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ABSTRACT

This paper describes a number of factors which go into determining weight. The paper describes what calories are, how caloric expenditure is measured, and why caloric expenditure is different for different people. The paper then outlines the way the body tends to adjust food intake and exercise to maintain a constant body weight. It is speculated that obese people have a regulatory mechanism which makes them eat more than they need. The paper then evaluates exercise as a means of modifying body weight, but.cautions that there must be sound medical reasons to maintain a person at a colorie deficit. Diseases caused or exacerbated by obesity are listed. Norms of ideal weight are then discussed, and it is pointed out that individuals may have different biological set-points regardless of absolute weight. Finally, the paper describes procedures which accurately measure body fat. References are included. (CD)

EXERCISE AND WEIGHT CONTROL*

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The role of exercise in modifying body composition has been of interest to researchers as well as the general public for numerous years. It is often considered that exercise is one of the key variables in the well-known thermodynamic equation: Energy maintenance equals caloric intake + caloric expenditure. The daily energy expenditure for any individual can be ascertained by assessment of daily caloric intake needed to maintain body weight at a constant level, or by estimation of 24-hr caloric expenditure on the basis of time-activity data or actual caloric expenditure. These two methods usually agree within ten percent. It is known that a given specific metabolic substrate (e.g. carbohydrate), in the presence of one liter of oxygen, will yield a given amount of Kcal (Kilocalories) of energy when metabolized in the body or burned in a bomb calorimeter. (For example, 1 gram of carbohydrate metabolized by 1 liter O_2, results in the release of 5.05 Kcal of energy). This establishes the validity of using oxygen uptake as a basis for measuring energy expenditure within certain limits and allows for the easy determination of caloric cost for a variety of activities. There is a large quantity of data on estimates of caloric cost for various activities in the research literature. Use of oxygen uptake to estimate caloric expenditure is usually expressed in net terms, i.e. that amount of oxygen (or Kcal equivalent) over and above the resting requirement. Since oxygen uptake is elevated following exercise above the resting rate, it is necessary to include this portion of oxygen in the

calculations of net caloric cost. However, the fact that a portion of this recovery oxygen uptake can be accounted for by non-energy producing functions (e.g. increased body temperature, oxygen cost of increased circulation, etc.) should be recognized.

It should be mentioned that the expression of energy expenditure can be in terms of liters of oxygen/min or Kcal/min. However, since it is the former which is measured and the caloric coefficient of oxygen varies and is difficult to measure during exercise, the transformation of O_2/min to Kcal/min is subject to error. Nevertheless, it is generally acceptable for non research purposes, to assume that carbohydrate is the preferable metabolic substrate during exercise so that by multiplying the oxygen uptake by 5.05 Kcal/liter, it is possible to arrive at a reasonable estimate of caloric expenditure in Kcal units. There is wide individual variations in caloric expenditure depending on profession, leisure activity, geographical location, age, size, and body weight. Likewise, there is considerable individual variation in caloric consumption with environmental factors, occupation, age, sex, and economic considerations being the major determinants.

It should be realized that for most types of activity where the body is not weight supported, e.g. running, the energy expenditure is "nearly" proportional to body weight. Of course, in experimental research the degree of dependence between energy expenditure and body weight should be determined directly so that the proper term for expressing calorie expenditure can be utilized (Kcal/min, Kcal/kg-body weight/min, Kcal/kg-lean body weight/min, etc.). In some circumstances, use of the ratio term Kcal/kg-body weight/min

would be most unwise to use, as for example often happens in correlational analyses.

For individuals with excess body weight (and increased body fat), the energy cost of exercise will increase at a rate which is surprisingly disproportionate to body weight. This is particularly true during exercise. Thus, for individuals of the same body weight, the more active individual will be more likely to maintain an equilibrated body weight, or even lose body weight. For a sedentary individual, less energy will be expended moving the extra weight and hence weight gain will be more rapid and more pronounced. Consequently, since the caloric expense for a given amount of exercise will be greater for the individual carrying excess poundage, the opportunity is greater for that individual to benefit from increased energy expenditure in the form of weight loss. However, it should be pointed out that it has never been satisfactorily demonstrated whether increased energy expenditure for a given duration and intensity in the over-fat is caused by increased body weight alone. Other factors, perhaps etiological or metabolic, associated with the "obese-hyperglycemic" person may be responsible (e.g. metabolic inefficiency, metabolic imbalance, improper temperature regulation, etc.).

If overweight (over-fat) individuals expend more calories than normal individuals for a given unit of work and these calories are primarily derived from fat metabolism, then this would be revealed in a reduced respiratory quotient (R.Q.) and also greater fat reduction. There are only related data indicating that obese individuals exhibit lower R.Q.'s (respiratory quotient, CO_2/O_2) during

prolonged exercise than do control normal subjects. It is interesting to speculate whether obese individuals exhibit the same metabolic characteristics as the normal individual on a high fat diet in terms of Free Fatty Acid levels and cardio-respiratory response to exercise stress.

The inter-relationships between hunger, food intake, and physical activity have provided some interesting, yet conflicting findings. It is generally believed that in reasonably exercised animals or humans, food intake is slightly increased to a level which is equal to, or even in some cases greater than the energy expenditure of the exercise. This is supported by data which show little if any change in the total body weight of subjects participating in programs of moderate exercise (jogging, etc.). This phenomena has been found to be true regardless of the length of the exercise program. This suggests the possible existence of some kind of "feedback mechanism" for the control of energy balance. This could involve information processing from gastric sensors by way of neural or humoral pathways or both, to the hypothalamus - the hunger-feeding regulatory center. This could also be related to blood glucose levels and to the availability of glucose to the cells mediated by glucose receptors in the cell itself. From an exercise standpoint then, depending on the activity range (sedentary, normal, habitual) the body, via hypothalamic control, maintains energy intake and expenditure at the same level in order to maintain a constant biologically "pre-set" body weight.

In the case of intense habitual physical activity, hunger and food intake appear to be somewhat depressed, at least for a short period following the exercise. This has usually been explained by

increased Free Fatty Acid mobilization during the exercise. However, there is also evidence indicating that in the "long run" if individuals are allowed to freely adjust their energy input, they will do so, stabilizing their body weight (and percent fat) at what appears to be a rather constant "set" level.

In the case of the low activity range (sedentary range) it has been observed that animals will consume more calories than they require and therefore gain weight. This fact has been the basis for the practice known as cooping or penning animals by farmers for the purpose of quick fattening. Surprisingly, humans who are very sedentary, also increase their caloric intake and as a result gain weight. In the example concerning humans, the extent of caloric intake may well be under control of a lipostatic regulatory mechanism, or "long term feed-back control system." There is good reason to believe that this regulatory mechanism may be controlled by the number of fixed lypocytes, determined by genetic propensity, as well as early nutritional experience. In other words, individuals will continue to consume calories until they reach their biological set-point. Of course it is a matter of controversy whether or not the increased caloric intake is caused by lack of exercise or the biological need to reach one's body weight (body fat) set-point.

Those individuals who are below their body weight set-point seem to be in a state of caloric deficit (continual hunger), as indicated by eating behavior and increased levels of resting Free Fatty Acids. This seems to imply that biologically the individual has to reach his body weight set-point before he can be considered "normal." If this were true, then one would expect caloric intake

to increase progressively until the set-point is established, regardless of the level of caloric expenditure (level of activity range). Individuals who are already at their set-point would not increase caloric intake, except to exactly counterbalance any caloric expenditure. There are those who would argue that some obese individuals are below their set-point, despite their apparent excessive body weight. Evidence for this comes from food intake, hunger, and eating habit data. This theoretical position would argue then that exercise is not the most important variable in weight maintenance; rather, it is the degree of deviation from one's set-point.

This does not deny the effectiveness of exercise in modifying body composition; this is well established. Consideration must be given to the notion of any potential deleterious side effects, medical and psychological, of maintaining individuals below a biologically determined set-point via exercise and/or dietary restriction. Aside from social indignation and pressure, medical reasons must be presented to support attempts to maintain individuals in a state of continual energy deficit (below their set-point). The medical support, while not overwhelming, certainly seems to indicate that excessive body fat (regardless of whether it is at, or below the set-point) is associated with increased morbidity and mortality. "Over-fatness" is generally associated with cardiovascular-renal and digestive diseases, diabetes, and disorders of the liver. It also may be a factor in hypertension, gall bladder disease, degenerative joint disease, and certain types of cancer. Of course the possibility exists that the cause for the above

diseases may be continual energy deficit (regardless of absolute body weight, i.e. individuals who are below their set-point are most likely to suffer these diseases), rather than an excessive "energy overload." Further research is needed in this area.

It may turn out that there are individual differences in biological set-points (there is no reason to believe otherwise), thus it would be unwise to attempt to establish norms for ideal body weight or body fat. Nevertheless, typical values for body fatness are available from several sources. Norms based on age-height-weight and physical condition for men and women are not available, thus only values for various age groups can be listed. For males, age 1-5 yr., 1-22% fat; 10-17 yr., 15-20%; 18-25 yr., 15-20%; 25-45 yr., 20-30%; 45-65 yr., 25-40%; 65-85 yr., 25-40%. For women, the respective % fat for the above age groupings are: 1-22%; 15-20%; 25-30%; 30-35%; 30-40%; and 35-40%.

The human body may be thought of as being composed of four major substances; bone, water, fat, muscle and internal organs. There are several indirect methods for estimating the percentage fat in the human body. The most popular, for research purposes, is the procedure of hydrostatic weighing. In this method, body specific gravity is determined using the principle discovered by the famous mathematician Archimedes (an object immersed in water displaces water equal to the volume submerged). Knowing that body fat has a specific gravity of around 0.93 g/ml and specific volume of 1.10 l/kg and the fat (lipid) free tissue has a specific gravity of 1.10 g/ml and a volume of 0.93 ml/g, it is possible to determine the relative proportion of body fat in the body. This procedure

results in body fat calculations that are very similar to the fat content determined from direct chemical analysis. There are several "prediction" formulae, each based on a slightly different theoretical value for the true biological constant for the density of human fat: The most popular being the revised formula of Brozek et. al., % Fat = ((4.570/body density) - 4.142)100). Other techniques for estimating body fat involve regression formulae to predict body density (and hence % fat) from various combinations of skinfold thickness measurements at specific body sites, body diameter and girths, or a combination of both. These anthropometric techniques for estimating body density are accurate enough for screening purposes, resulting in validity coefficients of r = .70 to r = .90 with low to moderate standard errors of prediction, .0071 to .0094 density units.

Exercise in combination with dietary control has been shown to alter body composition, as measured by these various techniques. Usually % fat decreases, lean body weight increases, thus keeping gross body weight at a relatively constant level. If in fact there is a biologically determined set-point which the human organism attempts to reach and maintain, regardless of energy expenditure levels, then this indicates the importance of strict dietary control in maintaining weight below this set-point.

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