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Effect of food and nutrition factors on the maintenance and increase of skeletal muscle

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Skeletal muscle is one of the largest metabolic organs in the human body. Maintaining and increasing muscle mass plays an important role in the prevention of several metabolic diseases and also in enhancing exercise capacity. Losing fat mass and increasing fat-free mass improves physical performance, particularly for athletes. Muscle mass is determined by a net protein balance of muscle protein synthesis and breakdown where several signaling pathways are involved. The purpose of this study was to examine how nutritional factors can affect these signaling pathways to increase muscle mass. This study was composed of two parts where we initially investigated the effects of lactate on muscle hypertrophy using primary myoblasts and a mouse model; next, we examined how nutrients and food impact fat-free mass maintenance during weight loss in college student rugby players.

We have previously demonstrated that lactate promoted myoblast differentiation and myotube hypertrophy in the C2C12 murine myoblast cell line via a pathway involving myoblast determination protein (MyoD), a muscle specific transcription factor; therefore, we examined whether lactate-induced muscle differentiation and hypertrophy were also observed in primary myoblasts and in damaged mouse muscle. When primary myoblasts were differentiated for 3 days in the presence of lactate, cell fusion was observed and the calculated fusion index was significantly increased by lactate treatment. In addition, we investigated the effect of peritoneal injection of lactate in mice with glycerol-induced muscle injury; cross-sectional areas of regenerated muscle fiber were found significantly increased after lactate treatment on days 14 and 28 after injury. Furthermore, the gene expression of MHC2b on day 7 was significantly increased after lactate administration. These results indicate that lactate promotes muscle repair through myoblast fusion and induces muscle hypertrophy both in primary myoblasts and in vivo.

Next, we investigated the relation between nutrition intake and the changes that occur in fat-free mass during weight loss period to explore what key nutrients help to maintain and increase muscle mass. Thirty two male college rugby players were challenged to lose weight in a self-regulated manner over a 4-month competitive season. Body composition was measured by underwater weighing and dietary intake was assessed by the use of an 8 day food record with

pictures. Analyses were conducted on 23 subjects who completed all food records and succeeded to lose fat mass. The data was categorized into two groups according to changes in fat-free mass: increased fat-free mass group (n = 12) and decreased fat-free mass group (n = 11). Nutrition and food intake were compared between the groups. Dietary intake of nutrients such as proteins, fibers, vitamin E (α-tocopherol and β-tocopherol), polyunsaturated fatty acids, and ash and amino acid composition were significantly different between the two groups. Intake of these nutrients was significantly correlated with changes in fat-free mass and a particularly strong positive correlation was found for the intake of protein ($r = 0.558$) and polyunsaturated fatty acids ($r = 0.547$). In contrast, there was no difference in energy intake, fulfillment rate of energy intake, and food group intake between the two groups. These data suggest that ingestion of sufficient protein and polyunsaturated fatty acids may prevent the decrease in fat-free mass during weight loss and help maintain muscle mass independently of energy intake.

This study demonstrated two findings about the association between nutritional factors and muscle mass. First, lactate showed inducible effects on muscle differentiation and hypertrophy not only in C2C12 cells but also in primary satellite cells and during in vivo muscle regeneration. Second, several nutrients potentially contribute to the increase in muscle mass during weight loss. Further research is needed to elucidate the detailed mechanisms of the effect of these factors on the increase of muscle mass.