Original Research Article

The acute effect of resistance exercise on serum growth hormone and blood glucose in healthy non-obese adolescent subject

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ABSTRACT

Background: The growth hormone (GH) response to resistance training is altered by many factors including sex steroid concentrations, fitness, intensity of exercise, age, gender, duration of exercise and glycemic state but the exact understanding of the interplay of different exercises to GH levels and its induced physiological adaptations is still obscure. This study aimed to see how resistance exercise affects GH levels and its correlation to plasma glucose levels in healthy non-obese adolescent subjects.

Methods: 48 healthy non-obese adolescent subjects, 24 males and 24 females were included in the study. High volume exercise training regimen was used which involved major muscle group of arms, legs and trunk. Pre and post exercise levels of serum GH and random blood sugar were estimated in male and female groups.

Results: The mean body mass index (BMI) of male and female groups was 23.22 ± 3.12 kg/m^2 and 20.40 ± 4.49 kg/m^2, respectively. The post-exercise serum GH levels in male and females increased significantly by 0.54 ± 1.041 ng/ml ($p<0.05$) and 0.85 ± 1.023 ng/ml ($p<0.001$) respectively. The random blood sugar levels in males after exercise significantly increased ($p<0.05$) by 7.16 ± 12.61 mg/dl and in females by 6.20 ± 12.09 mg/dl ($p<0.05$). There was significant correlation ($p<0.05$) between increase in serum GH levels and increase in random blood sugar levels in both male and female group.

Conclusions: Exercise induced increase in GH and its interplay with serum glucose can be better gained access into via metanalytical/elaborate studies of the major hormones and fuels involved.

Keywords: Resistance training, Growth hormone, Glucose, Body mass index

INTRODUCTION

Systematic strength training has a potent effect in promoting size and strength of skeletal muscle due to combinations of multiple factors, that is, mechanical stress, neuromotor control, metabolic demands and endocrine activities.[1] A heavy resistance exercise protocol performed with the progressive overload principle leads to acute responses, observed as increase in serum anabolic hormone concentrations and temporary decrease in neuromuscular performance.[2] Therefore, the magnitude of acute hormonal and neuromuscular responses can be considered as important indicators of training effects of various heavy-resistance exercises. It has been hypothesized that during long-term strength training, acute hormonal responses induced by the single-resistance exercises are important contributors to muscle hypertrophy.[3]

By undertaking a systematic evaluation of the effect of resistance activity on circulating growth hormone in healthy non-obese adolescents, we intented to study the correlation of anthropometric variables to baseline blood glucose and GH levels in the two genders, also correlating them to the post exercise changes. We knew that hypoglycemia induces GH secretion but in the presence of heavy volume exercise and pre-existing baseline blood glucose level, data regarding its modified secretion is vague and needs better understanding. Thus, the aim of our study was to enhance our understanding as to how exercise protocols can be customized in different genders, to develop a hypertrophy-specific routine for maximizing muscle growth.

Aim

The aim was to study the effect of acute resistance exercise on serum GH and blood glucose in healthy non-obese adolescent subjects.

Objectives

The objectives of this study were to measure BMI, to measure random blood sugar level before exercise and 10 minutes after exercise and to measure serum GH level before exercise and 10 minutes after exercise.

METHODS

This study was an experimental analytical study. A pilot study comprising of sample size of 48 subjects was taken of MBBS first year professional, comprising of 24 males and 24 females at G. S. V. M. medical college, Kanpur, U. P.

All the volunteers who took part in the study were screened via comprehensive health questionnaire and physical examination to rule out any disease. We sought out individuals who were sedentary or doing moderate activity and were not previously involved in any kind of weight training, athletic training or any sport activity for at least one year. After screening procedure, all the volunteers were instructed to refrain from any kind of sports activity or physical training during the study period that can expose them to any muscle stress and so at the time of performing resistance exercise, subjects feel maximum stress in their untrained muscle.

The subjects were informed about the study and written consent was duly taken. Ethical clearance was duly taken from institutional ethical committee.

Inclusion criteria

Subject who had a sedentary lifestyle for at least 1 year with no exposure to any kind of physical training like gymnasium (gym) or athletic activity or training for outdoor games for at least 1 year and having no history of major illness were included in the study.

Exclusion criteria

Participation in the outdoor sports, gymnasium (gym) training, history of any musculoskeletal injury or disorder, history of any kind of hormonal intake were excluded from the study. For female subjects, history of oral contraceptive pill intake or hormonal therapy were also in the exclusion criteria. Patients with history of treatment with steroid for any disorder and patients with history of diabetes mellitus were also excluded.

High volume exercise training regimen previously shown to cause significant acute exercise induced hormone elevations was used. This training protocol was considered to provide the best prospects for evaluating potential adaptations in the acute exercise induced hormonal responses and the importance of hormonal factors on other training responses.[4] The same protocol regime was followed in which a stress to the muscle was given. As subjects were untrained and not familiarized with the exercise regime, their muscle faced sudden stress which was increased by increasing the weight. All the subjects were informed of the protocol in detail. Subjects were instructed to fast overnight and exercise protocol was done in the morning from 6:00 am to 7:00 am.

Procedure

Intensity (load) has been shown to have a significant impact on muscle hypertrophy and is arguably the most important exercise variable for stimulating muscle growth. Intensity is customarily expressed as a percentage of 1 repetition maximum (RM) and equates to the number of repetitions that can be performed with a given weight. Repetitions can be classified into 3 basic ranges: low (1-5), moderate (6-12), and high (15+). Each of these repetitions ranges will involve the use of different energy systems and tax the neuromuscular system in different ways, impacting the extent of the hypertrophic response.[5]

Exercise training involved major muscle group of arms, legs and trunk. Free weights were used for all exercises. Regime involved 5 exercises with 3 sets.

First set consist of 10 repetitions maximum with same weight. Then in the second set, load was increased as per the muscle group being stressed and subjects have to perform 8 repetitions maximum and in the last set, load was further increased and subjects had to perform 6 repetition maximum. Between each set, subjects took rest for 30 seconds and with each exercise, a rest period of 1 minute. Similarly, this protocol was followed with other exercises.

The exercise regime consisted of following exercises

Dumbbell's biceps curl

This exercise was for the biceps and forearms. The alternating of each arm eliminates any muscular

imbalances on each side. Grab a pair of dumbbells, stand up straight and with a braced core. Allow the dumbbells to hang at arm's length with palms facing forward. Without moving your upper arms, bend your elbows and curl the dumbbells as close to your shoulders as you can. Pause for a second and slowly allow the weights to return to the starting position with arms fully extended.

Bench press

It is an upper body strength training exercise that consists of pressing a weight upwards from a supine position. The exercise works the pectoralis major as well as supporting chest, arm and shoulder muscles such as the anterior deltoids, serratus anterior, coracobrachialis, scapulae fixers, trapezii, and the triceps. A barbell is generally used to hold the weight. The person performing the exercise lies on their back on a bench with a weight grasped in both hands. Push the weight upwards until arms are extended, not allowing the elbows to lock. Then lower the weight to chest level.

Barbell bent over with dumbbells

It is muscle building exercise for the back and also for the shoulders. To perform the exercise with your left arm, position your right knee and lower leg and your right hand, on a bench. Leave your left foot flat on the floor and bend forward so your torso is horizontal. Hold the dumbbell with your palm facing the bench and your arm extended straight down. Lift the weight to the left side of your chest and then lower it slowly to the starting position. The exercise was performed with both arms.

Seated front shoulder press

It effects throughout the core complex and upper back region, while increasing overall stability. This exercise is done with feet shoulder width apart which required less core strength. On a weight bench with an upright back support, grab a barbell using a double-overhand grip so your hands are slightly wider than shoulder-width apart. Slowly bend the arms and lower the barbell to your collar bone, keeping your elbows by your sides. Gripping the barbell firmly, press it overhead until your elbows are completely locked out.

Squats

It trains primarily the muscles of the thighs, hips and buttocks, quadriceps femoris muscle, hamstrings as well as strengthening the bones, ligaments and insertion of the tendons throughout the lower body. Stand as tall as you can with your feet shoulder-width apart, toes slightly pointed outward. Keep arms in front of you at chest height to help maintain balance. Drop your hips and sit back until your thighs are parallel with the floor. Pause, then drive through the heels and lift body upwards back to the starting position, squeezing the gluteus maximus muscle at the top of the movement.

There were two different regimes as per the load for the two genders. With each exercise, the load was different for different muscle group (Tables 1 and 2 for males and females respectively).

Blood sampling and measurements

2 ml blood was withdrawn just before exercise and 10 minutes after exercise was collected in a plain glass vial with gel base. Post exercise samples were collected 10 minutes after the exercise. Serum was separated with centrifuge machine with 3000 rpm. Then samples were stored at -17 to -20ºC at the college blood bank. Random blood sugar (RBS) values were taken with strip digital glucometer. Fasting blood sample was taken as soon as subjects reached to the exercise training arena and 10 minutes after exercise.

For quantitative measurement of serum GH, ELISA kit was used. GH normal range (ng/ml) in adult was taken as 5-10 ng/ml.

Anthropometric parameters like height and weight were taken by the standard measuring scale and weight was taken by digital weighing machine and BMI calculated.

The BMI or quetelet index is universally expressed in units of kg/m^2, resulting from mass in kilograms (kg) and height in meter (m).

WHO classification of obesity (2006)[6]

Underweight: <18.5 kg/m^2; normal (healthy weight): 18.5-24.9 kg/m^2; overweight: 25- 29.9 kg/m^2; obese class 1 (moderately obese) 30-34.9 kg/m^2; obese class 2 (severely obese) 35-39.9 kg/m^2; obese class 3 (very severely obese) ≥40 kg/m^2 is the WHO classification of obesity.

Statistical analysis

Statistical analysis was duly done using SPSS software version 26. Continuous data were summarized as mean±SD and discrete data in number and percent. The same students were compared on two different times so paired t test was performed. P<0.001 was considered statistically highly significant while p>0.05 was considered non-significant.

RESULTS

The mean age (years) with ±SD for males was 19.95±1.93 and 18.80±0.98 for females which did not differ statistically. Similarly mean height, weight and BMI have non-significant differences between males and females (Table 1).

In males, pre-exercise serum hGH level (mean±SD) was 3.25±1.26 ng/ml and post-exercise level was 3.80±1.39

ng/ml. There was 0.54±1.04 ng/ml (14.21%) increase in serum hGH. The paired t test shows significant correlation (r=0.16) between BMI within the group (males) with p value <0.05 (Table 4).

Table 1: Males exercise regime.

Exercises	Dumbbells			Bench press			Barbell bent over			Seated front press			Squats		
Repetitions	10	8	6	10	8	6	10	8	6	10	8	6	10	8	6
Weights (kgs)	5	7.5	10	15	20	30	7.5	15	20	7.5	15	20	15	20	30

Table 2: Females exercise regime.

Exercise	Dumbbells			Bench press			Barbell bent over			Seated front press			Squats		
Repetitions	10	8	6	10	8	6	10	8	6	10	8	6	10	8	6
Weights (kgs)	3	5	7.5	10	12	15	5	7.5	10	10	12	15	10	12	15

Table 3: Sex wise distribution of height, weight and BMI.

Parameters	Males (N=24)	Females (N=24)
	Mean±SD	Mean±SD
Height (in cms)	170.12±7.80	157.04±5.08
Weight (in kgs)	66.95±9.11	52.91±7.13
BMI (in kg/m^2)	23.22±3.13	20.40±4.49

Table 4: Correlation of serum GH in males with BMI.

Serum GH	Mean±SD (ng/ml)	r value	BMI (kg/m^2)	P value
Pre-exercise	3.25±1.26	-0.16		
Post-exercise	3.80±1.39	-0.26	23.22±3.13	<0.05
Difference	0.54±1.04	-0.16		

Paired t test.

Table 5: Correlation of RBS in males with BMI.

Serum RBS	Mean±SD (mg/dl)	r value	BMI	P value
Pre-exercise	86.79±10.02	0.20		
Post-exercise	93.95±10.032	0.019	23.22±3.13	<0.05
Difference	7.16±12.61	-0.02		

Paired t test.

Table 6: Correlation of serum GH in females with BMI.

Serum GH	Mean±SD (ng/ml)	r value	BMI	P value
Pre-exercise	3.09±0.98	- 0.28		
Post-exercise	3.95±1.06	- 0.25	20.4±4.49	<0.001
Difference	0.85±1.02	0.007		

Paired t test.

Table 7: Correlation of RBS in females with BMI.

Serum RBS	Mean±SD (ng/ml)	r value	BMI	P value
Pre-exercise	90.41±11.41	0.36		
Post-exercise	96.62±9.95	-0.28	20.40±4.49	<0.05
Difference	6.20±12.09	0.15		

Paired t test.

Table 8: Correlation of serum GH in males with RBS.

Serum GH	Mean±SD (ng/ml)	RBS (mg/dl)	P value
Pre-exercise	3.25±1.26	86.9±10.03	
Post-exercise	3.8±1.39	93.95±10.03	<0.05
Difference	0.54±1.04	7.16±12.61	

Paired t test.

Table 9: Correlation of serum GH in females with RBS.

Serum GH	Mean±SD (ng/ml)	RBS	P value
Pre-exercise	3.09±0.98	90.41±11.41	
Post-exercise	3.95±1.06	96.62±9.95	<0.05
Difference	0.85±1.02	6.20±12.09	

Paired t test.

In females, pre-exercise random blood sugar (fasting overnight) level was (mean±SD) 86.79±10.03 mg/dl and post-exercise level was 93.95±10.032 mg/dl. There was 6.20 mg/dl (6.41%) increase in random blood sugar. The paired t test showed significant change in pre and post-exercise random blood sugar (p value <0.05) but there was no significant correlation (r=-0.02) with BMI (Table 5).

In females, the pre-exercise serum hGH levels (mean±SD) was 3.09±0.98 ng/ml and post-exercise level was 3.95±1.064 ng/ml. There was 0.85±1.023ng/ml (21.59%) increase in serum hGH. Paired t test showed highly significant correlation (r=0.007) between BMI within the group (females) with p value <0.001 (Table 6).

Their pre-exercise random blood sugar (fasting overnight) level (mean±SD) was 90.41±11.41mg/dl and post-exercise level was 96.62±9.95 mg/dl, with 6.20 mg/dl (6.41%) increase in random blood sugar with p value <0.05. The paired t test shows significant change in pre and post-exercise random blood sugar but there was no correlation (r=0.15) between BMI as random blood sugar (Table 7).

The paired t test showed significant correlation between random blood sugar and rise in serum GH in males with p value <0.05 (Table 8).

The paired t test showed significant correlation between random blood sugar and serum GH in females with p value <0.05 (Table 9).

DISCUSSION

Human GH is a polypeptide chain of 191 amino acid and molecular weight of 21500. It is released by anterior pituitary gland of men and women. The secretion stimulated 3-4 hours after meal, about 1 hour after the beginning of sleep and after physical exercise. Hyposecretion of GH becomes apparent in infants a few months after birth and may result in dwarfism. In the opposite case, hypersecretion of GH results in gigantism and may be due to hypophyseal tumors. In adults, when epiphysis fuses with bones, hyper secretion provokes an increase in soft tissue (hand, feet, lips) and proliferation of bones (acromegaly syndrome) and limited tolerance of glucose.[7]

hGH has profound effect on tissue growth and metabolism, which is thought to be mediated through GH dependent production of insulin like growth factor (IGF)1

and 2 and there associated binding proteins. GH apparently stimulates IGF production after binding to specific cell surface receptor in the liver. The major target tissue affected by the IGF-1 in combination with GH signals are muscle, cartilage, bone, liver, kidney, nerves skin and lungs. Evaluation of GH deficiency is complicated by the episodic nature of GH secretion and low circulating levels. A variety of physiologic and pharmacologic stimuli have been used to stimulate pituitary GH release during testing and failure to achieve a normal serum GH levels in response to at least 2 GH stimuli to provocative test is considered to be a diagnostic of GH deficiency. The normal serum GH values generally range from 5 to 10 ng/ml.[8]

In this study, we investigated the serum GH response to maximal resistance exercise in young untrained males and females, who had been leading a sedentary life for at least a year and tried to sought out correlation, if any to the BMI and random blood glucose levels. Resistance exercise (RE) stimulates GH secretion in a load-dependent manner, with heavier loads producing larger GH responses.[9] But our study revealed, that although in both the groups of males and females a significant rise in serum GH was recorded, the females had significantly more increase in serum GH levels than males, inspite of the difference in the loading weight between the males and the females, determined as per their strength and muscular mass. This finding may be due to estrogen stimulating GH secretion, by decreasing liver secretion of insulin-like growth factor-I (IGF-I), resulting in stimulation of the pituitary to synthesize and secrete GH.[10]

GH acts on insulin-like growth factor-I (IGF-I) secretion which has metabolic actions on its own and depends on weight status. Large population studies show that IGF-I is dependent on BMI with a bell-shaped relation and a maximal level between a BMI of 30-35.[11] As compared to their male counterparts, females in our study had low baseline GH levels contrary to the fact that estrogen enhances GH secretion and females have a higher level of estrogen physiologically. This can be explained by their (females) relatively lower BMI thus reflecting as low estrogen levels. In addition, the measurement timings might have coincided with those phases of menstrual cycle when estrogen level is low. Estrogen levels increase with increasing BMI, presumably because conversion of androgens to estrogen in adipose tissue takes place. Studies of estrogen in premenopausal women are complicated by the fact that estrogen levels vary greatly during the menstrual cycle. However, an association between high BMI and low estrogen concentration is

apparent when concentration is measured during a specific phase of the menstrual cycle except the mid follicular and mid luteal phase.[12] Mulligan et al too found that during the early follicular phase and mid luteal phase of menstrual cycle, women showed significantly higher baseline serum GH values than men although heavy resistance exercise showed the similar response in both genders.[13]

In our study, the baseline BMI of males was more than the females for the given age group (18-22 years) primarily because of the androgen induced effects in males, but there was no significant direct correlation between BMI and blood glucose level (BGL).[14] Instead, the females in our study had a higher baseline BGL. A study conducted by Awadh et al corroborated our findings stating that female subjects have high blood glucose levels but do not results from high BMI, instead, are associated with high sugar consumption thus demanding for an increase in awareness among the university students in order to reduce the prevalence of hyperglycemia and consequent pre-diabetes.[15]

A study has shown that GH is acutely elevated from routines employing moderate repetitions sets as compared to those using lower repetitions, thereby increasing the potential for downstream cellular interactions that facilitate remodeling of muscle tissue.[16] The high-intensity, heavy-resistance exercise is well known to induce a great acute GH response. It has been suggested that exercise-induced acute increase in serum GH concentrations may be responsive to the central stimuli as brain motor center activity and/or changes in acid-base balance within the loaded muscles via afferent feedback from peripheral chemoreceptors.[17]

Thus, the exact contribution of exercise induced alteration of GH to muscle tissue growth and physiological adaptation to exercise stress in men and women require further studies. Thus emphasizing that the appropriate program variables (volume, intensity, duration, resting interval) of exercise must be in place in a training program in order to elicit desired hormonal responses needed to stimulate optimal physiological adaptation.

CONCLUSION

In the present study, we concluded that inspite of a comparatively lower BMI as compared to their male counterparts, females had higher baseline blood glucose levels. this emphasizes the importance of making the females aware of the probable causes like high calorie intake and more sedentary lifestyle they pursue, thus preventing them from falling in the prediabetic category. Females also had a low baseline serum GH level, inspite of the fact that they have higher estrogen level than their male counterparts. The serum GH levels increased significantly in post-exercise in both the groups of males and females where the latter had comparatively more

rises in GH levels inspite of lighter weights used in exercise regime in comparison to males. There was a significant correlation between increase in serum GH levels and increase in random blood sugar levels in both males and females' group. Thus, exact contribution of exercise induced alteration of GH to muscle tissue growth and physiological adaptation to exercise stress in men and women require further studies.

REFERENCES

1. Kraemer, William &Vingren, Jakob & Hatfield, Disa & Spiering, B.A. & Fragala, M.S. (2007). Resistance training program. ACSM's resources for the personal trainer. 372-403.
2. Izquierdo M, Ibañez J, Calbet JAL, Navarro-Amezqueta I, González-Izal M, Idoate F, et al. Cytokine and hormone responses to resistance training. Eur J Appl Physiol. 2009;107(4):397-409.
3. Rønnestad BR, Nygaard H, Raastad T. Physiological elevation of endogenous hormones results in superior strength training adaptation. Eur J Appl Physiol. 2011;111(9):2249-59.
4. McCall GE, Byrnes WC, Fleck SJ, Dickinson A, Kraemer WJ. Acute and chronic hormonal responses to resistance training designed to promote muscle hypertrophy. Can J Appl Physiol. 1999;24(1):96-107.
5. Schoenfeld BJ. The mechanisms of muscle hypertrophy and their application to resistance training. J Strength Cond Res. 2010;24(10):2857-72.
6. WHO. Obesity and overweight Fact sheet N°311 September 2006.
7. "Immunoassays site.iugaza.edu.ps." Available at: http://site.iugaza.edu.ps/hesawwaf/files/2016/02/Immunoassays-ELISA-part-two-growth-hormon.pptx. Accessed on 3 March 2021.
8. Bio Vision. Fact sheet: Human Growth Hormone ELISA Kit. Available at: https://www.biovision.com/documentation/datasheets/K7412.pdf. Accessed on 30 May 2021.
9. Manini TM, Yarrow JF, Buford TW, Clark BC, Conover CF, Borst SE. Growth hormone responses to acute resistance exercise with vascular restriction in young and old men. Growth Horm IGF Res. 2012;22(5):167-72.
10. Cook DM. Growth hormone and estrogen: a clinician's approach. J Pediatr Endocrinol Metab. 2004;17(4):1273-6.
11. Kreitschmann-Andermahr I, Suarez P, Jennings R, Evers N, Brabant G. GH/IGF-I regulation in obesity-mechanisms and practical consequences in children and adults. Horm Res Paediatr. 2010;73(3):153-60.

12. Green LE, Dinh TA, Smith RA. An estrogen model: the relationship between body mass index, menopausal status, estrogen replacement therapy, and breast cancer risk. Comput Math Methods Med. 2012;2012:792375.
13. Mulligan S, Fleck S, Gordon S, Koziris L, Triplett-McBride N, Kraemer W. Influence of resistance exercise volume on serum growth hormone and cortisol concentrations in women. J Streng Condition Res. 1996;10(4):256-62.
14. Centers for Disease Control and Prevention. Fact sheet: About Child and Teen BMI, 2018. Available at: www.cdc.gov/healthyweight/assessing/bmi/childrens_BMI/about_childrens_BMI.html. Accessed on 30 May 2021.
15. Awadh FA, ALRamadhan F, =Baaleis M, Alhanwah B. Correlation between body mass index and blood glucose levels among female students of King Faisal university. Int J Sci Eng Res. 2018;9(1):998-1003.
16. ISSUU. Fact sheet: Mechanisms of muscle hypertrophy by Guan, 1966. Available at: https://issuu.com/guan1966/docs/mechanisms_of_muscle_hypertrophy. Accessed on 30 May 2021.
17. Ahtiainen JP, Pakarinen A, Alen M, Kraemer WJ, Häkkinen K. Muscle hypertrophy, hormonal adaptations and strength development during strength training in strength-trained and untrained men. Eur J Appl Physiol. 2003;89(6):555-3.