Impact of Nutrition on Lean Body Mass and Exercise Recovery in Athletes

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Improving body composition by increasing the amount of lean body mass relative to fat mass is a goal of many people for the purpose of increasing physical performance and general health. Greater muscle mass is associated with increased strength and power, as well as better metabolic health and reduced risk for chronic disease. Lifestyle approaches aimed at improving body composition focus on nutrition and exercise, but the type of diet and exercise program and their interaction are important factors that affect responses in percent body fat. Reduced-calorie weight loss approaches usually result in considerable loss of both fat and lean body mass.[1,2] Maximizing fat loss while preserving or building lean body mass requires consideration of macronutrient composition and the inclusion of resistance training.

Low-Carbohydrate Diets and Body Composition

Decreased energy intake is required to induce weight loss, but the composition of macronutrients (carbohydrate, protein, and fat) has a significant effect on the composition of weight loss. According to a recent comprehensive review of weight loss diets, lower carbohydrate intake was associated with greater fat loss and higher protein intake was associated with better retention of lean body mass independent of energy intake.[3] Several recent studies have shown that carbohydrate-restricted diets result in greater weight and fat loss compared to low-fat diets,[4,5] and in fact, lean body mass may actually increase in response to a very low-carbohydrate intake in normal weight men.[6] Even severely

hypocaloric very low-carbohydrate diets spare lean tissue as evidenced by studies showing positive nitrogen balance in subjects consuming <800 kcal/day.[7]

The central role of the glucose-insulin axis in the control of metabolic processes is the basis for the use of carbohydrate-restricted diets. Insulin has anabolic functions that inhibit breakdown and promote storage of nutrients. Adipose tissue lipolysis and fat oxidation are exquisitely sensitive to changes in insulin within the physiological range of concentrations.[8] Small reductions in insulin levels, such as those easily achieved with dietary carbohydrate restriction, remove the normal inhibition on access to and oxidation of fat for fuel. Thus, low-carbohydrate diets are associated with significant changes in lipid metabolism favoring decreased storage and increased breakdown and oxidation of fat, as well as improved atherogenic dyslipemia (decreased triglycerides, increased high-density lipoprotein cholesterol [HDL-C], and increased low-density lipoprotein [LDL] particle size).[4] The ability of low-carbohydrate intake to inhibit lipogenesis and to bias lipid metabolism toward oxidation was demonstrated in a recent experiment in which we showed a significant decrease in plasma saturated fatty acids despite greater intake of saturated fat on a very low-carbohydrate diet.[9]

Diet in Combination With Resistance Training

Resistance training is a potent stimulus for increasing muscle size and strength, and when combined with dietary caloric restriction helps preserve lean body mass. For example, we showed that overweight men and women consuming a low-fat, high-fiber diet for 12 weeks lost about 10 kg of body weight, of which 69% was from fat.[2] A separate group

who followed the same diet and performed resistance exercise workouts three times a week had the same weight loss that was almost exclusively from fat (97%).

The effects of low-carbohydrate diets in combination with resistance training was addressed by Layman and colleagues.[10] They reported that the combination of a low-carbohydrate diet and resistance exercise had the most favorable response for both fat loss and preservation of lean body mass in middle-aged women.

We performed a similar experiment in overweight/obese men who were placed in a low-fat-diet group that restricted fat to less than 25% of energy, or in a very low-carbohydrate-diet group that reduced carbohydrate to less than 15% energy.[11] Both groups also participated in a resistance training program (3 or 4 times a week). Body composition was assessed using dual energy x-ray absorptiometry before and after the 12-week program. The results were compared to non-training diet-only groups. As expected, the low-carbohydrate-diet group lost more fat mass, which was associated with greater decreases in insulin. Resistance training, independent of diet, resulted in increased lean body mass without compromising fat loss in both diet groups. The most dramatic reduction in percent body fat was in the low-carbohydrate-diet resistance-training group (-5.3%), followed by the low-fat resistance-training (-3.5%), low-carbohydrate-diet only (-3.4%), and low-fat-diet only (-2.0%) groups. These studies show that low-carbohydrate diets promote greater fat loss independent of training, whereas resistance training promotes increased lean body mass independent of diet. The combination of a low-carbohydrate diet and resistance training is therefore additive, promoting the largest decreases in percent body fat (Fig 1).

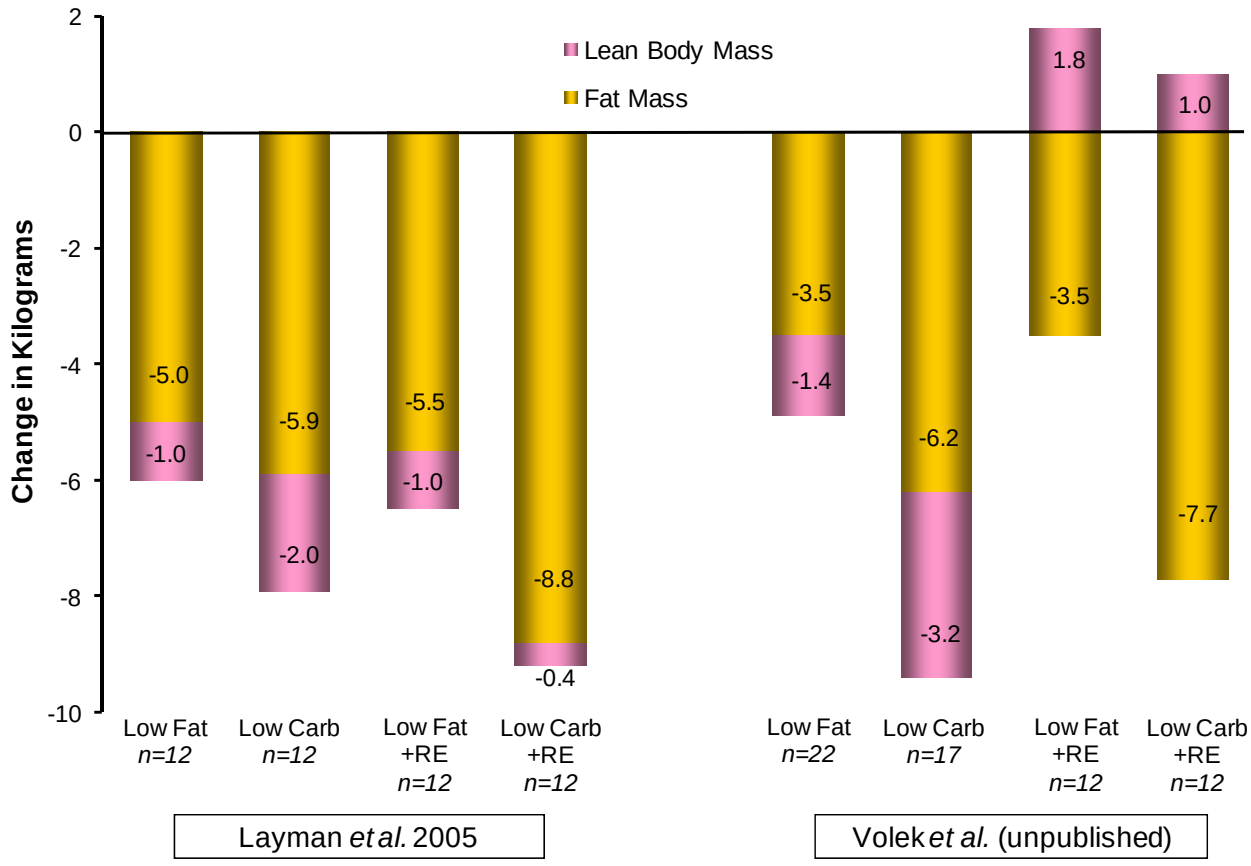

Fig 1. Effects of diet composition with and without resistance training on change in lean body mass and fat mass after 16 wk in untrained women[10] and 12 wk in untrained men.[11] RE=resistance exercise

Creatine Supplementation and Lean Body Mass

Creatine is one of the most extensively studied dietary supplements over the last 15 years. Short-term studies involve a loading phase of creatine (15-25 g/day for 5 to 7 days) and have shown significant improvement in muscle strength and power during short-burst high-intensity exercise tasks. Creatine loading increases the muscle content of creatine (and phosphocreatine) and accelerates the rate of resynthesis of phosphocreatine, a high-energy compound in muscle, during recovery so that muscle phosphocreatine levels are

higher at the start of the next exercise bout. We showed that 7 days of creatine supplementation (25 g/day) allowed subjects to perform a total of eight more repetitions during a bench press workout consisting of 5 sets,[12] translating into a better training stimulus for inducing gains in muscle.

Chronic studies that examined the effects of taking creatine while engaged in a resistance-training program have found consistent benefits on gains in strength and muscle mass.[13] In a recent review, we concluded that the average increase in muscle strength following creatine supplementation plus resistance training was 24% compared to 18% in subjects training and taking a placebo.[14] Similarly, the average increase in maximal repetitions at a given percent of maximal strength following creatine supplementation plus resistance training was 34%, compared to 13% in the placebo groups. In terms of gains in lean body mass, creatine supplementation plus resistance training results, on average, in 2-3 kg of additional muscle over a 12-week training period, and this is associated with significant muscle fiber hypertrophy in all fiber types (Fig 2).[15]

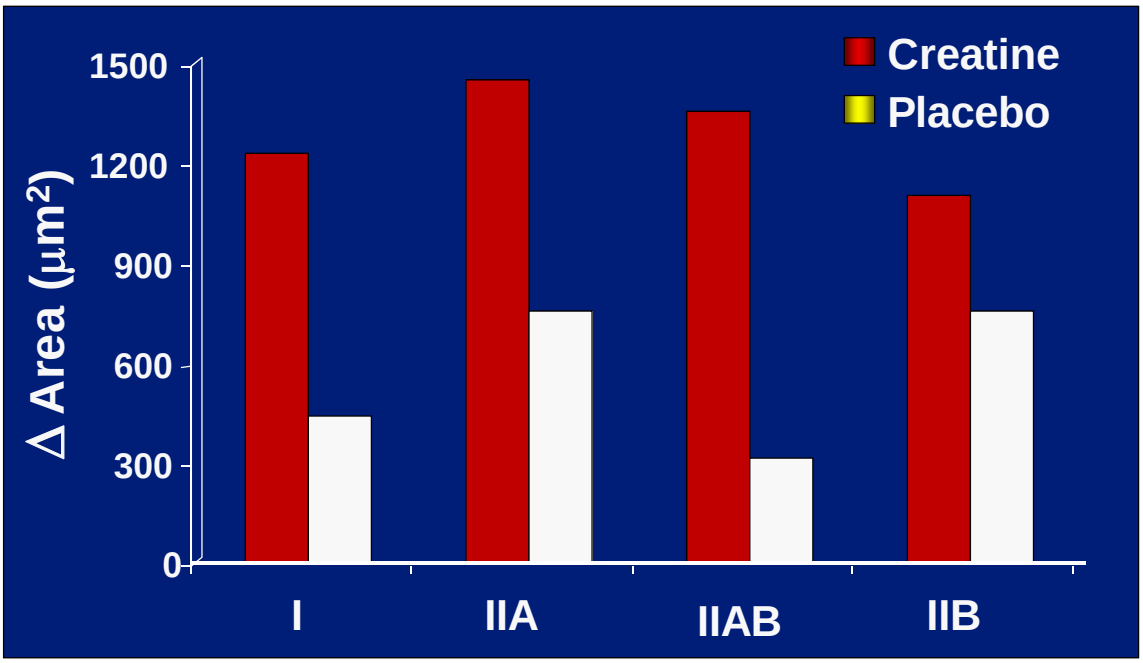

Fig 2. Effects of 12 weeks of resistance training in subjects consuming creatine or placebo on muscle fiber hypertrophy.[15]

These outcomes represent average expected improvements in strength and muscle mass with creatine. Many individuals exceed these average responses, and some do not respond to creatine. People who have low muscle creatine levels tend to have the largest increases in muscle creatine after a loading period, and this translates into better gains in performance.

HMB Supplementation and Lean Body Mass

A number of studies have also investigated the effects of β-hydroxy-β-methylbutyrate (HMB) supplementation on lean body mass and muscular performance. Some, but not all, have reported that gains in muscle strength and lean body mass from resistance training are augmented by HMB.[16] We recently reported that a formula consisting of HMB and amino acids taken during 12 weeks of resistance training resulted in significantly greater

increases in lean body mass (5.3 kg) compared to placebo.[17] Thus, HMB may work best when combined with amino acids.

Conclusion

In summary, a primary concern with conventional weight loss approaches is the loss of lean body mass that occurs when fat mass is decreased. Consuming moderate protein while restricting carbohydrate and increasing fat allows for greater preservation of lean body mass. A low-carbohydrate diet in conjunction with resistance training results in greater fat loss while preserving lean body mass and improving metabolic health. Considerable scientific work has shown that creatine and HMB supplementation augment gains in muscle size and strength in response to resistance training.

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Q&A

Dr Johnson: Can you speak to the benefit of creatine and then creatine plus HMB in the elderly?

Dr Volek: Several studies have been done with creatine in the elderly. We have done a couple of studies in which we acutely load elderly patients with creatine [references] and have shown improved functional capacity and strength and ability to sit up and get out of a chair—activities of daily living [Gotshalk LA et al: *Eur J Appl Physiol* 2008;102:223-231. Epub 2007, Oct 18; Gotshalk LA et al: *Med Sci Sports Exerc* 2002;34(3):537-543]. So elderly people respond similarly to younger adults.

Dr Tisdale: I was interested in your studies with the low-carbohydrate/high-fat diet. I was confused about the mechanism because you attributed it solely to a reduction in insulin. You did not measure catacholamines or glucagons in the subjects. I understand that, if you have a low-carbohydrate diet, you might get increased lipolysis because gluconeogenesis from amino acids is needed for energy, but I was not sure about the increase in lean body mass because insulin would stimulate that. If gluconeogenesis increases, you have to decrease precursor population for muscle protein synthesis.

Dr Volek: You are right—insulin would promote protein synthesis. Insulin is not that important for maintaining protein balance and has a much more potent effect on fat balance, so the ability to use fat more efficiently and use alternative fuels would spare lean tissue during negative caloric intake. The preponderance of evidence indicates that low-carbohydrate diets that promote increased reliance on fat for fuel result in better preservation of lean body mass during weight loss. If resistance training is added, we can actually build lean body mass while insulin is very low and fat breakdown is accelerated. I do not want to oversimplify the situation. Certainly insulin is not the only mechanism here, but it is a key variable that regulates metabolism, and in some ways is a switch to allow access to body fat stores. A lot of people are insulin-resistant and have problems with hyperinsulinemia. Getting that condition under control is important, and restricting carbohydrates is probably the most direct way to do that.

Dr Hegazi: In the nutrition field, we struggle with the placebo effect, and the HMB study you showed was mixed with arginine and glutamine. Have you controlled for arginine and glutamine? Do you think that the additive effect of three nutrients is better than just HMB?

Dr Volek: We do not know from that experiment. It is not, however, a reductionist approach. We are looking at a formula. The placebo was isonitrogenous, so we can rule out an effect of nitrogen, but the nitrogen was coming from non-essential amino acids. I tend to think that, looking at pure HMB studies, the magnitude of the effect was much

greater. My hunch is that amino acids are playing a synergistic role with HMB in this case and at bioactive levels that could affect protein synthesis.

Dr Holick: Is there any downside to increasing creatine intake at these levels?

Dr Volek: There does not appear to be. These levels are relatively benign; a person excretes the extra creatine in urine. There is no need for high doses; a person just needs to maintain a normal breakdown. Increased muscle creatine levels are resilient and slowly return to baseline over a period of 4-6 weeks. Previously, someone alluded to cramping issues. There probably are some water shifts as creatine moves into cells, so creatine is an osmolyte. It will accumulate in muscle and bring some water into the muscle, so there could be cramping because this may alter electrolyte balance. A steady amount of research has been conducted with creatine for nearly 20 years with some long-term follow-ups, and all this research has found no remarkable side effects.

Dr Morley: Two studies have found that creatine improved cramping, and another study in athletes said it does not affect cramping.

Dr Volek: Most of the information about cramping is anecdotal.

Dr Edens: With respect to your low-carbohydrate diet effects, do you think that you would get the same effects with very low glycemic carbohydrates?

Dr Volek: A study by Eric Westman at Duke University [Westman EC et al: *Nutr Metab* (Lond) 2008;19:36] compared a low glycemic index (GI) diet to a low-carbohydrate diet in diabetics. The low GI diet was beneficial, but the low-carbohydrate diet was more beneficial. At any given level of carbohydrate intake, a low GI intake probably will have beneficial effects, but restricting the total amount of carbohydrates has a more direct effect because of the reduction of the supply of glucose.