A Method of Studying Physical Activity in Man

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THIS PAPER describes a method of studying physical activity in man, and some of the limitations and potentialities of this method. The instrument utilized for measuring activity is the mechanical pedometer.

Despite the attested value of the measurement of physical activity in laboratory animals, and despite the paucity of such measurements in clinical studies, there are surprisingly few reports of investigations which utilized the pedometer. In 1926 Lauter[1] described his own physical activity as measured by a pedometer, but reported little more than his surprise at the relatively large degree of activity recorded in the course of a sedentary occupation. In 1949 Larsen[2] reported that a group of hospitalized obese persons walked less than a group of non-obese persons as measured by the pedometer. Finally, two investigators attempted to describe patterns of physical activity corresponding to phases of the menstrual cycle with, unfortunately, contradictory results.[3,4]

For the past four years we have been using the mechanical pedometer for studies of physical activity in man. This instrument, the size of a pocket watch, is inexpensive, easy to use and relatively reliable. It functions on a simple principle. A delicately balanced arm is displaced by slight jolts in the vertical plane and these displacements turn a series of gears. When the pedometer is worn suspended from the waist each step taken during walking transmits an impulse to the balance arm. By calibrating the pedometer for the length of stride of its user it is possible to convert such impulses into distances. Standardization of the pedometer by subjects walking a measured mile indicates that it can measure distances walked with an error of less than 15 per cent.

PROBLEMS

There are three types of problems in the use of the pedometer. The first problems are those of the instrument itself, the second are the uncertainties as to what it measures and the third are the difficulties in interpreting these measurements.

Currently available commercial pedometers are relatively fragile and their accuracy is readily impaired by events incident to their use. Dropping a pedometer, for example, may break it outright, while the entrance of dust and moisture through the loosely fitted case sooner or later interferes with the performance of all pedometers. It is, therefore, necessary to retest pedometers at frequent intervals. Since such testing is most satisfactorily carried out by the subject walking a measured mile, considerable cooperation is needed for long-term studies.

Despite its relative accuracy in measuring distances walked over a measured mile the pedometer has limitations both as a direct measure of distances walked and as an indirect measure of caloric expenditure. Bodily movements other than walking may move the balance arm and thus result in an exaggeration of the distances walked. Since these movements are a measure of the total activity of the

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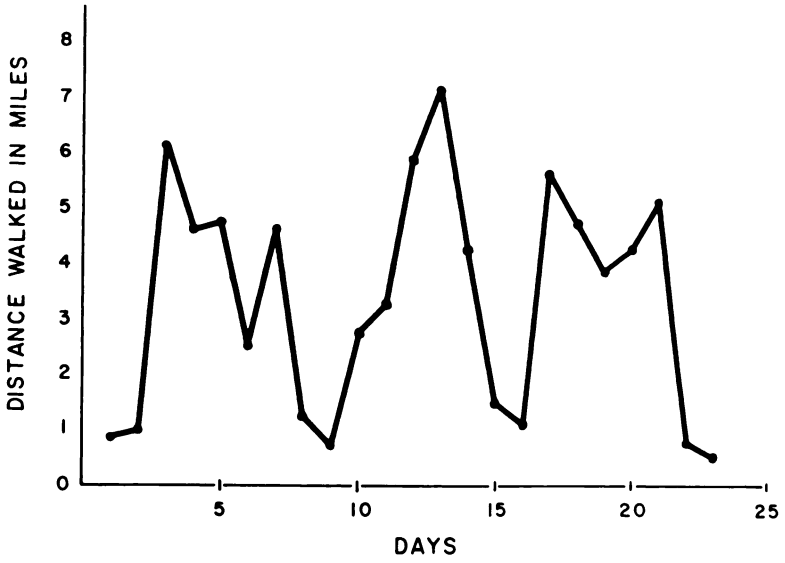

FIG. 1. Fluctuations in physical activity of a thirty-year old man over a period of twenty-three days. On the ordinate are measured distances walked in miles, on the abscissa, time in days. Note the marked variability of the data.

subject, however, recording them may actually increase the precision of estimation of caloric expenditure. It should be borne in mind, nevertheless, that distances walked in a pedometric study serve as an index of physical activity rather than as a precise measure of actual distances walked. Another lesser problem is that bodily movements, such as those of the extremities, which do not affect the pedometer, nevertheless result in at least some degree of caloric expenditure.

The third problem in the use of the pedometer arises from the great variability of the data which it measures. In contrast to the remarkable regularity in the patterns of physical activity of some of the lower animals, physical activity in man follows a course so irregular as to appear at times almost random. Figure 1, for example, is a record of the daily physical activity of a thirty-year old man over a period of twenty-three days. By contrast, Figure 2 shows a plot of twenty-three consecutive numbers from a table of random numbers. After some years of study, we have come to believe that this apparent randomness of the data in man is simply an expression of the many factors which determine his physical activity. In our work we have tried to deal with this problem by using two kinds of studies.

The objectives of the first type of study were to identify the various determinants of physical activity in man and to ascertain the relative contribution of each. If these are achieved it should be possible to factor out the influence of each determinant as it is identified, thereby reducing the apparent randomness of the data and rendering more evident the influence of factors which have not yet been identified. The purpose of the second type of study was to compare groups of persons, keeping constant as many determinants as possible and seeking differences between the groups in the factor under investigation. The first type of study is primarily exploratory and hypothesis-forming, the second one, confirmatory and hypothesis-testing.[5] Examples of each of these types of studies follow.

EXPLORATORY STUDIES

The basic data for exploratory studies were obtained from the daily pedometer readings of patients who were undergoing psychotherapy and of colleagues who were keeping diaries. We simply asked these subjects to record every night the distance they had walked during the day. It was possible by this means to accumulate large amounts of information in a short time, and in a very economical way.

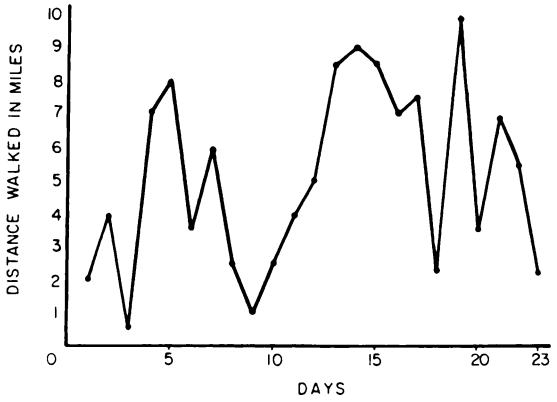

FIG. 2. Fluctuations of a series of random numbers. The similarity of this plot from a table of random numbers to the pattern in Figure 1 emphasizes the apparently random quality of human physical activity.

We had available for analysis, for example, measures of the daily activity of fourteen subjects over periods of from four to thirty-six months.

We began the analysis of these data by trying to set down all the possible determinants of physical activity. Then we examined the data, considering the evidence for each of the possible determinants. Using our current scheme of organization, which is largely an *a priori* one, we divided the determinants of physical activity into three main groups: the "biological," the "social" and the "emotional."[6]

Under "biological" determinants, the following five factors which influence the activity of lower animals have been listed.

(1) *Physical illness* and *injury* play as important a role in the physical activity of man as in that of the lower animals. Indeed, these relationships are so constant as to suggest that a measure of physical activity might profitably supplement standard clinical procedures. The physical activity of two cardiac patients, for example, has proved as sensitive a measure of the status of their congestive failure as have such clinical tools as heart rate and vital capacity.

(2) *Body weight* appears to play a role similar to that in lower animals, in that excessive body weight decreases physical activity.

(3, 4 and 5). Three determinants of physical activity in lower animals *environmental temperature, phase of the female reproductive cycle* and *alterations in food intake*, did not appear to affect our subjects. Man may well be susceptible to such influences but other factors, primarily social and emotional, appear so much more potent as to obscure their effects.

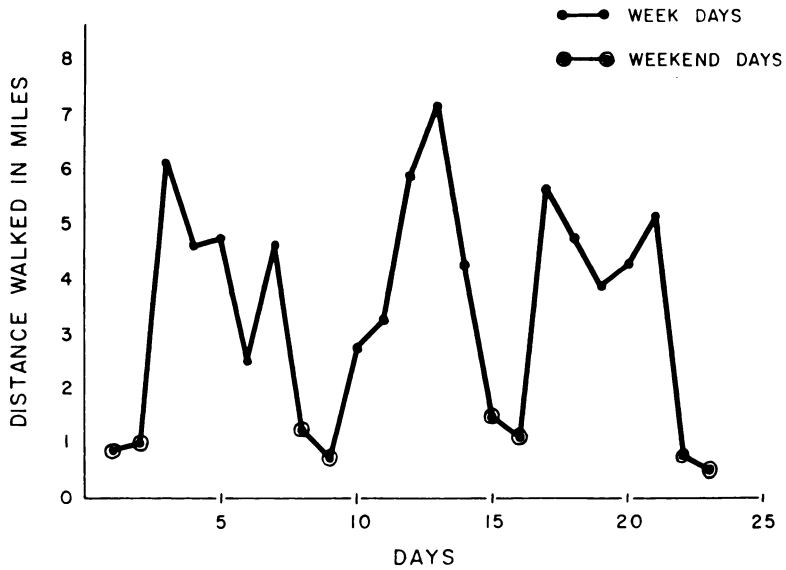

FIG. 3. Variations in physical activity associated with occupational requirements. On the ordinate are measured distances walked in miles, on the abscissa, time in days. The apparently random pattern of Figure 1 is seen to be in part a function of differing amounts of physical activity on weekdays and weekends.

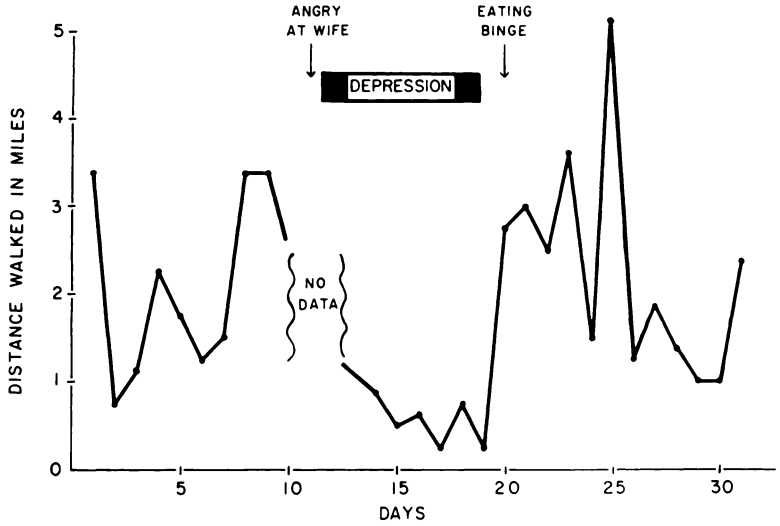

FIG. 4. Decreased physical activity in the course of a depressive reaction. The subject is the thirty year old man, whose activity was shown in Figures 1 and 3, and the scale is the same as in those figures. From an average activity of 2.1 miles per day, the subject fell to 0.5 miles per day, returning to an average of 2.1 miles per day with clearing of the depression. This episode is described elsewhere at greater length.[6]

"Social" determinants of physical activity may be defined as those factors which are derived from the requirements of one's social role. Among physically healthy persons the influence of occupational status can be the single most important determinant of physical activity. This influence may be noted in Figure 3, which presents the apparently random data on physical activity shown in Figure 1. It will be noted, however, that on the weekdays when the subject was busy at work his physical activity was four times greater than that on the weekends when personal preference largely determined his degree of physical activity. Such variations are not found in every person, and people who show them at one time may not at another. But the marked influence of occupation on physical activity emphasizes the need for careful matching for occupation in comparisons of groups of subjects, and for separate analysis of weekday and weekend data on longitudinal studies of individual subjects. Furthermore, the apparent precision of pedometer readings in measuring these differences suggests that the instrument may be of value in classification of occupations.

Under "emotional" determinants, have been classified all types of individual reaction patterns to situations causing stress. A wide variety of environmental stresses seem to decrease physical activity in man, one reaction pattern in obese persons is particularly associated with decreased physical activity. This is depression. Among our obese subjects, almost every episode of depression for which pedometer measurements were available was associated with decreased physical activity. A short-term depressive reaction with decreased physical activity is illustrated in Figure 4.

Most of our observations have been of obese persons; we do not know if this finding of decreased physical activity during depression applies to non-obese persons, as well. Recently, we observed two episodes of depression in non-obese persons which were not characterized by decreased physical activity. This raises an intriguing possibility: is a special kind of depressive reaction, one characterized by decreased physical activity, a pathogenic factor in obesity?

HYPOTHESIS-TESTING STUDIES

Studies carried out in collaboration with Dorris[7] and with Chirico[8] have tested the hypothesis that decreased physical activity

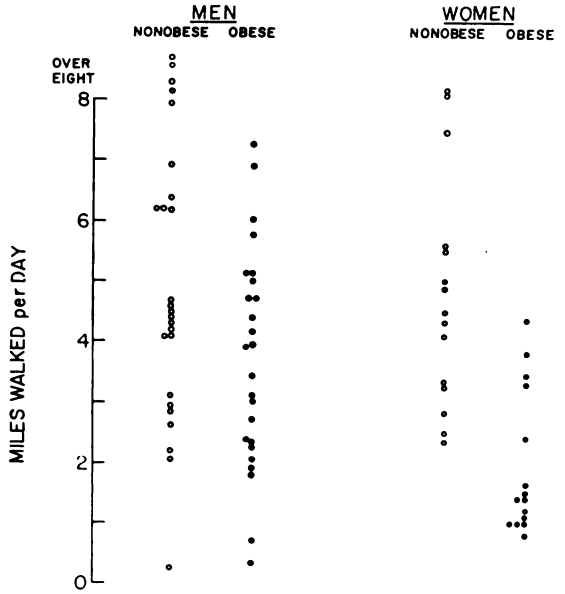

FIG. 5. A comparison of the physical activity of obese and non-obese men and women. Each point represents the average distance walked per day for each subject.

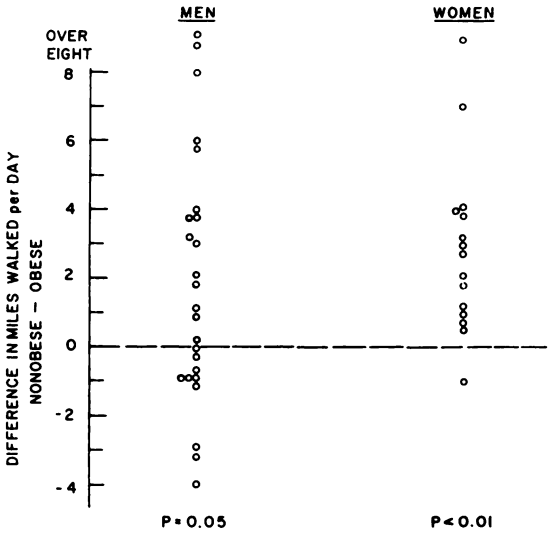

FIG. 6. Further demonstration of the difference in physical activity between obese men and women when compared with non-obese control subjects. (See text.)

plays a role in human obesity.[9–12] Both of these studies were carried out on outpatients from the general medical clinic of a large teaching hospital. Fifteen obese women and twenty-five obese men were matched with respect to age and occupation with an equal number of non-obese women and men from the same clinic. Neither group contained persons with illnesses which might impede activity; the selection was otherwise a random one. Median per cent overweight of the obese women was 52, of the men, 54 per cent. Each subject wore a pedometer for a period of one or two weeks and the distance walked per day was used as the basis of comparison.

The results of the study of women were striking and unequivocal: the obese women were far less active than their non-obese control subjects (Figs. 5 and 6). Figure 5, which shows the distribution of physical activity among the various subjects, reveals that ten obese women walked less than 2 miles per day, a shorter distance than was walked by any of their non-obese control subjects. The mean activity of the obese women was 2 miles per day as compared with 4.9 miles per day for the non-obese women. Since the population on which these observations were made was not normally distributed, and since matched pairs were studied, the data were analyzed by the Wilcoxon matched-pairs signed-ranks test.[13] The data used for this calculation are illustrated in Figure 6. This figure shows the differences in physical activity between each pair of subjects. If there were no differences, the point representing one pair would fall on the 0 line. If the non-obese subject walked farther the point falls above the line, if the obese subject walked farther the point falls below the line. Only once in fifteen times did the obese woman walk farther than her non-obese control subject. The difference between groups is significant at the 1 per cent level of probability.

A study of the physical activity of men revealed differences between obese and non-obese subjects which, although statistically significant, were far less striking than the differences between obese and non obese women. Figure 5 illustrates the similar distribution of the physical activity of obese and non-obese men and contrasts it with the marked difference in the activity of obese and non-obese women.

The mean activity of the obese men was 3.7 miles per day as compared with 6 miles per day for the non-obese men. Although this difference between the means is nearly as

great as that found with the women, it is deceptively large because of the disproportionate effects of four extraordinarily active non-obese men. A more valid comparison is that illustrated in Figure 6 which shows the differences in physical activity between pairs of subjects. It will be seen that non-obese men usually walk farther than their obese partners, and the Wilcoxon test reveals that this difference is significant at the 5 per cent level. However, the difference between obese and non-obese groups is far less striking among men than among women.

Since obese persons must expend more calories than non-obese persons to perform the same amount of activity,[14] the caloric expenditure of obese men due to physical activity may be fully as great as that of non-obese men. One might conclude from this study that whereas decreased physical activity may frequently play a role in the obesity of women, it does so only rarely in men. The origins of obesity in men, thus, may be sought more profitably in the area of food intake.

SUMMARY

A method for the measurement of physical activity in man is described. Such activity shows great variability as compared with the activity of the lower animals. It also appears to be the result of a wide variety of determinants, ranging from what might be called "biological" to "social" and "emotional" ones. Measurement of the physical activity of obese women reveals that they are far less active than non-obese women. A study of men, on the other hand, demonstrates a significant but far less striking difference in physical activity between obese and non-obese subjects.

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DISCUSSION

Dr. Jean Mayer (*Boston, Massachusetts*): I would like to confirm some of Dr. Stunkard's statements about the difference in obesity between men and women, at least in this particular culture. We find that in adolescent girls, again inactivity is an extraordinarily prevalent condition among obese subjects.

About five or six years ago we carried out a study in Brookline, and we have made confirmatory studies in other communities in Massachusetts. Generally we find that the food intake of adolescent girls who are obese is less, on the average, than the food intake of non-obese adolescent girls. However, the first law of thermodynamics is not flouted, because if you look at the other side of the balance sheet, you find that the degree of inactivity of the obese adolescent girls is such that it is easy to account for the extra calories.

This goes with all sorts of other psychological characteristics. We find, for example, that obese girls do not apply to go to college even though they may have the marks for it.

This is a pattern of behavior which we do not find in boys. In boys we find that inactivity is probably less of a factor, and that the psychological makeup of the obese boy is quite different from that of the obese girl. Again to give just one example, the matter of applying to college is not correlated with body weight.

It is difficult to know to what extent this has to do with the pressure of society on the obese child, rather than vice versa.

I think this type of environment may be a poor one in which to study the effect of activity on body weight. I was struck, when we made a study in India a few years ago, by the correlation between body weight and prevalence of obesity and physical activity. In that case, however, the range in physical activity of the subjects studied was enormous as compared with the range that we see in our society, where other effects, such as social factors, obscure the differences due to activity.

DR. JAMES SALTER (*Toronto, Ontario, Canada*): There was one factor I wondered about. Most men work for a living whereas this is not quite the case with women. If your data were replotted, would they show that the obese women were the housewives whereas the non-obese women were the ones who went out to work? I wondered whether there was any correlation there at all.

DR. ALBERT STUNKARD: That is a good question but I am afraid I cannot answer it. We only have information on the occupation of ten of the women we studied and the housewives in this group did not walk less.

DR. VINCENT DOLE (*New York, New York*): I wonder whether it is possible to reverse the interpretation. Rather than thinking of underactivity as being etiologic in causing the obesity, is it possible that the state of physical activity is something of a symptom of the nutritional state?

For instance, it is true that normal people who have been starved show quite quickly a drop-off in physical activity. This seems to be quite compensatory as energy supplies dwindle. We do not normally think of the fat person as being undernourished, because to look at him, he is so overfed. However, it is perfectly possible that these people are functionally undernourished, that the actual supply of fuel to their muscles is low.

One would then say that perhaps a critical experiment in this would be to study the physical activity of fat people during and after a course of weight reduction.

It has been my impression—just as a sort of passing impression without a measurement—that physical activity in fat people, whether or not they have an initial depression of physical activity, is likely to become subnormal when these fat people reduce toward their normal weight, even when they are still somewhat obese.

DR. STUNKARD: The idea that obese persons may be undernourished is an interesting one. I had not really thought of that, and will have to think it over.

Actually, we have a great deal of information on what happens to obese people when they reduce. In almost every single instance in which there has been a weight loss physical activity has gone up. We must have thirty or forty such examples. This is quite symmetrical. Which comes first, is pretty hard to say. My hunch is that whatever makes them go on a reducing diet, also makes them walk more, so there may not be any causal connection between those two factors.