Exercise with or without dietary restriction and obesity treatment

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Summary

If short term weight loss is the main treatment objective, it is clear that exercise does not give any success. Dietary restriction can potentially induce much faster rates of weight loss. Adding exercise and especially weight training, to a diet-induced weight loss programme induces small improvements in the change in FFM/FM and possible RMR after a relatively long period. Exercise treatment alone is an option for longer term treatment with relatively small changes in body weight and body composition. Especially in obese subjects energy intake and expenditure compensation does not occur. Although it is not the scope of this review exercise seems to be the ideal option for successful maintenance of a reduced body weight.

Energy cost of daily physical activity

Exercise is perhaps the most powerful physiological challenge for the healthy human body. It requires major metabolic adjustments to increase the supply of oxygen and fuels to the working muscle. From the moment exercise is initiated, energy requirements increase significantly above resting values. Resting Metabolic Rate (RMR) for the adult is fairly close to 3.5 ml of oxygen.kg\(^{-1}\).min\(^{-1}\) or 1 kcal.kg body weight\(^{-1}\).h\(^{-1}\) and the energy cost of activities is frequently expressed as multiples of RMR or METs. An extensive compendium of METs values was recently published.\(^1\)

The continuum of physical activity may vary considerably among individuals and ranges from almost complete absence of activity associated with bedrest to extremely high levels of energy expenditure in world class endurance performers. The 24 h MET value, also frequently called Activity Factor (AF), will vary from 1.1 to 1.2 up to a value of 4.0 to 5.0 which is considered as the energetic ceiling of the human body for exercise over a longer period of time.\(^2\)

In relation to obesity treatment an exercise programme aimed at weight loss, must generate a large energy expenditure. The gross energy cost of activities that can be maintained for more than a few minutes, roughly varies between 8 kJ.kg\(^{-1}\).h\(^{-1}\) (leisure walking) and 85 kJ.kg\(^{-1}\).h\(^{-1}\) (running). However, to expend 85 kJ.kg\(^{-1}\).h\(^{-1}\) for a longer period of time, the maximal oxygen uptake of an individual has to be above 60 ml.kg\(^{-1}\).min\(^{-1}\) which indicates that in general only well-trained young subjects will be able to expend this amount of energy per minute. An individual with a VO\(_{2}\)max of 35 ml.kg\(^{-1}\).min\(^{-1}\), average for a 40 years old female, is not able to expend more than 30 kJ.kg\(^{-1}\).h\(^{-1}\) (corresponding with 70% VO\(_{2}\)max for a longer period of time). For this individual fast walking may be as effective as running or cycling. Exercising 1 h per day for a 70 kg not-very-fit person, may therefore increase daily energy expenditure somewhere between 1.2 and 1.7 MJ. Assuming that the extra energy expended is not compensated by an increased energy intake and that the energy equivalent of weight loss is 25 MJ.kg\(^{-1}\). This means that about 0.3 kg body weight is lost per week by incorporating a 1 h vigorous training programme for 5 days a week in one's daily activity pattern. Reviewing the literature, Epstein and Wing\(^2\) found in 16 studies with five or more subjects, a mean weight loss of 0.1 kg per week. Wilmore\(^4\) reviewed 16 and 37 training studies in respectively women and men and found even lower values of approximately 0.07 kg per week. In both reviews it became clear that obese individuals lost more weight than lean individuals. This difference in weight loss may partly be explained by the extra cost of exercise at a higher weight, as is the case in overweight subjects. This was demonstrated in an elegant study by Weigle\(^5\), where the experimental subjects wore a vest with weights compensating exactly for the body weight lost due to a 3 MJ diet. 24 h Energy expenditure dropped with 1.7 MJ in the experimental group while in the control group with identical weight loss a decrease of 3.8 MJ was found. The loss of body weight reduced the energy costs of physical activities sufficiently to account for more than half of the reduction in 24 h energy expenditure.

Daily physical activity and obesity

Based on the energy kinetics of exercise it is clear that training is far less effective in reducing body weight than dietary restriction and from the studies done so far the picture is even more discouraging to start an exercise programme to lose weight.

A number of factors could play an important role in these lower than expected results. One approach to this question is to address the opposite question whether
a reduced physical activity proceeds or follows the onset of obesity.

If expenditure levels are not lower in obese compared to lean individuals, it is not realistic to increase expenditure to even higher than normal levels in the obese. Several studies have addressed this question. Of the 16 studies cited in a review of Pacy et al.6, 6 reported lower activity levels in obese subjects and 10 failed to find significant differences. One of the major problems in this type of comparison is the difference in weight which ultimately leads to higher expenditure levels in an obese individual for the same activity, for example walking 1 km at 4 km·h⁻¹. No differences in energy expenditure were found in the studies of Waxman and Stunkard3 and Saris et al.7 between obese and lean children when corrections were made for body mass. The observation scores of physical activity however, were significantly lower in the obese groups.

Recently the first studies were published about energy expenditure and AF levels of obese and lean children, using the accurate doubly-labeled-water (DLW) method to estimate energy expenditure over a relatively long period of 14 days. So far, no differences have been found between the lean and obese groups of children.8 This observation earns even more credit knowing that with the same DLW method significantly lower AF values were found in a group of children with cerebral palsy, known for the severe restriction in physical activity.

In general, one can conclude that although definite data are lacking, there is growing evidence that in children, once obesity is established, physical activity is restricted but the extra weight will compensate for a great deal the decrease in energy expenditure.

Exercise and energy intake and expenditure

Reviewing the literature on the effects of exercise alone on body weight, one has to consider two other important factors on both sides of the energy balance equation which can alter body weight drastically due to increased physical activity. Does exercise produce energy intake and expenditure compensation? The first by an even or more than proportionally food intake. The latter by a decrease in activity outside the training hours leading to an equal or lower level of energy expenditure.

The number of studies in which individuals were trained and which have actually measured food intake is limited. The measurement of food intake is tedious and not very precise, leading to many questions.

Although it is commonly believed that exercise gives an anorectic response and thus diminishes food intake, only few data are available to confirm this. Under carefully controlled conditions in a metabolic ward, Woo et al.8 did not find an increase in energy intake in ad libitum eating obese women subjected to a walking programme, with an energy cost calculated to increase energy expenditure with 25%. These findings have been confirmed with prolonged-duration exercise in obese women10 and obese men.11 It is suggested that starting a training programme, especially in the obese state will induce an energy deficit at least for a period of time, contrasting to the normal lean state where prolonged exercise is associated with energy intake compensation even if energy expenditure is extremely high.2

Secondly, it is clear that, if training is compensated by inactivity outside the training hours, the energy balance is negative influenced leading to no extra increase in the 24 h energy expenditure.

We studied this question in two adult groups and in a group of 10 year old obese boys following a training programme. In lean and obese women, no indication of compensation in normal daily activities was detected while in lean males, training stimulated physical activity during the non-exercising part of the day.12,13 In obese boys the stimulating effect on energy expenditure was even greater than in the adult groups. The extra expenditure due to training was effectively doubled outside the training hour.14 Some have suggested that this relative large increase in expenditure can be explained by the so-called Excess Post-Exercise Oxygen Consumption (EPOC) because energy expenditure does not immediately return to pre-exercise levels after a bout of exercise. Recently Poehlman et al.15 reviewed the literature on this matter and they concluded that the greater the exercise perturbation, the greater the magnitude of the EPOC. However, considering that the exercise prescription for the general population consists of low to moderate exercise, EPOC does not produce a substantial contribution to 24 h energy expenditure (15-300 kJ).

Exercise and body composition

Another important factor which has to be taken into account is the change in body composition as a consequence of regular exercise. Since Fat Free Mass (FFM) is the major determinant of RMR, it is of importance to assess whether effects on energy expenditure are mediated by changes in body composition. Ballor and Keesey16 concluded from their meta-analysis that regular exercise leads to a modest weight and fat mass (FM) loss and increase in FFM, depending on duration and intensity of exercise and initial body fatness. Especially weight training produced a more substantial increase in FFM. These effects will change energy expenditure and more in particular RMR. The effects of regular exercise on RMR, independent of the effects on body composition, are more controversial. It is suggested that regular exercise may lead to a higher RMR as a consequence of a better training status leading to a higher aerobic power. Poehlman et al.17 hypothesized that RMR could be increased when the energy turnover rate is high, con-
current with the maintenance of energy balance. In support of this hypothesis is the observation of Tremblay et al\textsuperscript{14} showing a 6.6% drop in RMR in highly trained subjects who followed 3 days of detraining. If there is an effect of training status on RMR, one should also expect an effect of the level of physical activity on RMR due to the fact that a higher level of daily physical activity will increase aerobic fitness. In general, cross-sectional and longitudinal studies have failed to provide support for this view. Poehlman et al\textsuperscript{15} suggested that differences in experimental design and especially the lack of precise methods to measure daily physical activity, may have obscured such a relationship. In a recent study by Westerterp et al\textsuperscript{19} using the DLW method in sedentary and moderately active individuals, a positive relationship was found between activity levels and RMR. This observation found with the use of the precise and valid DLW technique, underlines the suggestions of Poehlman et al.\textsuperscript{15}

Even more controversial is the issue whether obese individuals have a defective thermogenic response to food (TEF) and whether regular exercise can potentiate the effect of TEF.

A wide variety of answers to these questions has been found. A salient finding of these studies is the relatively low reproducibility of the measurement of TEF. Intra-individual coefficients of variation of around 30% may pose serious problems for studies that aim to determine within-person responses to the potentiating effect of exercise. In addition, the lack of standardized protocols also contributes significantly to the existing confusion.

A final interesting observation regarding the effect of regular exercise on energy balance and body weight, is the consistent finding of a sex dimorphism. In general, men respond better than women.\textsuperscript{16} Meyer et al\textsuperscript{13} showed that this is not due to differences in net energy costs of the exercise itself. Gender differences in adipose tissue metabolism may play a role. Epinephrine-stimulated lipolysis was considerably more pronounced in males (+66%) than in females (+46%) after a 20-week aerobic exercise programme.\textsuperscript{19} Differences in adipose tissue lipolysis response to exercise may play an important role. However, mechanisms responsible for this apparent gender difference are poorly understood and additional research is clearly warranted.\textsuperscript{20}

The role of exercise in the dietary treatment

Since 1990 at least 7 papers have reviewed the effects of additional exercise to a diet-induced weight loss programme in about 20 well-designed studies completed on this topic.\textsuperscript{21-27} The major findings will be reviewed briefly in order to avoid repetition of arguments.

As already shown in the classical starvation study of Keys, energy restriction produces a rapid and substantial fall in RMR, mainly caused by a loss of FFM. In the analysis of 515 subjects from 29 studies Prentice showed clearly that this self-protecting adaptation in decrease in FFM and energy expenditure is a real phenomenon. Increasing the energy deficit seems to cause a greater loss of lean tissue. Adding exercise to the diet-induced weight loss is especially focussed on the preservation of FFM with a possible extra loss of FM. The observed differences are relatively small due to the fact that the exercise only adds 10 to maximal 20% to the energy deficit. With the existing uncertainties in the body composition measurements, the risk of finding no effect is relatively high, especially when the number of subjects is small and the period of intervention short as was calculated by Van Dale et al.\textsuperscript{28} In most studies, exercise added to diet restriction did not produce a smaller drop in RMR.

One should expect that this also implies that no differences in decrease of FFM is found as we have found in our pooled data set of 4 studies.\textsuperscript{29} However, Ballor and Poehlman\textsuperscript{26} showed in their meta-analysis of 46 studies a relatively strong effect of conservation of FFM (50% lower weight loss (% total weight) as FFM), while only minor effects could be detected in weight and FM loss.

Possibly these unexpected findings are related to the relatively large data base, not using very strict criteria of entering the analysis.\textsuperscript{30}

The observed extra effect of weight training on FFM was confirmed recently in a well-designed study of Donnelly et al.\textsuperscript{31} They showed that sequential use of first weight training for 4 weeks and endurance training for 7 weeks results in a 11.4% lower FFM loss. They concluded that the changes are small and the clinical importance is presently unknown.

References


