The Role of Amino Acids in Skeletal Muscle Adaptation to Exercise

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The muscular adaptation to strength (muscle hypertrophy) and endurance (mitochondrial biogenesis and angiogenesis) type exercise is dependent on the synthesis of new myofibrillar (contractile) and mitochondrial (energetic) proteins, respectively [1]. The bigger muscles in the strength athlete are the result of protein synthesis proceeding faster than protein breakdown. In the endurance athlete, the muscle gets more mitochondrial proteins when this subset of proteins is synthesized faster than they are broken down. Therefore, protein balance (protein synthesis subtract protein breakdown) is key to determining whether our muscles will be bigger or more fatigue resistant after training. Even though the rate of muscle protein breakdown increases after we exercise [2], muscle protein synthesis increases 3- to 5-fold more [2, 3], and therefore, synthesis seems to be the most important measure to study.

The rate of myofibrillar protein synthesis is controlled by a protein called mTOR (mechanistic target of rapamycin). The activation of mTOR after strength exercise predicts the increase in muscle mass and strength following training [4], and when mTOR is blocked resistance exercise does not increase protein synthesis [5]. These studies tell us that mTOR activation is the goal of strength exercise. In contrast, endurance exercise increases mTOR and protein synthesis only transiently, and mTOR is not necessary for the increase in mitochondrial protein synthesis [6].

mTOR can be further activated in active muscles by proper timing of protein intake, specifically proteins rich in the amino acid leucine. Leucine activates mTOR through a molecular pathway involving its transporter (LAT1), the leucyl tRNA synthase, Rag proteins, and the regulator complex (fig. 1). So, if we can deliver leucine to our active muscles at the right time, this will increase mTOR activity more than exercise alone, and as a result this will make our muscles bigger and stronger.

From a series of elegant experiments we know that, to make our muscles bigger, the best form of protein is one that is rapidly digested and rich in leucine, such as whey [7], the amount of protein that we need to
consume is 20–25 g (fig. 2) [8], and that we should consume the protein either before [9], or immediately after exercise [10]. There are also very strong data showing that taking in 20–40 g of protein before going to bed has the further benefit of increasing protein synthesis while you sleep [11].

From the studies conducted to date, consuming protein following endurance exercise does not further increase mitochondrial protein synthesis [12]. This is likely due to the fact that mTOR is not important in regulating mitochondrial protein synthesis [6]. However, it is also possible that the time when protein intake improves mitochondrial protein synthesis is different, and we simply have not seen the beneficial effect as of yet.

Even though protein intake does not seem to improve mitochondrial protein synthesis after endurance exercise, protein supplementation may still improve endurance performance. After intense endurance exercise, our immune response is decreased leading to an ‘open window’ for

**Fig. 1.** Depiction of the activation of mTOR by amino acids. Leucine enters the muscle via LAT1, and through the leucyl tRNA synthase this activates the Rag complex. Through binding to raptor and the regulator, the Rag complex brings mTOR to its activator Rheb resulting in the activation of protein synthesis. LRS = Leucyl-tRNA synthetase.
infection [13]. One hypothesis as to why we lose immune function after exercise has to do with loss of the amino acid glutamine from our bloodstream. In support of this idea, glutamine, or branched-chain amino acid, supplementation reverses the glutamine loss and decreases the incidence of infection [14]. However, this is not a universal finding, and therefore whether glutamine supplementation really decreases infection needs to be studied more.

In conclusion, it is clear that strength athletes should eat 20–25 g of rapidly absorbed leucine-rich protein (such as those found in milk or whey) right before or after their strength training and another 20–40 g right before bed. However, it is not clear whether protein intake improves the adaptation to, or decreases the immunosuppressive effects of, endurance exercise. Either way, we now know that what we eat has a dramatic effect on our adaptation to exercise, and therefore a proper diet is essential to optimal performance.

References


