



PROTEIN AND EXERCISE IN WEIGHT LOSS: CONSIDERATIONS FOR ATHLETES

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- Weight loss is not uncommon in athletes and is practiced most often with the goal of increasing efficiency of movement with the realization that, for many sports, high strength, endurance or power to body weight ratios can enhance performance.
- Weight loss can be accomplished “passively” by restricting energy intake, and there are numerous propositions for diet-only plans claiming superiority. Some of these have been tested in head-to-head studies, and there are multiple dietary patterns that allow weight loss.
- However, weight loss via diet alone results in the loss of both body fat and lean tissue, which would likely include skeletal muscle and, particularly if calcium and/or vitamin D intake is inadequate, the loss of bone mass.
- Weight loss can also be accomplished through increasing the volume/intensity of training without changing dietary intake, or as is more common, in combination with a reduction in dietary energy intake.
- Timed ingestion of protein, as close as possible following exercise, as well as greater overall daily dietary protein intake can mitigate losses in muscle mass, which may be relevant to some athletes.
- While in an energy deficit, the interactive effects of exercise and protein can, under some circumstances, allow the simultaneous loss of body fat and gain of skeletal muscle; however, this is not a universal observation.
- The speed of weight loss, and hence the magnitude of the caloric deficit, can affect the ability to retain lean mass, and if the caloric deficit is too large then dietary protein may have little effect in mitigating losses of lean tissue mass.
- It is unclear whether loss of lean tissue compromises exercise performance; however, limited evidence suggests that the maintenance of training would mitigate most performance declines except in rapid weight loss or in cases of extreme loss (>20% of body weight).

INTRODUCTION

Weight loss is a goal of some athletes with the recognition that a high strength/power/endurance to body weight ratio is desirable to enhance exercise performance in a variety of sports. The first law of thermodynamics dictates that weight loss is accomplished by shifting energy balance in favor of increasing energy expenditure to exceed energy intake. With two degrees of freedom with which to operate, people desiring weight loss could choose to either increase their expenditure through a greater volume or intensity of training, to decrease their energy intake or to combine the two. Restricting dietary intake to consume less energy is a common practice and has been shown numerous times to reduce body weight. Restricting dietary energy intake to result in a negative energy balance results in a composition of lost weight (excluding changes in body water) that is for most part body fat (~70-80%) but also includes lean tissue (~20-30%), which is mostly comprised of skeletal muscle (Weinheimer et al., 2010). While the loss of body weight per se is generally viewed as beneficial from a health perspective, if the individual is overweight or obese then the components of the weight lost is perhaps as important a consideration in terms of health. In addition, and from an athlete's perspective, the composition of the weight lost is also important due to the recognized role that skeletal muscle plays in sport performance. In general, athletes would likely prefer to lose only body fat and retain skeletal muscle, a pattern that we have referred to as “high quality” weight loss (Churchward-Venne et al., 2013). It

is also important to recognize that during weight loss there is the possibility, particularly if a diet with sub-optimal calcium and vitamin D intake is consumed, that bone loss could occur at a rate more rapid than when in energy balance (Cifuentes et al., 2004). While it is acknowledged that in certain situations of weight loss, athletes may not be concerned about skeletal muscle loss, which could be regained through training, the accelerated loss of bone may be a predisposing factor in the development of osteoporosis (Otis et al., 1997). It is most often the case, however, that athletes and coaches would be concerned less about measuring the actual composition of weight loss as long as exercise performance was improved or at least did not decline. Regrettably, we know very little about how weight and particularly high-quality weight loss affects exercise performance. The purpose of this Sports Science Exchange article is to explore the role of diet and exercise strategies in promoting high-quality weight loss; defined here as weight lost that comprises the highest possible ratio of fat to lean tissue and bone mass that does not compromise exercise performance.

DIETARY STRATEGIES FOR WEIGHT LOSS

The usual strategy for weight loss is to reduce dietary energy intake to levels that provide energy below that which is expended in any given day. Unlike non-athletes, many athletes would have a large component of their daily energy expenditure (DEE) accounted for by

exercise energy expenditure (EEE) with the balance coming from resting energy expenditure (REE). In contrast, non-athletes would, in most cases, find that their REE comprised the largest proportion of their DEE (Heymsfield et al., 2002). As a result, the decline in REE that accompanies weight loss in non-athletes (Wycherley et al., 2012) means that initial pre-weight loss caloric restriction is sharply reduced as a result of the decline in REE. Simulations of changes in body weight (Hall et al., 2011) have recently been described to have attempted to take into account the reduction in REE and its impact on rates of weight loss (<http://bwsimulator.niddk.nih.gov/>). Such models more accurately predicted weight loss patterns than the “static” and unrealistic model of weight loss that suggests 1lb (0.454 kg) of fat loss/wk requires a daily caloric deficit of 500 kcal/d to total 3,500 kcal/wk (Hall et al., 2011).

An important question is whether a particular dietary approach, comprising specific ranges of macronutrients, has an advantage over another in terms of weight loss as some would suggest (Taubes, 2013). Meta regression (Krieger et al., 2006) and meta analyses (Wycherley et al., 2012) have shown that diets that are higher in dietary protein than is regularly consumed may offer strategic advantages, namely a greater fat mass loss and lean mass preservation during energy restriction. The use of the term “higher” to describe the protein in these diets refers to a protein intake that is raised from 15% of the total dietary energy intake, which is a regular population-level protein intake in most developed countries (Fulgoni, 2008), to between 25-35% of energy intake. Intakes of protein between 10-35% of total dietary energy intake – defined by the Acceptable Macronutrient Distribution Range (AMDR) – are associated with good health by the Institute of Medicine in the US-Canadian Dietary Reference Intakes (Institute of Medicine, 2005). It is worth acknowledging that intakes of protein comprising 25-35% of energy intake will result in intakes greater, and in some cases much greater, than the Recommended Dietary Allowance (RDA) of 0.8 g of protein/kg/d. Nonetheless, as has been argued, the RDA likely suggests a minimum amount of protein to establish nitrogen equilibrium, which is a variable that athletes and coaches are not concerned with (Phillips, 2012). Instead, as those that set the guidelines for the protein RDA (Institute of Medicine, 2005) focused on minimally satisfying protein requirements, the goal with athletes would be to promote optimal adaptation to their exercise training stimulus (Phillips, 2012). Thus, during a weight loss program to promote higher-quality weight loss, the ingestion of protein, usually at the “expense” of carbohydrate or fat, is one strategy that athletes could use to mitigate losses of lean mass and promote fat mass loss.

EXERCISE STRATEGIES FOR WEIGHT LOSS

Increasing EEE can, if energy intake is kept constant, result in weight loss and this has been shown numerous times with some of the most convincing data to date coming from the Midwest Exercise Trials (Donnelly et al., 2003; 2013). In these trials, subjects used exclusively aerobic exercise during their training and showed

substantial weight loss that, in men, was comprised for the most part of body fat (94%). The exercise regime was, however, less effective in promoting high-quality weight loss in women, with 76% of their weight loss comprising body fat. Nonetheless, these trials provide proof of principle that aerobic exercise alone is an effective stimulus for losing body fat (Donnelly et al., 2003; 2013).

COMBINING DIETARY AND EXERCISE STRATEGIES

Mettler et al. (2010) conducted a study in young men engaging in resistance training during a 2 wk period of hypoenergetic dieting during which subjects consumed ~40% less dietary energy than required for stable weight. Subjects were divided into groups receiving either 1.0 or 2.3 g protein/kg body mass/d with equivalent dietary carbohydrate (3.3-3.4 g carbohydrate/kg/d). Those consuming the lower quantity of protein lost more total body weight, but also more weight as lean mass than those consuming the higher protein diet. A factor that was not strictly controlled in this trial, however, was the quantity, intensity and conduct of training. Instead, participants were asked to simply maintain their training, which consisted mainly of resistance training, making it difficult to know what influence the subjects' training habits may have had on the results (Mettler et al., 2010).

Garthe and colleagues (2011) subsequently conducted a study in which athletes had their dietary energy intake restricted to promote differing rates of weight loss: slow (0.7%/wk or ~0.5 kg/wk) vs. rapid (1.4%/wk or 1.0 kg/wk). The investigators hypothesized that the fast loss vs. slow loss group would show a more detrimental change in the body composition (i.e., loss of lean body mass) as well as potentially compromised performance gains since all athletes were training. The study was, however, designed to promote equivalent degrees of weight loss so those in the slow loss group spent 8.5 wk in the intervention versus only 5.3 wk in the fast loss group. The resulting weight losses were comparable as the fast loss group lost 5.5% of their body weight and the slow loss group 5.6%. Both groups consumed ~1.6 g protein/kg body mass/d and yet the slow loss group showed a gain in lean body mass of 2.1% whereas the fast loss group showed no change (-0.2%). In addition, some measures of performance (1 repetition maximum strength test and sprint performance) were increased to a greater degree in the slow loss group. However, it is uncertain if this was simply because that group spent more time training (>3wk) than the fast loss group. Nonetheless, these data highlight that rates of weight loss should be moderate if athletes are aiming to lose fat mass and improve performance while simultaneously gaining lean mass and improving performance (Garthe et al., 2011).

Lean mass gain while losing fat mass (i.e., a hypoenergetic state) is a difficult proposition. However, results from a few trials in humans show that higher-quality proteins, particularly from dairy sources (Josse et al., 2010; 2011), as well as timed to be consumed post-exercise and spread out in an even pattern throughout the day

(Areta et al., 2013), are definitely beneficial strategies to promote lean mass retention. Recently, Pasiakos et al. (2013) showed that intakes of protein that were 2 and 3 times the RDA (1.6 and 2.4 g/kg/d) were protective against lean mass loss during 21 d of a hypocaloric diet (30% below energy intake for weight maintenance). Subjects in the higher protein groups lost less lean mass than did a group who consumed the protein RDA. The highest protein group, at 3 times the RDA or 2.4 g/kg/d, did not experience any greater benefit than the 2 times the RDA group in terms of lean or fat mass loss. Thus, there appears to be a limit to consuming protein at which the benefit of protecting against lean mass loss is not any greater. It should be emphasized, however, that the subjects in this study were performing only moderate amounts of low-to-moderate intensity (40-65% of peak $\dot{V}O_2$) aerobic work on a daily basis, which may not be as stimulatory for muscle protein synthesis (MPS) as resistance exercise (Wilkinson et al., 2008). Nevertheless, there are case reports of highly aerobic athletes in whom lean mass increases and performance gains can be made while in a state of energy deficit that promoted a substantial fat mass loss (Haakonssen et al., 2013). The strategies employed in this type of situation are highly detailed but center on what has previously been stressed: consuming high-quality protein in close temporal proximity to exercise, coupled with evenly spaced and higher protein containing meals throughout the day.

Combining all of the aforementioned strategies of higher protein, timed ingestion post-exercise, evenly spaced protein-containing meals and high protein quality (whey), Longland et al. (2016) showed that in trained athletes coming from an off-season, it is possible to engage in very high intensity work (aerobic, sprinting and resistance exercise) while consuming 40% less energy than required and still gain lean body mass. Interestingly, even at the lower protein intake of 1.2 g/kg/d subjects lost no lean body mass, indicating that 100% of the lost weight came from fat. Nonetheless, in a group that consumed 2.4 g/kg/d of protein 1.2 kg more fat mass was lost and 1.2 kg of lean body mass was gained vs. the group consuming 1.2 g/kg/d.

Over recent years, interesting results are beginning to emerge from studies of pre- and during-sleep protein administration (Groen et al., 2012; Res et al., 2012). Sleep is a time without provision of food and thus there is no periodic stimulation of MPS by high levels of amino acids in the blood. As such, individuals are regularly exposed to a prolonged period in which they are likely to experience negative protein balance. However, Res et al. (2012) showed that pre-sleep provision of a protein meal (40 g of casein) improved overnight MPS. Although impossible to reproduce without waking, the same research group showed that intragastric feeding (via a feeding tube implanted prior to sleep) increased overnight MPS in older men (Groen et al., 2012). Thus, as proof of principle it appears that pre-sleep or during sleep (i.e., during a brief waking period) protein provision could aid in offsetting overnight fasted lean mass losses. A more recent trial has shown that these proof-of-concept studies (Groen et al., 2012; Res et al., 2012) do result in greater muscle hypertrophy and greater

strength gains (Snijders et al., 2015). Thus, pre-sleep protein appears to be a valid strategy to adopt for athletes looking to remodel muscle proteins and promote hypertrophy and strength gains (Snijders et al., 2015).

PERFORMANCE EFFECTS

A critically important question is whether an athlete can, if they lose too much muscle mass during weight loss, experience impaired performance. There are few studies in this area, but those that are available suggest that performance decrements are minimal if they exist at all. For example, Zachwieja et al (2001) showed that men and women in a short-term (2 wk) energy deficit (-750 kcal/d vs. daily requirements) did not experience any reduction in their capacity to perform aerobically, anaerobically or strength-wise compared to a group who maintained their weight. The weight loss in this study was, however, comparatively moderate at 1.3 kg with 60% of the weight loss (0.78 kg) coming from lean mass and so it is perhaps not surprising that performance was not adversely affected. Similarly, using a very low calorie ketogenic diet (VLCKD), Paoli et al. (2012) reported no decrements in performance after 30 d on a VLCKD in elite artistic gymnasts during which time the gymnasts lost 1.6 kg of body mass and 1.9 kg of fat. While performance decrements were not apparent in these two short-term studies, reviews have called for both education and, in some cases, rules, governing esthetic and some weight class sports due to extreme dieting practices that compromise both health and performance (Sundgot-Borgen & Garthe, 2011). Thus, the lack of change in performance in short-term trials is not indicative of long-term issues with persistent restrictive eating as well as dieting practices.

PRACTICAL APPLICATIONS AND SUMMARY

What is clear is that weight loss requires a negative energy balance, and this can be facilitated through exercise alone. What then can one reasonably suggest as a strategy for athletes who wish to undertake a weight loss program but to emphasize "high-quality" weight loss? If we accept published work examining protein dose-response effects, then a dose of ~0.25-0.3 g protein/kg/meal of high-quality protein maximally stimulates MPS following resistance exercise (Moore et al., 2009). Recently, the extension of this work to encompass a 12 wk period has shown that both whole-body (Moore et al., 2012) and muscle protein synthesis (Areta et al., 2013) appear optimally stimulated by following a pattern of protein ingestion every 3 h across 12 h of waking. If one were to extend these data (Areta et al., 2013; Moore et al., 2012) to a 24 h period, it appears that a recommended practice would also be to ingest a pre-sleep meal (Res et al., 2012) to attenuate the expected overnight-fasted negative muscle protein balance. Given the duration of the overnight sleep and fasted period (typically encompassing ~8-10 h), a practical recommendation would be to consume a protein dose that is larger, i.e., ~0.5-0.6 g protein/kg/meal. It would seem that a higher protein and lower carbohydrate diet facilitates a greater loss of body fat and a greater preservation

of lean mass, according to meta regression (Krieger et al., 2006) and meta analyses (Wycherley et al., 2012).

Exercise adds to the lean mass sparing effect of higher protein (Weinheimer et al., 2010) and likely it is whole body resistive exercise, that targets all major muscle groups, that is most effective in promoting the retention of lean mass (Josse et al., 2011; Layman et al., 2005). That resistance exercise could be used to target lean mass retention is perhaps an important consideration for some athletes, such as road cyclists, who may wish to only retain (or potentially increase) muscle in their legs while not being concerned about losing upper body musculature.

It appears that rapid rates of weight loss (>1 kg/wk), which would require a theoretical energy deficit of ~1,100 kcal/d (assuming 7,700 kcal/kg of fat and that all the weight lost were fat), is associated with a greater propensity for lean mass loss (Garthe et al., 2011) and potential declines in performance. In the short-term (3-4 wk), it appears that performance is not hampered by moderate rates of weight loss (Paoli et al., 2012; Zachwieja et al., 2001). However, longer-term studies in well-conditioned athletes are not available beyond case reports (Haakonssen et al., 2013) or shorter-term (4 wk) trials (Longland et al., 2016).

It is also advisable for athletes who are restricting energy intake to practice consumption of nutrient-dense foods that, on a restricted energy allowance, would still consume adequate quantities of vitamins and minerals that may be required for optimal health and performance. Evidence exists that dairy-based proteins, which contain a good source of many nutrients, can also enhance fat loss and aid in lean mass retention during energy restriction (Abargouei et al., 2012; Chen et al., 2012).

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