The interaction between Leucine and Exercise on Muscle Growth

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Abstract

Three critical stimuli for protein balance include leucine concentrations, insulin, and various exercise stimuli. The following paper will analyze the interaction between exercise and leucine concentrations. In particular the paper attempts to distinguish between catabolic or exercising conditions which lower muscle tissue compared to those which increase muscle tissue. It is demonstrated that leucine levels may differentiate between these conditions, followed by recommendations on how to maximize muscle tissue growth and hinder muscle tissue loss.

Introduction

Bodybuilder's goals are directed towards maximizing muscular hypertrophy. In parts one of this series the general role of leucine as a modulator of protein balance was discussed, while in part two its effects and interaction with insulin were analyzed. Generally the findings of these papers suggest that leucine is the primary regulator of meal induced protein synthesis, while insulin appears to be the primary regulator of protein degradation.

When analyzing the effects of leucine on protein synthesis it is found that protein synthesis increases from 30 minutes to 2 hours following ingestion of a leucine containing meal, followed by a return to baseline. Therefore its effects are transient, causing the bodybuilder to opt for a high frequency of feeding periods. In contrast external resistance training changes protein synthesis for up to 72 hours.

The interaction of exercise with leucine is a complex situation. As a brief overview:

1. Resistance training is associated with little change in protein synthesis during exercise, with an increase in protein synthesis for up to 72 hours following training. However, because protein degradation is increased, overall net protein balance is negative unless a protein containing meal is consumed (Biolo et al, 1997).

2. Endurance exercise is associated with a depression of protein synthesis during and after exercise that is proportional to the duration and intensity of the exercise session (Norten et al., 2003).

The differences between the two appear to be related to plasma leucine concentrations. For example Durham et al. (2004) had participants perform 8 sets of 10 repetitions at 75 % of their 1-RM on the leg press, followed by 8 sets of 8 repetitions on the leg extension at 80 % of their 1-RM. No significant changes in plasma leucine concentrations were found. In contrast Durham et al. (1996) found that participants performing 90 minutes of cycling had significant decreases in plasma leucine levels.

Norten et al. (2003) modeled the endurance bout and had rats perform an exhaustive long duration treadmill run. After the run was completed the rats had a 25 % decrease in protein synthesis. Following the bout of exercise the animals were given either a glucose and sucrose drink, a complete meal containing protein, or a leucine alone. Results found that the CHO condition did not recover protein synthesis, while both the meal, and leucine alone did.

Therefore differences in resistance exercise and endurance exercise appear to be related to plasma (or intracellular) leucine concentrations.

Mechanisms of Action

As stated in article one of this series immediate changes in protein synthesis are regulated at the level of translation initiation, or the beginning stage of protein synthesis. Translation initiation is comprised of assembling the mRNA which contains instructions for said protein to a ribosome molecule. A family of proteins known as initiation factors is responsible for regulating this process. Further, the cell can increase its capacity for protein synthesis by activating ribosomal protein S6, which specifically enhances the production of ribosomal proteins, initiation, and elongation factors. It appears that the Mamallian Target of Rapymysium (mTOR) is the machinery responsible for both up regulating initiation factors, and enhancing the cells capacity for protein synthesis.

Evidence suggests that by hindering mTOR the effects of leucine, insulin, exercise, and growth factors such as IGF-1 are hindered. Therefore mTOR acts as an integrating center for signals which regulate protein synthesis.

mTOR is also sensitive to the energy status of the cell, and it is this process which is critical for the reader to grasp. Muscle cells contain a protein kinase known as AMP activated protein kinase. ATP is our body’s main energy source. ATP can be broken down into ADP, and finally AMP. When this occurs the energy released is used to power muscular contraction (see Wilson and Wilson, 2004 for a review). AMP activated protein kinase is increased in activity when AMP levels increase. This is because increased AMP levels indicate lower energy status in the cell. Continual long term contractile activity associated with endurance activity maximally stimulates AMPK. AMPK is able to inhibit mTOR through downstream events.

During resistance training exercise leucine levels are maintained and it appears that these maintained concentrations are able to counter the effects of AMPK. However, during endurance training when leucine levels lower, AMPK is not hindered from inhibiting mTORs actions, and protein synthesis lowers until leucine is provided.

Supplementing with Leucine Prior to Exercise

Often it is stated that individuals should not perform long duration cardiovascular sessions because they can be highly catabolic in nature. Further, cardiovascular training on an empty stomach in the morning serves as a double edged sword. Both long duration cardiovascular training and morning training are associated with a higher reliance on fat metabolism due to depletion of the body’s energy reserves.

The negative aspect is that the catabolism of muscle tissue is also high during this time period (see Wilson and Wilson, 2005 for an in depth review). The research question that needs to be asked is why is this the case. Evidence presented above suggests that it may be due to a depletion of plasma leucine levels. This is based on the finding that the negative protein balance seen after an overnight fast, and during and after endurance exercise is reversed when leucine is administered. Therefore it may be that athletes can perform longer duration endurance training sessions, as well as cardiovascular training in the morning if they consume a large dose of essential amino acids prior to the training session.

Summary and Conclusions

mTOR appears to be the regulating center for stimuli which effect protein synthesis. Exercise increases protein synthesis most likely due to increased blood flow and amino acid delivery during and after training. Further high intensity resistance exercise is associated with increases in insulin like growth factor and growth hormone, which are potent regulators of protein synthesis. Evidence also suggests that they are mTOR dependent (see Wilson, 2005 for a review).

Resistance exercise is associated with little change in protein synthesis during training, and an increase in protein synthesis following training. However protein balance remains negative unless a leucine rich meal is administered after. It should be noted however, that because protein degradation increases during exercise, protein balance during this time is typically negative. Tipton et al. (2001) found that an EAA supplement prior to exercise caused a positive protein balance. Therefore athletes should consume an EAA or protein supplement prior to and after resistance exercise.

Endurance exercise is associated with a decrease in protein synthesis during exercise, and this appears to be linked to lowered leucine levels. Evidence suggests that lowered energy levels in the cell stimulate AMPK which inhibits mTOR. When leucine levels are low, AMPK is not antagonized, and protein synthesis plummets. If athletes consume leucine along with other EAAs prior to long duration endurance exercise and possibly in the morning they can maximally stimulate fat metabolism, while sparing muscle tissue.

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