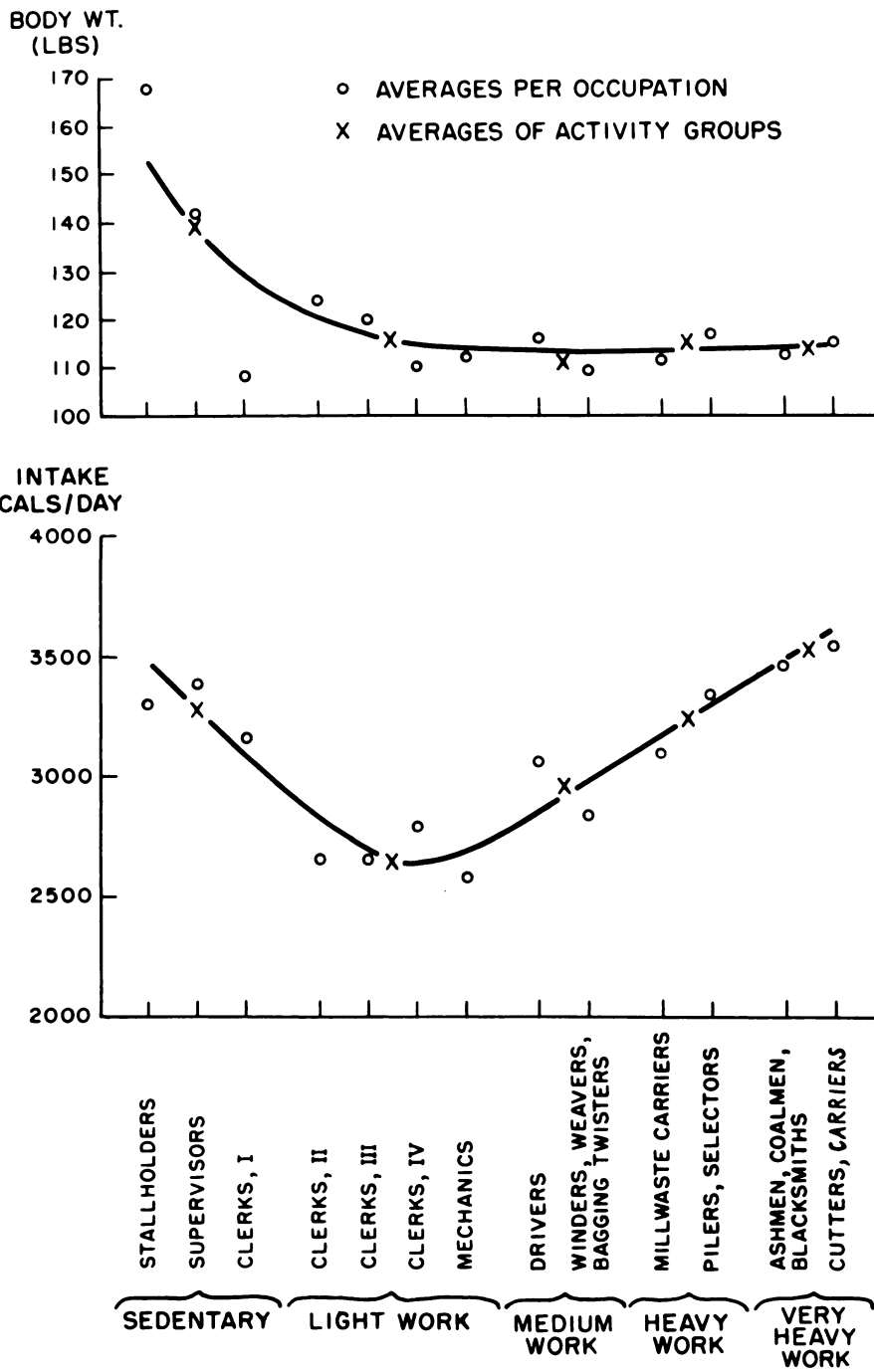


Figure 1



TABLE I

Average Daily Nutrient Intake<sup>1</sup> and Median of Money Spent per Week (exclusive of loan repayments and money sent home)<sup>2</sup>

Occupational Group	Animal Protein g	Vegetable Protein g	Fat g	Thiamine μR	Ribo- flavin μR	Niacin mR	Vit. C mg	Money spent per week Rupees
Stall holders	38.2 ± 18.7	54.6 ± 11.8	102.9 ± 44.1	1630 ± 331	1169 ± 351	14.6 ± 5.6	57.6 ± 34.3	12(8-15)
Supervisors	29.3 ± 21.2	59.7 ± 16.1	81.2 ± 36.3	2150 ± 696	1237 ± 452	14.4 ± 5.5	76.6 ± 43.3	70(28-144)
Clerks I	23.5 ± 17.7	52.5 ± 12.6	45.8 ± 35.9	1435 ± 453	848 ± 329	11.7 ± 3.7	53.6 ± 28.2	50(26-168)
Clerks II	17.1 ± 10.0	59.3 ± 17.5	42.5 ± 22.4	1672.4 ± 493	997 ± 391	11.6 ± 4.7	50.1 ± 21.2	
Clerks III	26.3 ± 16.6	56.4 ± 15.6	46.3 ± 23.6	1703 ± 517	1100 ± 436	12.0 ± 4.2	50.3 ± 11.0	
Clerks IV <sup>3</sup>	28.0 ± 19.9	63.1 ± 24.6	54.3 ± 27.1	1851 ± 655	1053 ± 467	13.7 ± 5.5	60.3 ± 30.7	
Mechanics	8.1 ± 7.0	53.1 ± 14.5	19.3 ± 9.7	1499 ± 366	616 ± 196	10.1 ± 2.3	37.8 ± 10.8	
Drivers	16.2 ± 6.8	67.6 ± 15.5	38.3 ± 16.7	1903 ± 550	904 ± 331	15.3 ± 6.5	37.7 ± 12.7	7(3-15)
Winders	5.6 ± 5.0	62.7 ± 7.2	17.3 ± 4.7	1677 ± 209	727 ± 355	11.2 ± 2.1	37.1 ± 14.3	3(2-4)
Weavers	10.3 ± 6.3	68.4 ± 15.2	23.5 ± 6.3	1829 ± 482	887 ± 219	13.5 ± 3.0	37.0 ± 5.2	10(2-18)
Bagging twisters	12.5 ± 5.7	65.9 ± 11.2	37.9 ± 16.9	1809 ± 304	779 ± 303	15.0 ± 3.3	33.3 ± 9.7	5(2-9)
Mill waste carriers	9.9 ± 3.6	71.2 ± 8.9	29.2 ± 10.3	1892 ± 199	749 ± 96	15.2 ± 2.6	29.4 ± 10.3	4(2-8)
Pilers	16.0 ± 5.4	72.2 ± 9.3	51.3 ± 9.6	1449 ± 948	973 ± 187	17.5 ± 2.5	43.6 ± 18.5	8(3-16)
Selectors	15.6 ± 7.1	77.9 ± 11.2	53.2 ± 12.0	2150 ± 697	1238 ± 452	14.4 ± 5.4	76.7 ± 43.3	6(2-12)
Ashmen, coalmen								
blacksmiths	12.2 ± 6.2	80.3 ± 17.1	51.6 ± 10.6	2301 ± 730	1081 ± 315	19.8 ± 8.8	32.2 ± 13.4	12(2-27)
Cutters	13.1 ± 7.7	90.1 ± 16.1	50.3 ± 15.1	2845 ± 760	1193 ± 332	25.7 ± 8.2	56.9 ± 62.2	7(1-11)
Carriers	16.2 ± 7.5	88.2 ± 11.3	58.1 ± 12.1	2108 ± 335	732 ± 187	18.9 ± 3.3	31.2 ± 9.5	6(2-17)

Figures after ± are standard deviations. One rupee = 0.21 dollar. Figures in parentheses give range.

<sup>1</sup> Main sources of animal protein are (in order of decreasing importance): fish, eggs, buffalo and cows' milk, meat, curds, and cheese; of vegetable proteins: rice, lentils; of fat: vegetable oil, ghee, invisible animal fat; of thiamine: rice (undermilled); of riboflavin: leafy vegetables; of niacin and vitamin C: vegetables and fruits.

<sup>2</sup> Difficulties are encountered when computing real income due to the communal family and living systems; thus the very low incomes reported for some workers are compatible with life because they feed themselves as members of a community of similarly situated individuals. Loan repayments have been excluded from incomes, because of the colossal interest rates (up to 30 or 40 per cent per month) often exacted by money lenders. Only medians and ranges are given for incomes; the degree of accuracy obtained, for the reasons given above, does not warrant elaborate statistical treatment. On the average, stall holders and supervisors had five dependents over the age of 10 years, three dependents in the 1-10 year range, and one half in the 0-1 year bracket. Clerks had six dependents over 10 years of age, four in the 1-10 bracket, and three-fourths under 1 year. Workers had four dependents above 10 and four under 10 (infants included).

<sup>3</sup> This group was the most heterogeneous in terms of physical activity because of the differences in athletic schedules between members. At least one of the men could qualify as "heavy worker" and several as "medium workers" because of their athletic activity. This variability is reflected in the larger standard deviations.

variation of weight as a function of exercise (average height 5 feet 3 inches, average weight 119 lb) is given in Figure 1. Differences in average weight between the "light work," "medium work," "heavy work," and "very heavy work" classes were not significant. The "sedentary" group was on the average much heavier. The "stall holders" and "supervisors" were obviously much fatter than the other occupation groups. Although the group "Clerks I" (very sedentary individuals) was relatively light, it may have been actually a relatively "fat" group where the visibly poor degree of muscular development obscured, from the point of view of weight, a relatively greater adiposity than in the "work" groups.

#### DISCUSSION

Inasmuch as it is legitimate to draw a parallel between purely experimental results and the results of a population study, there is a striking parallelism between the findings in animals<sup>3</sup> and those in man. In both cases it appears that food intake increases with activity only within a certain zone. By analogy with previously used terminology,<sup>1-3</sup> this zone can be called the "normal activity range." Below that range, in what has been termed the "sedentary" zone, a further decrease in activity is not followed by a decrease in food intake but, on the contrary, by an increase. It may be at first surprising to note that a fundamental mechanism, that of the regulation of food intake,

ceases to respond in a certain interval to variations of energy expenditure. This may be interpreted by considering the fact that, in his hundreds of thousands of years of evolution, man did not have any opportunity for sedentary life except very recently. An inactive life for man is as recent (and as "abnormal") a development as caging is for an animal. In this light, it is not surprising that some of the usual adjustment mechanisms would prove inadequate.

The increase in weight associated with inactivity appears to be of significance in relation to the problem of obesity. The importance of inactivity in various forms of experimental obesity has already been recalled. As regards human obesity, Greene<sup>12</sup> has reported on more than 200 overweight individuals in whom the beginning of obesity could be traced to a sudden decrease in activity. Bruch<sup>13</sup> has emphasized the frequency of the coexistence of physical inertia and obesity in children. Peckos<sup>14</sup> and Fry<sup>15</sup> have questioned the role of hyperphagia in the positive energy balance leading to obesity in children. Finally, in collaboration with Johnson and Burke, one of us (J.M.) has found that the average caloric intake of obese high school girls in Boston suburbs was no greater than that of the normal-weight individuals of similar age, height, and school grade, but their physical activity was very much less.<sup>16</sup> The fact that mechanized, urbanized modern living may well be pushing an ever greater fraction of the population into the "sedentary" range may thus be a major factor in the increased incidence of obesity.

#### SUMMARY

The relation between caloric intake, body weight, and physical work was established in a group of 213 mill workers in West Bengal. These workers covered a wide range of physical activity, from sedentary to very hard work. It was found that caloric intake increases with activity only within a certain zone ("normal activity"). Below that range ("sedentary zone") a decrease in activity is not followed by a decrease in food intake but, on the contrary, by an increase. Body weight is also increased

in that zone. The picture is similar to that previously found in experimental animals.

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### *Coffee: Pro*

"In January 1719, Paris became a big café. Three hundred cafés were open to conversation. It was the same in the big cities: Bordeaux, Nantes, Lyon, Marseille, etc.

"Never did France converse more or better. There is no doubt that the honour of this scintillating explosion belongs partly to the happy revolution of the times, to the great event that created new habits and modified temperaments: the advent of coffee.

"Coffee, the dark liquor, powerfully cerebral, which, altogether unlike the spiritous kind, increases clearness and lucidity; coffee which suppresses the vague and heavy poetry of the fumes of the imagination; which, out of reality, clearly seen, calls forth the spark and flash of truth. . . .

"The three ages of coffee are those of modern thought; they mark the solemn moments of the brilliant century of the mind."

—Jules Michelet. *History of France: The Regency*, 1863.

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### *Coffee: Con*

"When the Moslems drank wine the Golden Age of Eastern civilisation was in full bloom. The immortal 'Arabian Nights' was written; mathematics was at a high stage of its development; medicine and the sciences were making great progress. However, after the fifteenth century, when strong-willed fanatics got the controlling hand and prohibited the use of alcohol as a beverage, and turned the Moslems into a coffee-drinking people, civilisation began to set in the East. In fact, so stupid had the Moslem coffee-drinkers become that they had to employ alcohol-drinking Copts to keep their accounts in workable order."

—Edward Podolsky. *Med. Press* 234: 614, 1955.

