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Sports & exercise medicine switzerland

published online on 01.12.2022
https://doi.org/10.34045/SEMS/2022/21

REVIEW

Why exercise by itself is often ineffective for weight loss but crucial for weight management

EXERCISE IS MEDICINE

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Abstract

The prevalence of obesity is increasing worldwide, and excess body weight is associated with a substantially increased risk of adverse health conditions. Exercise supports the prevention and management of obesity; however, when used for weight loss, exercise (even at high volumes) is usually relatively ineffective, frequently producing less weight loss than expected based on measured energy expenditure. The difference between observed and expected weight loss is called compensation and it is

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https://doi.org/10.34045/SEMS/2022/21

primarily caused by increases in energy intake in response to exercise (compensatory eating). On the other hand, it has been shown that energy balance and body weight are better regulated in individuals with moderate to high levels of physical activity (i.e., energy intake = energy expenditure) compared to those with a sedentary lifestyle (energy expenditure < energy intake), demonstrating that physical activity and exercise are crucial for long-term maintenance of a healthy weight. Weight loss approaches should combine dietary components (calorie restriction) and physical activity for increased success. Calorie restriction facilitates weight loss while physical activity can support the conservation of fat-free mass to avoid a state of increased hunger, often occurring following calorie restriction interventions due to the associated loss in fat-free mass, which ultimately encourages weight regain.

Zusammenfassung

Die Prävalenz von Adipositas ist in den letzten Jahren weltweit dramatisch angestiegen, und übermässiges Körpergewicht (Körperfett) ist mit einem deutlich erhöhten Risiko für langfristige gesundheitliche Beeinträchtigungen verbunden. Körperliche Bewegung unterstützt die Prävention und Behandlung von Adipositas; als alleiniges Mittel zur Gewichtsabnahme ist Bewegung (selbst bei hohen Trainingsumfängen) in der Regel jedoch relativ unwirksam und führt häufig zu einem geringeren Gewichtsverlust als aufgrund des gemessenen Energieverbrauchs zu erwarten wäre. Die Differenz zwischen dem beobachteten und dem erwarteten Gewichtsverlust wird als Kompensation bezeichnet und ist in erster Linie auf eine erhöhte Energiezufuhr als Reaktion auf das Training zurückzuführen (kompensatorisches Essen). Andererseits hat sich gezeigt, dass der Energiehaushalt und das Körpergewicht bei Personen mit mässiger bis hoher körperlicher Aktivität (d.h. Energieaufnahme = Energieverbrauch) besser reguliert sind als bei Personen mit einem sitzenden Lebensstil (Energieverbrauch < Energieaufnahme), was verdeutlicht, dass körperliche Aktivität und Bewegung für die langfristige Aufrechterhaltung eines gesunden Gewichts entscheidend sind. Ansätze zur Gewichtsabnahme sollten ernährungsbezogene Komponenten (Kalorienrestriktion) und körperliche Aktivität kombinieren, um den Erfolg zu steigern. Eine Kalorienrestriktion erleichtert die Gewichtsabnahme, während körperliche Aktivität die Erhaltung der fettfreien Masse unterstützen kann. Dies kann wiederum helfen, das verstärkte Hungergefühl zu reduzieren, das nach einer Kalorienrestriktion aufgrund des damit verbundenen Verlusts an fettfreier Masse häufig auftritt und letztlich eine erneute Gewichtszunahme begünstigt.

Introduction

Overweight and obesity rates have reached epidemic proportions worldwide. In Europe, approximately 60% of citizens are either overweight (body mass index [BMI] ≥25 kg/m^2) or have obesity (BMI ≥30 kg/m^2) [1]. It has been estimated that the worldwide obesity prevalence will reach 18-21% by 2025, suggesting that over one billion people will be affected by obesity [1]. Obesity is associated with an increased risk for serious health conditions, presenting a substantial public health and economic burden worldwide [2]. Weight loss is one of the most important reasons why individuals with overweight and obesity choose to engage in an exercise or physical activity (PA) program [3], and the fitness industry frequently advertises specific ‘weight loss workouts’ to target these individuals. Regular exercise and PA are associated with a plethora of health benefits, including improvements in psychiatric, neurological, metabolic,

published online on 01.12.2022
https://doi.org/10.34045/SEMS/2022/21

cardiovascular, respiratory, and musculoskeletal conditions and diseases as well as many cancers are well established [4]. However, despite the many important health benefits of exercise and PA, by itself, exercise is often ineffective for weight loss, with most individuals losing less weight than expected based on measured energy expenditure, and some individuals even gaining weight after engaging in an exercise or PA program [5]. Villareal et al. showed that average weight loss during a 1-year randomized controlled trial (N=107) was only around 1% (not significant) following an exercise intervention (3x90min per week) compared to around 10% following a diet intervention (daily energy deficit of 500-750 kcal), independent of whether or not the diet intervention was combined with an exercise program [6].
Various factors contribute to the seeming ineffectiveness of exercise in producing weight loss. Most importantly it is due to an insufficient energy deficit primarily caused by changes (increases) in energy intake in response to the exercise program that (over-) compensate the exercise-induced energy deficit and negate weight loss.

Energy-related aspects of weight loss

Both PA, which is defined as any bodily movement produced by skeletal muscles [7], and exercise, a subset of PA that is planned, structured, and repetitive and aims to improve or maintain physical fitness [8], increase energy expenditure. The amount of energy expenditure during exercise is dependent on the type, intensity, and duration of the activity. One metabolic equivalent (MET) equals an oxygen uptake of 3.5 mL/kg/min or 1 kcal/kg/h, which roughly corresponds to a person's resting metabolic rate. For example, at a running speed of 12 km/h (11.5 MET), a person weighing 70 kg would expend ~400 kcal during a 30-min run, whereas a person weighing 90 kg would expend ~ 520 kcal [9]. Of course, the exercise-related energy expenditure (EEE) only accounts for parts of the total daily energy expenditure (TDEE), with resting metabolic rate (RMR; ~60-70% of TDEE), thermic effect of food (TEF; ~5-10% of TDEE), and non-exercise activity thermogenesis (NEAT = TDEE−[RMR+TEF]), making up the other components. As illustrated in *Figure 1*, regular PA and exercise increase TDEE; however a moderate PA level (PAL=1.8) only increases TDEE by around 20% compared to a sedentary lifestyle and even in very active individuals such as competitive athletes with a training load of 2-3h per day, TDEE is only about 50-60% higher than in physically inactive individuals. This illustrates why calorie restriction diets such as a very low-calorie diet (VLCD, ~600-800 kcal/d) and even more moderate diet approaches (1600-1800 kcal/d) can induce a much greater calorie deficit, which is subsequently reflected in more substantial weight loss.

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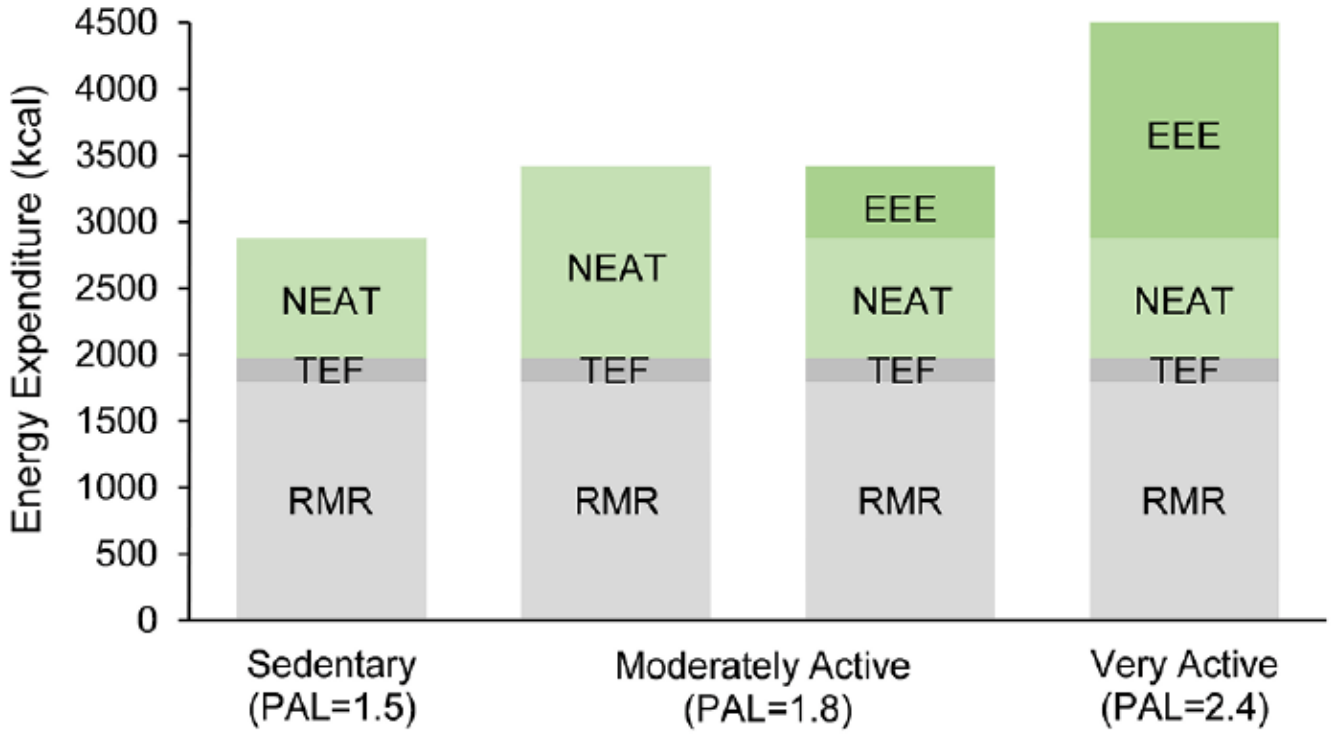

Figure 1: Relative contribution of exercise-related energy expenditure and non-exercise activity thermogenesis to total daily energy expenditure. EEE, energy-related energy expenditure; NEAT, non-exercise activity thermogenesis; PAL, physical activity level; RMR, resting metabolic rate; TEF, thermic effect of food

Additionally, regular exercise alters the energy deficit necessary to lose 1 kg of weight. During a typical calorie restriction intervention, 3/4 of the lost weight consists of fat mass while 1/4 consists of fat-free mass (FFM). In a weight loss intervention that combines calorie restriction and exercise, this ratio shifts to approximately 7/8 (fat mass) and (1/8 FFM), and in an exercise intervention without calorie restriction, almost all FFM is conserved, and the weight loss is almost exclusively due to a reduction in fat mass [10]. While the conservation of FFM is, of course, positive and beneficial for health and longevity [11], it explains the slower rate of weight loss. Because fat mass has a substantially higher energy density than FFM (9400 vs. 1800 kcal/kg) [12], an about 25% greater energy deficit is needed to lose the same amount of weight solely from exercise compared to solely from calorie restriction.

Further, while PA and exercise increase TDEE, most individuals increase energy intake in response to the PA or exercise program [13], which reduces or even negates the exercise-induced energy deficit and consequently the weight lost from exercise (weight compensation). The 6-month E-Mechanic (Examination of Mechanisms of Exercise-Induced Weight Compensation) study examined the mechanisms of weight compensation by comparing two exercise interventions with different weekly energy expenditures: 8 kcal/kg/wk (8KKW) and 20 kcal/kg/wk (20KKW) [5]. For an individual with a body weight of 70 kg, this would equate to a total weekly EEE of 560 kcal (8KKW) and 1400 kcal (20KKW), respectively. The study found that only 58% (8KKW) and 77% (20KKW) of participants lost work at all during the 6-month intervention and that in 76% (8KKW) and 90% (20KKW) of participants weight compensation (less weight loss than expected based on measured EEE) occurred. On average, participants in the 8KKW group lost 0.4 kg (vs. the expected 1.9 kg) and participants in the 20KKW group lost 1.6 kg (vs. the expected 4.3 kg).

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Measurement of energy intake via doubly-labeled water further showed that participants increased their daily energy intake by 91 kcal (8KKW) and 124 kcal (20KKW) on average compared to baseline [5]. Various factors contribute to compensatory eating, for example, physiological changes such as an increased release of appetite-stimulating hormones or psychological factors such as food reward after an exhausting workout [14].

Effect of exercise on eating behavior

As early as the 1950s, Jean Mayer found that an increased TDEE leads to an increased energy intake, but that conversely, a decrease in TDEE does not cause a reduction in energy intake. Specifically, in experiments on factory workers in India, Mayer et al. found the greatest energy intake both in workers with the highest work-related energy expenditure and those with the lowest work-related energy expenditure. Those workers conducting light-to-moderate work had the lowest energy intake [15]. This J-shaped association between energy expenditure and energy intake has been confirmed in several studies [16], demonstrating that becoming sedentary does not downregulate energy intake (unregulated zone of energy intake), which consequently leads to higher body weight and BMI over time. In the unregulated zone, non-homeostatic factors such as the availability of food influence food intake [17]. Increasing PA on the other hand improves satiety signaling, and homeostatic factors (i.e., factors to maintain body weight) influence energy intake (regulated zone) [17,18]. Importantly, this association also holds for the intake of sugar and nutrient-dense foods. An analysis of NHANES (National Health and Nutrition Examination Survey) data further showed *(Figure 2)* that intake of sugar and sweetened beverages (energy-dense and low-nutrient foods) was highest in sedentary individuals and those with very high PA levels, while it was the lowest among moderately active individuals [19]. Conversely, intake of nutrient-dense, “healthy” foods (fruit and vegetables, fiber, whole grain, dairy products) increased from sedentary to moderately active but then remained stable despite further increases in energy intake *(Figure 2).* Finally, and consistent with the Mayer curve, a secondary analysis of the E-Mechanic study found that PA behavior before participating in the 6-month exercise intervention predicted weight compensation, with greater amounts of habitual PA (moderate-to-vigorous intensity) being associated with less weight compensation and more weight loss during the intervention [20].

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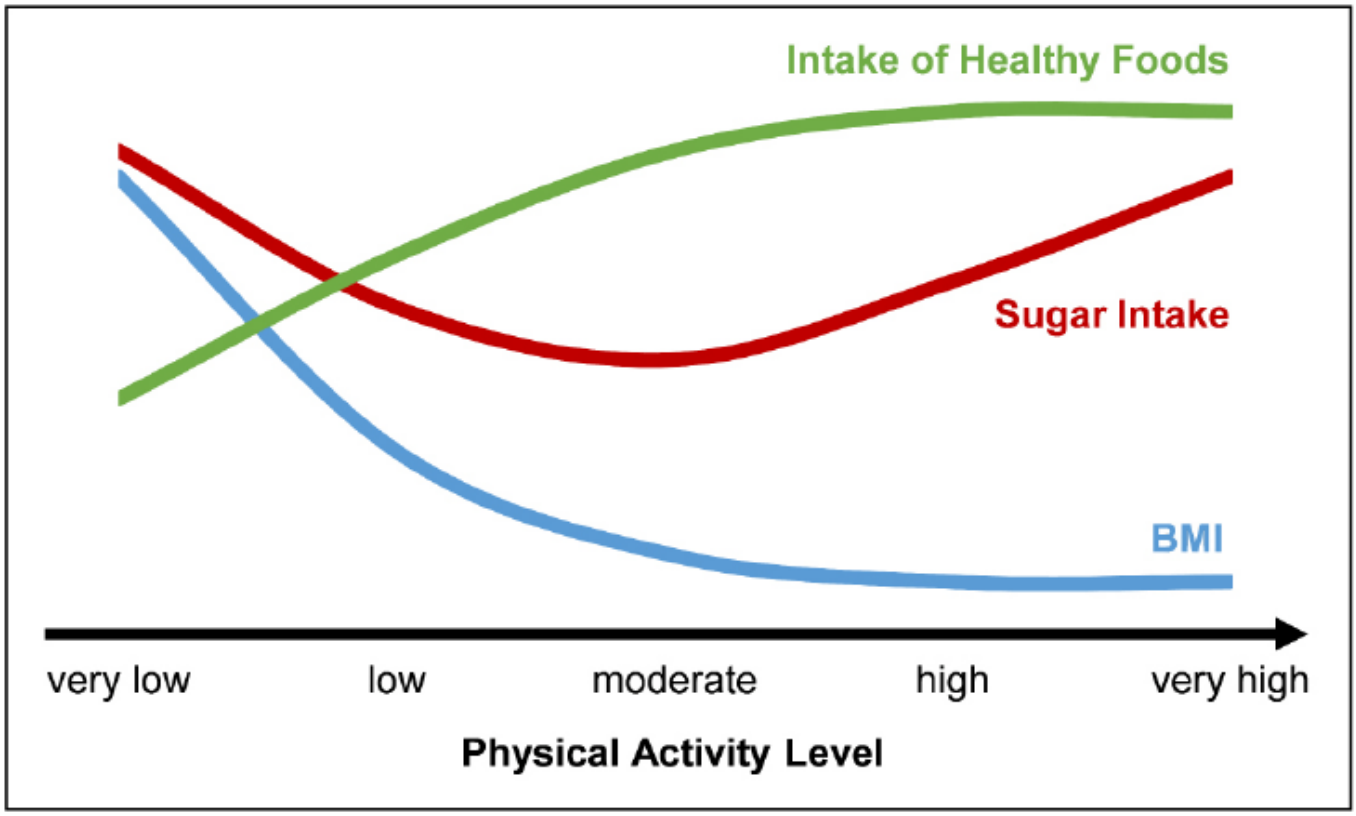

Figure 2: Intake of added sugar and healthy foods (fruit and vegetables, fiber, whole grain, dairy products) as well as BMI at different levels of physical activity. Figure modified from Koehler et al. (2019)[19].

In addition to affecting general long-term eating habits and energy balance, PA and exercise also acutely affect how much and what we want to eat. A recent study examined hypothetical food choices before, immediately after and 30 min after a 45-min exercise session on a bike ergometer (60% VO2peak) compared to a rest condition of identical duration [21]. Specifically, participants viewed a series of food images displaying hypothetical food choices with varying palatability and energy density (sweet/low fat, non-sweet/low fat, sweet/high fat, and non-sweet/high fat, respectively) and rated their food amount preference at these time points after each study condition (bike ergometer vs. rest). The results showed that the selected food amount (kcal) increased after the exercise condition, with increases of 23% (immediately after) and 30% (30 min after), whereas the rest condition did not induce such increases in food amount preference [21]. Another field-based study asked participants to choose between a “healthy” snack (apple) and an “unhealthy” snack (brownie) either before or after a gym visit, with the consumption of the snack taking place after the gym visit in either case [22]. The proportion of participants, who chose the healthy snack option (to be eaten after the gym visit) decreased from 74% (choice before the gym visit) to 55% (choice after the gym visit) and the proportion of the unhealthy snack option increased from 14% to 20% from before to after [22]. These findings are consistent with the behavioral phenomenon of *immediate gratification* that leads to more impulsive food choices in a state of increased hunger, irrespective of longer-term consequences, and has been linked to an increased risk of obesity [23]. Further, these results suggest that food choices are generally better (i.e., less food, healthier choices) before compared to after exercise. This may have implications for clinical practice, as food choices and preparation before exercise

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may help reduce compensatory energy intake and thereby support long-term weight loss through exercise.

Exercise and long-term weight management

While the aforementioned phenomena are responsible for a slowed initial weight loss through exercise, this explains at the same time, why (the addition of) PA and exercise are crucial for long-term weight management and advantageous compared to mere calorie restriction interventions. Importantly, the conservation of FFM through exercise can help prevent rapid weight regain after the end of the calorie restriction intervention. That is because the loss of FFM during a mere calorie restriction intervention leads to a state of hyperphagia that persists until FFM is fully recovered. The recovery of FFM is inevitably accompanied by fat deposition, causing weight regain [24]. Conserving FFM during a weight loss intervention through moderate-to-high levels of PA will consequently facilitate better maintenance of the new weight, as demonstrated in a follow-up study to a large weight loss intervention [25]. Participants in that study who were highly active (2500 kcal/wk) during the 6-month behavioral weight loss intervention had a lower weight 2 years after the end of the intervention compared to those who were moderately active (1000 kcal/wk) during the intervention. Even more impressive, those participants who sustained the high PA levels during the 2 years after the weight loss intervention maintained 12 kg weight loss, whereas those who ceased to be physically active returned to their baseline weight [25].

Conclusions

Despite the numerous positive effects in the prevention and treatment of various diseases, the effects of PA and exercise on body weight are at least in the initial period of weight loss interventions small to negligible. It is, therefore, crucial to lower (unrealistic) expectations of rapid exercise-induced weight loss in clinical practice and to counteract compensatory eating behaviors, which further reduce the weight lost during an exercise-based weight loss intervention. However, the positive effects of PA and exercise for long-term weight management are undisputed, and lasting benefits for energy balance are particularly achieved through the lifelong implementation of a physically active lifestyle.

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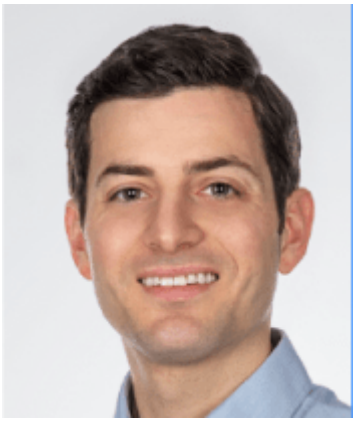

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COMPENSATORY EATING ENERGY BALANCE WEIGHT COMPENSATION WEIGHT LOSS WEIGHT MAINTENANCE