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A Review of Literature: Hormonal Responses to Resistance Training and its Effects on Strength Adaptations

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ABSTRACT

With Strength training becoming very popular over the last couple of years, this paper looks at the role hormones play in improving both muscular strength and muscular remodelling. The hormones in question in this research paper are: testosterone, human growth hormone, insulin growth factor and cortisol. All the above hormones have been of hot debate especially with the introduction of transgender athletes competing on the world stage. The Edith Cowan online library Database and Google Scholar were the main databases used to search for articles between the years 2000 to 2019. Fifteen articles were selected for review with two additional papers selected from other research articles. One research review article was also included. Collectively, the selected studies demonstrated that although acute hormonal levels are elevated after bouts of resistance training, there was little evidence shown that these increases cause significant strength and hypertrophy adaptations. The Key findings during this review was that: 1) Muscle protein synthesis is present with or without hormonal elevations. 2) Evenly spread protein consumption between 5-6 meals a day with an intake of 2.0g/kg.bw.day was more import than increases in hormonal levels to elicit strength adaptions. 3) Higher set ranges >3 sets per exercise elevates protein signalling such as p70S6K1 resulting in greater strength and hypertrophy adaptations.

Keywords: Resistance Training, Hormonal Response, Muscle Protein Synthesis, Strength Adaptations

INTRODUCTION

Strength training has become very popular over the last couple of years and has become one of the most utilized methods of training [1]. In athletic performance, strength training is applied to improve an athlete's strength, power, muscular endurance and to increase muscle size (hypertrophy), these adaptations can occur both neurologically and physiologically [1-4]. This review assessed the acute and chronic physiological changes of the endocrine system and how nutrition, age, sex and exercise programming can influence physiological adaptations due to strength training.

It was implied that there are several hormones that help improve both muscular strength and muscular remodelling. Testosterone, human growth hormones and insulin growth factor are suggested to aid both muscle growth and muscle repair by improving protein synthesis and inhibiting protein degeneration .Hormonal increases due to strength training occurs in four generic ways: acute adaptations during and after training; chronic and acute changes to the training stimulus; improvements in muscle receptors and chronic changes in resting levels [4-6].

Testosterone and human growth hormone are both anabolic hormones that are suggested to increase muscle protein synthesis and impede protein degeneration .Testosterone is synthesised by the secretion of the luteinizing hormone in the anterior pituitary gland .The luteinizing hormone stimulates the Leydig cells to produce testosterone .Human growth hormone is secreted through the anterior pituitary gland and assists in elevating muscle protein synthesis whilst delaying protein degeneration [6-8].

Cortisol is a catabolic hormone and is the major hormone of the glucocorticoid. Cortisol is produced by the adrenal cortex and accounts for 95% of all glucocorticoid activity .Cortisol affects many fuel sources such as glucose, protein and free fatty acid metabolism. Cortisol assists in the breakdown of protein into amino acids and supports growth hormone. If cortisol is not supressed it can decrease protein synthesis and promote protein degeneration [8-9].

MATERIALS AND METHODS

The hormones: testosterone, human growth hormone, insulin growth factor and cortisol found in the endocrine system are the main hormones assessed in this review. A clinical approach was used to review the literature. The Edith Cowan online library database, Google Scholar and PubMed were used to searched for articles between 2000 and 2019. Key words and phrases were searched in different combinations (hormonal effects with resistance training, growth hormone, testosterone, cortisol, IGF-1, resistance training, strength adaptations). Fifteen articles were then identified with an additional 2 papers selected from reference lists of other papers and 1 research review article was selected.

The Articles had to meet certain selection criteria:

1. Must involve human subjects
2. Examined the effects of natural hormonal levels produced in the body (no steroid induced adaptations) in response to exercise. Papers were not included if they used animal subjects or had a small participation number (>10n).Only papers written in English were accepted and reviewed in this review.

Testosterone

Acute Changes in Testosterone

Serum free testosterone levels in both men and women have shown to elevate acutely after a bout of resistance training .The acute increases in testosterone were notably higher in men than women [10]. Surprisingly, there was no significant difference in testosterone levels between un-trained middle-aged men and trained middle aged men .Resistance trained men however, showed higher acute increases in testosterone than endurance trained men. This suggests that chronic adaptations from resistance training could increase testosterone levels.

Acute responses in Testosterone concentration can be elevated through multiple factors of resistance training. The largest elevations in testosterone levels were found in exercises that included large muscle groups such as Olympic lifts i.e cleans, squat and deadlift. Other factors included high volume and intensity with short rest durations. Rahimi, Rohani, & Ebrahimi found that, exercises performed for 3 sets to 5 sets and 8 reps -12 reps with rest periods of 60 seconds to 120 seconds achieved the greatest acute elevations of testosterone [11]. These increases of testosterone where found to have peaked around 15 minutes post exercise returning to basal levels 1 hour after exercising.

Research has found mixed reports about whether acute elevations in testosterone lead to an increase in protein synthesis. There are a few studies that suggest testosterone assisted in increasing strength adaptions through protein synthesis [12]. Findings by Urban , showed that, Testosterone would not only increase muscle protein synthesis, but also reduce breakdown by suppressing inflammatory processes in skeletal muscle. However, there are other studies that found muscle protein synthesis occurs with or without the presence of acute elevations in testosterone [13-15]. These mixed findings show that research into how muscle protein synthesis is elevated in response to exercise is needs further investigating.

Chronic Changes in Testosterone

Chronic changes in testosterone concentrations due to resistance training has been shown to be non-existent or incomprehensive. Tarpenning et al., reported significant increases in chronic concentrations in both pre-pubertal and pubertal boys. The findings however were incohesive as these elevations could have occurred due to multiple other factors. One study showed that chronic elevations in testosterone could be caused by resistance training as they found that middle-aged trained men had higher concentrations in testosterone than their non-trained counterparts . However, multi studies found that there are no elevations in chronic testosterone concentrations .

Cortisol

Acute changes in Cortisol

Research has shown that resistance training causes significant increases in acute cortisol levels .The same exercise protocols that increase testosterone and growth hormone are also shown to increase acute cortisol levels .Exercise programs that are high intensity, high volume and with short rest intervals show the greatest increases in serum cortisol levels. it was also shown that increases in stress placed on the body correlated to an increase in cortisol levels.One study showed that concurrent training significantly increased cortisol more than performing strength training in isolation .The concurrent training increased stress placed on the body which in turn caused acute cortisol levels to spike.

Increases in acute cortisol levels due to bouts of exercise, were shown to increase in both men and women. Strength training, increased cortisol levels in both men and women, men's levels however started to decrease after 8 weeks of training, even returning to baseline after 16weeks .Women on the other hand showed significant elevations in cortisol levels from 8 weeks to 12 weeks, levelling off at 16 week .This elevation in women cortisol levels was suggested to be from women being hypercortisolic.Findings from Bell et al. , suggested that gender differences are to be a consideration when writing exercise prescriptions as both men and women adapt to training stimuli differently (Figure 1 a,b).

Cortisol/Testosterone ratio

The testosterone/cortisol ratio (Ts/Co ratio) is suggested to be a physiological indicator for overtraining. It has been recommended that changes in the Ts/Co ratio are responsible for hypertrophy and strength gains [16]. Studies showed that, the Ts/Co ratio is frequently used as an index for measuring overtraining and stress levels brought on by bouts of exercise training .Consequently, there was little to no evidence in supporting the Ts/Co ratio as a strong predictor of overtraining syndrome [17].Urhausen, Gabriel & Kindermann, found that overtraining is caused by a reduction in both the secretion of catecholamines and the impairment of full mobilisation of anaerobic lactic reserves. This suggested that other markers need to be assessed when determining overtraining and elevated stress levels.

Growth Hormone

Strength training was shown to significantly elevate acute levels of growth hormone.The degree of elevation is dependent on: exercise selection, amount of muscle mass recruited, and the total work done during that session .Total work was an important factor in increasing growth hormone levels. Acute levels of growth hormone are significantly elevated by: increasing the volume and intensity of the sessions; decreasing rest periods and using muti-sets (super sets) instead of single sets . Several studies showed, using rest periods of 30 seconds to 60 seconds between sets were deemed most effective in elevating growth hormone[18]. These short rest periods along with increased intensity and volume helped to elicit a greater blood lactate level. This high blood lactate level aids in elevating the acute growth hormone concentration . he increases of H+ produced from lactic acid has been suggested to be the primary factor in growth hormone secretion [19].

IGF-1 (acute and chronic changes)

Studies which investigated Insulin Growth Factor (IGF-1), showed that resistance training caused an acute elevation in IGf-1. Some studies found, elevations in IGF-1 improved mRNA [20-21]. Willoughby, Stout, & Wilborn , investigated protein supplantation and its effect on IGF-1 and muscle protein synthesis. They found that, protein intake before exercise elevates insulin receptor activation, this in turn stimulates the PI3KAkt=PKB-mTOR signalling pathway. This pathway is known to have profound effects on the up-regulation of the muscle specific gene expression and protein synthesis .Willoughby et al. , found that protein pacing of (5-6 meals of high protein per day) or 2.0g/kg.bw.day, increased IGF-1 during training by 12%. Furthermore, this upregulation of IGF-1 mRNA also seems to be load dependant [22]. The greatest results were shown in large muscle groups (thigh extensor muscles) and with a high volume of load.

Hormonal role in strength related adaptations

There is little evidence supporting the notion that acute hormonal levels are elevated after bouts of resistance training and that the increased levels can cause significant strength and hypertrophy adaptations. It has been reported that muscle protein synthesis is present with or without hormonal elevations .A study by West , looked at the role resistance training-induced acute hormonal elevation plays on muscular hypertrophy. West found that, phosphorylation of the signalling proteins STAT3 and p70S6K were elevated in response to exercise regardless of increased acute hormonal levels. The phosphorylation of p70S6K resulted in the acute activation of muscle protein synthesis which lasted 1 hours -2 hours after exercise. This subsequently lead to muscular hypertrophy [23]. As acute elevations in hormones are not as important as recently suggested, other factors must play a role.

Factors for Strength related adaptations

There are several factors that all work in unison with each other which contribute to the stimulation of protein synthesis. West & Phillips, found that elbow flexor exercises resulted in little to no hormonal elevations and that the leg exercises produced high levels of

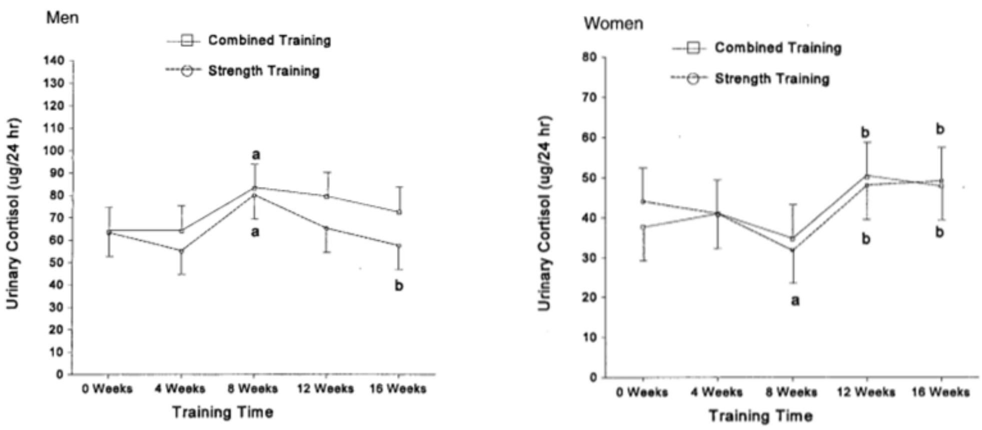

Figure 1.(a) Graphs from Bell, Syrotuik, Socha, Maclean & Quinney showing changes in urinary levels of cortisol after strength and concurrent training in Men **(b)** Urinary levels of cortisol after strength and concurrent training in Women [10].

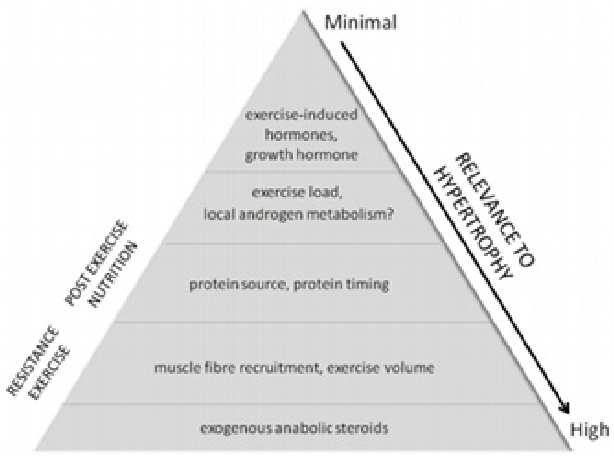

Figure 2. A photo showing the most to least influential factors leading to Strength adaptations.

acute hormonal elevations. Even though hormonal levels are elevated during leg exercises, both protocols produced the same results in muscle hypertrophy .This meant that other factors must play a role in muscle hypertrophy.

Muscular hypertrophy can be improved by increasing protein syntheses .Protein synthesis can be improved though efficient timing of protein intake. Post exercise nutrition increased both the acute and chronic anabolic responses to resistance training. Milk has been offered as a fairer protein source that produces high elevations of protein synthesis when compared to other fuel sources such as soy and carbohydrate drinks [24].

A study by West & Phillips , also found that lifting light loads (30% of 1rm) can stimulate protein synthesis to the same extent as heavy loads (90% 1rm) if the lighter loads are lifted to failure. This correlates to the size principle where the highly hypertrophic type II muscle fibres become active towards the end of the repetitions when fatigue starts to play a role . When examining resistance programs, it was observed that, 3 sets were more beneficial than 1 sets of resistance exercise . West, found that 3 sets enhanced both the intracellular signalling and the rate of which myofibrillar protein synthesis occurred. This meant that, regulatory anabolic signalling proteins such as p70S6K1 was active for longer period after a higher training stimulus. This resulted in an increase in strength adaptations induced by a longer activation of muscle protein synthesis (Figure 2).

DISCUSSION AND CONCLUSION

Collectively the research showed that exercise induced hormones are only elevated acutely, with little to no evidence supporting resistance training elicits chronic adaptions in baseline hormonal levels. It was also shown that only acute elevations in testosterone and IGF-1 may help in muscle protein synthesis. Women showed higher elevations in acute cortisol levels than men due to women being more hypercortisolic. Exercise selection, total training volume and nutritional timing were found to be of higher importance for muscle protein synthesis with acute hormonal elevations being less significant. The Key findings during this review was that:

Evenly spread protein consumption between 5-6 meals a day resulting in an intake of 2.0g/kg.bw.day was found to elevate protein synthesis.

Higher set ranges >3 sets per exercise elevates protein signalling such as p70S6K1 resulting in greater strength and hypertrophy adaptations.

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