Protein metabolism and exercise in children – a review

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Abstract. – **General nutritional strategies to promote whole body protein retention, particularly with relation to exercise, have been largely based on adult research that does not consider the dynamic process of growth and often ignores scenarios commonly experienced by children (e.g., exercise in the heat). Therefore, the aim of the present review is to highlight the importance of post-exercise protein quantity and timing in active children, specifically with respect to the whole body protein turnover.**

Key Words:
Protein metabolism, Exercise, Pediatric growth.

Introduction

Proper nutrition has an important role in optimizing health during childhood and throughout life[1]. Dietary protein, in particular, plays a central role in somatic growth as it provides the substrates necessary to build body proteins[2]. For active children and youth, nutrition is particularly important as a result of the increased nutritional requirements to meet the combined physiological demands for the normal processes of growth, as well as exercise[3]. As a result, establishing the optimal relationship between physical activity (hereafter referred to as 'exercise') and protein is of utmost importance for the pediatric age group[2]. Understanding the benefits of a nutritionally adequate diet to support exercise and growth is of particular importance now, as there has been an attempt in recent years to promote exercise among youth. Given the overwhelming concern of an inactivity crisis[4] that undoubtedly has contributed to the tripling rate of childhood obesity over the last 30 years[5], it is important to equip young people with the skills and mindsets needed to lead healthy, active lifestyles, which can carry over into adulthood[6]. Important benefits of exercise include (but are not limited to): reduced anxiety and depression, increased self- esteem, development of positive family interactions, increased musculoskeletal health[7,8] and decreased risk of obesity and related co-morbidities, cardiovascular disease, various cancers, and type 2 diabetes[9]. With the aim of stimulating children and youth to lead more active lifestyles, it is important to understand how to optimize benefits from specific episodes of exercise. Specifically, it is critical to gain an understanding of how this exercise can be complemented by appropriate protein intake to support developing bodies. Thus, the combined effects of protein and exercise on protein metabolism and the promotion of protein accretion for growth deserve further studies[10].

Regulation of Protein Metabolism

Protein Turnover

Protein within the body is in a constant state of turnover and is constantly being synthesized and degraded. One factor that can affect protein turnover is age; on a body- weight basis, the amount of protein turnover each day decreases from infancy to old age[11]. Protein turnover can also be affected by the complex interactions of various stimuli from some metabolic and physiologic conditions including substrate availability, hormonal signaling, and exercise[12]. Unfortunately, however, limited information is available regarding the effects of these stimuli on protein turnover in the pediatric population.

Effects of Amino Acids on Protein Metabolism

The ingestion of dietary protein and/or amino acids can have a significant impact on the biochemical responses of protein metabolism. When a mixed protein-containing meal is consumed, protein synthesis is increased while protein breakdown is simultaneously reduced[13]. It appears that the change in protein synthesis is a result of the increased availability

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of plasma amino acids and an increase in plasma insulin. The change in protein breakdown, on the other hand, is more likely mediated by the increase in insulin alone[14]. Thus, the fed state results in net protein deposition (where the rate of protein synthesis > protein breakdown). On the other hand, when the body does not receive a source of dietary amino acids (i.e., after an overnight fast or between meals) the rate of protein breakdown exceeds that of protein synthesis. This catabolic environment is maintained until an adequate supply of dietary protein is consumed, and the cycle repeats resulting in a diurnal fluctuation in protein turnover. Increasing the level of dietary protein intake during the fed state may not have influences on protein balance over the course of a day. For instance, Pacy “et al”[15] found that when the level of protein intake increased, the amplitude of both protein deposition and protein breakdown increased. Despite these increases, the mean daily rate of protein turnover was not affected. Therefore, to manipulate daily rates of whole body protein turnover (WBPT) and obtain the anabolic environment required for growth in children, it is possible that additional stimuli (e.g. exercise) are needed in combination with protein feeding. The composition of the dietary protein ingested can also influence the magnitude of the biochemical response, given that certain amino acids have the ability to regulate key metabolic pathways[16]. For example, decreased or insufficient intakes of essential amino acids can reduce the rate of protein synthesis and impair the use of other amino acids for protein synthesis. Therefore, if the diet contains an unbalanced proportion of essential amino acids, even if only one essential amino acid is in limited supply, or the overall protein intake is insufficient, a negative protein balance could occur. An increased concentration of essential amino acids in the blood could be particularly effective at stimulating muscle protein synthetic (MPS)[17]. Specific amino acids, which have been referred to as functional or signal amino acids are also beneficial for stimulating the protein anabolic pathways and optimizing metabolism. Leucine in particular is a potent regulator of metabolic activity[18]. High levels of leucine intake may have direct effects on muscle protein turnover (particularly, enhancing MPS) and tissue sensitivity, which is thought to occur through synergistic effects in signal transduction resulting from an increase in insulin release.

Exercise and Protein Metabolism

Regular exercise has a multitude of health benefits that stem from adaptations to both the cardiovascular system [e.g., an increase in vascular compliance, cardiac output, and capillary number as well as an expansion of plasma volume[19] resulting in an enhanced transport of oxygen to the active muscle] and skeletal muscle tissue [e.g. increased expression and deposition of the myofibrillar proteins leading to muscle hypertrophy[20] in response to the exercise stimulus]. These chronic changes likely arise from an accumulation of the acute responses to each exercise bout; however, these adaptive responses are not permanent and could be reversed in the absence of the stimulus[21]. The type of exercise performed (e.g. resistance- *vs.* endurance-based) has major implications for the alterations in protein metabolism that occur in response to an exercise stimulus. In general, it is less likely that young children will partake in high intensity resistance training programs, and the majority of active youth are less interested in obtaining the muscle hypertrophy characteristic of resistance exercise[20]. Instead, children tend to engage in free-play, or structured exercise programs that are more aerobic in nature [i.e., jump rope and dancing for girls, and team sports for boys][22]. Therefore, the findings from aerobic-based studies may be more applicable to the active child. For this reason, the following sections focus primarily on the effects of aerobic-based exercise with respect to protein metabolism. Given the infancy in our understanding of the effects of dietary protein ingestion following aerobic-based exercise, evidence from the resistance training literature would supplement the gaps in our knowledge.

Effects of Exercise on Protein Metabolism in Children

Only a handful of studies have directly examined protein metabolism and exercise in children (using the [15N] glycine method), and some existing studies have focused on overweight or obese children[23]. Since protein metabolism in response to exercise training may differ between normal weight and overweight children[24], this further limits the literature available to understand the physiological response in healthy, non-obese children. Indeed, there are currently only 3 researches that have used the [15N] glycine method to examine the effects of exercise on protein metabolism in non- obese children and, unfortunately, these works present conflicting results. The first study was conducted by Bolster et al[25] and examined the effects of a 6-wk walking program in nonathletic 8- to 10-year-old children (both boys and girls). Participants were asked to walk 5 d·wk^{-1} (about 45-60 min) and encouraged to cover a distance ranging from 3.2 to 6.4 km during each session. Another paper, conducted by Pikosky "et al"[24], investigated the effects of a 6-wk resistance exercise-training program in 7- to 10-year-old boys and girls. Exercise sessions occurred semiweekly and consisted of both body weight supported and machine exercises. In both of these studies the authors found that protein synthesis and protein breakdown were significantly decreased, while WBPB was not affected. Both of these investigations, however, are limited by the lack of a control group that did not exercise. A study by Boisseau et al[26] examined the effects of gymnastic training (defined as "routines of short and intensive exercise involving mainly upper and lower limb strains") on protein metabolism in 10 young (7-12 years) female gymnasts and included an age-matched control group (n = 10). The young gymnasts had trained an average of 8-10 h·wk-1 over the previous year, while the controls engaged in less than 3 h·wk-1 of mild levels of exercise. No differences in protein flux, protein synthesis or protein breakdown were found between the two groups. Unlike the previously described works[25], the authors reported that the gymnast group demonstrated decreased net protein balance (in g·d^{-1}, g·kg^{-1}·d^{-1} and g·kg^{-1} of FFM·d^{-1}) compared with the controls. There are, however, a number of limitations and possible explanations for these discrepancies. Boisseau "et al"[26] reported that the protein intake (g·d^{-1} and g·kg^{-1}·d^{-1}) in the gymnast group was less than that of the control group, the decreased net balance may have been a result of the lower protein intake rather than differences in protein oxidation or other mechanisms (i.e., insufficient energy intake in exercising gymnasts) related to regular exercise. Moreover, the time at which the protein measures were assessed differed between studies. The previously cited interventions[25,26] assessed children during a 10-h overnight fast, whereas Boisseau et al[26] examined the girls during both the post-absorptive and post-prandial states over the course of a day. This led Boisseau et al[26] to conclude that protein metabolism may be more related to dietary aspects (e.g. energy and protein consumption) than to the level of exercise and training. Another limitation that cannot be overlooked is the fact that during the training programs, energy intake was not increased despite increases in activity-related energy expenditure. This might have significant implications given the relationship between energy and protein metabolism. In an attempt to meet an individual's energy requirements, the body can interchange energy sources from macronutrients; thus, the availability of protein to serve as a substrate for protein synthesis is affected by its need to provide energy to the body. When an individual consumes adequate energy to be in a state of energy balance, the dietary proteins that are ingested could be used for protein-specific anabolic processes (e.g., repairing muscles damaged by exercise or increasing lean mass). On the other hand, when insufficient dietary energy is consumed, there are alterations in both protein and N metabolism and, subsequently, increased requirements. For example, when the body is faced with a reduction in available energy, the process of protein breakdown exceeds that of protein synthesis. Thus, in addition to ensuring an adequate consumption of protein, enough non-protein energy (i.e., CHOs and fat) must also be consumed. Given that exercise is known to further alter the complex interactions between energy requirements and protein metabolism, it is unknown whether the protein-energy balance affected the modulations in protein metabolism during the training programs.

Conclusions

Due to the paucity of information in this area of pediatric research and the number of limitations in the available studies, there remains a large gap in our knowledge regarding the effects of exercise on protein metabolism for non-obese children and youth. Given the importance for children lead an active lifestyle while attaining a positive WBPB for proper development, there is a need to better understand this relationship to formulate appropriate recommendations for protein for active youth.

Conflict of interest

The authors declare no conflicts of interest.

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