Original Article

The effect of 8 weeks endurance and resistance training on Myostatin and Follistatin serum level in postmenopausal women's

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ABSTRACT

Purpose and the basis: The purpose of this study is the effects of 8 weeks resistance and endurance training on the myostatin and follistatin serum levels in postmenopausal women. **Materials and Methods:** The subjects were 30 menopausal women randomly divided in one of the four groups aged as groups of endurance (55.33±2.75), resistance (50±3.11), control (53±2.16). Training program was conducted in 3 sessions for 8 week. The endurance training program included a 45-minute walk on a treadmill with severity of MHR (Maximum Heart Rate) of 40-65%. The resistance training program included some exercises selected from upper and lower extremities, with a severity of 1RM (1 Repeat Major) of 40-65%) which were done in 45 minutes. Two blood samples were taken 24hours before the first session and 48 hours after the last session of the subjects. To compare the data of all 3 groups we used a one way ANOVA test. **Results:** The result showed a significant difference between 3 groups in myostatin ($p = 0.036$) and follistatin ($p = 0.008$). After post hoc comparisons a significant decrease was found in myostatin serum in resistance exercise group compared to endurance exercise and control groups (respectively, $p = 0.048$ and $p = 0.004$). Also significant increase observed in resistance and endurance exercise groups (respectively, $p = 0.002$ and $p = 0.009$). **Conclusion:** Because endurance training just increased follistatin and resistance training increased follistatin and on the other hand decreased myostatin. Therefore, resistance training seems to be a more effective intervention for improving the metabolic status of postmenopausal women.

Keywords: Endurance, Resistance, Training, Myostatin, Follistatin, Postmenopausal

Introduction

Menopause is a physiological process that occurs in women at an average age of 50 years. This physiological process produces many damaging effects on body tissues and muscle tissue [1]. With the aging activated systematically myostatin postmenopausal in women's. This condition is more appear in postmenopausal women's [2].

The average age of menopause is 51 years. Approximately one third of women age in menopause. In this age range, muscle atrophy is more appear in women than in men

Sarco Penia is a complication of menopause. Myostatin prevents muscle growth. This situation leads to a change in the body's structural status and to the reduction of metabolism and joint diseases so many other complications [3]. Studies have also shown that acute exercise therapy helps to activate follistatin in the muscle and folicasin can be due to activities Exercise induces muscle relaxation. In sports studies, it has been shown that resistance and endurance exercises cause muscle repair and reduce their atrophy [4]. Regarding the literature and research studies, the basis of the research hypotheses is based on three types of practice that led the researcher to measure and compare

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the method of changes in myostatin and follistatin in an eight-week training program in three endurance,resistance and combined exercise groups.

Myostatin Function

Myostatin GDF-8 is a protein encoded by the MSTN gene in the human body. Myostatin is a unique component of the growth of the family of the TGF beta protein, which, in a process called myogenic, inhibits muscle growth. Myostatin is the major component of the skeletal cell produced by The blood flows in the body and eventually binds to receptors of muscle tissue called activin type II [5].

Myostatin's function is to regulate the growth of the muscles from the time of the embryo and this process will continue throughout the life of one person. Myostatin acts as an inhibitor of muscle growth and prevents excessive increase in volume. Myostatin is a protein containing two subunits The same subtype contains 110 amino acids. Myostatin adjusts all muscle growth from birth to adulthood [6].

Follistatin Function

Follistatin is an amazing protein that can increase muscle building up beyond body constraints through myostatin suppression. Scientists first detected folic acid in follicular fluid in a pig ovary.

Follistatin is found naturally in skeletal muscle of almost all mammals, such as humans and cows. Follistatin is found to be found in many unnecessary amino acids of Sistine, but unlike other proteins that you know in the bodyovera, follistatin has carbohydrates attached to itself [7].

Follistatin, in particular, folic acid 344 (FS344), is popular among bodybuilders as a supplement to the enhancement of pure muscle. Another protein called FLRG (FS344) works in the field of similar muscle building (FS344) [5].

Follistatin and muscle growth:

Follistatin acts by binding and inhibiting growth factor beta (TGF-β), such as myostatin, that these growth factors regulate and restrict muscle growth. It is noteworthy that myostatin in skeletal muscle can regulate arteriosclerosis. The amount High levels of myostatin can interfere with the function of the tissues and can cause severe disease in organs such as the tissues and bone marrow [8].

In addition, follistatin can suppress myostatin restricting properties, but it can also inhibit the production and secretion of hormone (FSH) by suppressing the pituitary gland. High levels of FSH in humans may indicate that the testes are not functioning properly. These conditions may limit In muscle growth, recovery and normal hormonal function. Also, very low levels of FSH in the body can have a negative effect on the health and capacity of the genitalia.

As one gets older, the activity of myostatin increases systematically.It's highlighted that this issue in women who are getting old and reaching the age of menopause increases. Myostatin prevents muscle growth, which in return causes a change in the body structure, decreases metabolism, Arthritis, and many other complications [9]. Overall, it seems like with growing old, increase in myostatin expression reduces the number, activity, and differentiation of satellite cells, resulting in decreased muscle mass and ultimately increases the incidence of sarcopenia in these individuals. In Addition, studies have shown that the incidence of sarcopenia is more common in older women than men [10].

Follistatin is also known as anotherconta related factor to muscle mass. Follistatin is an autocrine glycoprotein and a member of the TGF- β large family. With Follistatin and myostatin connection, Follistatin prevents myostatin from contacting the active receptorsun, which as a result, it neutralizes myostatin in the blood circulation [11]. Myostatin neutralization by follistatin, stimulates skeletal muscle growth (the same source). In brief, increase in follistatin level with Satellite cellular activity, increases the prevention from myostatin and its interaction with other regulatory proteins, and hypertrophy in muscles [12]. Many studies have shown that sport exercises are one of the most effective methods to prevent and cope with the risks of aging, such as menopause and being an elderly through improving physical and physiological functions of skeletal muscle tissue, [13, 14].

Recent studies have shown a lot of proof that the increase in muscle mass due to exercise may be related to regulating myostatin [15]. In confirmation of this, the reduction of myostatin expression after extreme exercise and after 9 weeks resistance training has been seen [13, 14]. It seems that the reduction of Myostatin gene expression after exercise may be due to hypertrophy of the muscles and factors associated with a decrease in the percentage of hypertrophic factors. Also, elderly people who have done strength training have shown 48% myostatin gene expression decrease compared to the untrained people [13]. However, the decrease in the expression of myostatin due to exercising especially in postmenopausal women, is still a controversial issue. Increase in myostatin expression after 30 minutes eccentric exercise activity has been observed [16]. Also, in response to 12 weeks resistance training the protein expression and the myostatin mRNA has increased [17]. On the other hand Joha and his colleagues (2007) observed the reduction of the expression of myostatin after one resistance training session in trained men [17]. Hittel and the colleagues (2010) also after 6 months of the aerobic training among middle-aged people observed reduced plasma and muscle myostatin [18]. follistatin gene expression in the muscles is regulated as a result of acute resistance training and long-term stretch [19]. It suggests that follistatin plays a role in modulating muscle tissue, and therefore it is assumed that follistatin is regulated as a result of exercise. In this regard, Hansen and colleagues (2011) showed that the plasma follistatin levels after acute endurance training in humans increases [12]. Overall, conducted studies have shown

that the effects of different training methods on the factors affecting atrophy and hypertrophy are limited, but considering the importance of the subject, especially in the mentioned group, the research intends to compare the effects of 8 weeks resistance and endurance training on serum myostatin and follistatin levels in postmenopausal women. To determine whether there is a difference between 8 weeks resistance and endurance training regarding serum myostatin and follistatin in postmenopausal women or not.

Methods and Material

A total of 40 postmenopausal women completed the volunteering consent form. Body mass index (BMI) of subjects was less than 30. Then the volunteers in Peugeot were randomly assigned to four groups of endurance, resistance and control. Entry requirements include: passing from at least one year of age from menopause , no smoking, no cardiovascular disease , haven't blood pressure , not having respiratory disease and haven't musculoskeletal disorders so to have age range 60-50. Exclusion criteria include: Cancellation of attendance at workout sessions, absence of more than 2 training sessions , fear of blood loss , general disability and physical activity prohibited by expert physicians. For Maximum Oxygen Consumption we used the Rockport Test. So to determine the intensity of the subjects' training we used Cousmous Treadmill from Germany manufacturer .For measurements of follistatin and myostatin has been used Katazabao Japan Laboratory Kit. In this study for measurements of follistatin and myostatin we used to biochemical laboratory of Ahvaz Jundishapur University of Medical Sciences.

Which was eva 70 luated using a PARQ questionnaire and a medical history questionnaire. All participants were provided with sufficient information about the benefits and potential risks of exercise. Also, all stages of this study were conducted under the supervision of sports physiologists. The participants were randomly divided into 3 groups of 14. Subjects got to know how the exercises are done in one session. 12 subjects due to the criteria of leaving the study or personal issues were eliminated. The total number of subjects was reduced to 30. (N = 10) endurance group (n=10), resistance group (n=9), combined group (n=8), and the control group (n=9). In this study three groups of resistance , endurance and combined training for 8 weeks training sessions and 3 sessions per hour each week. The range of activity was based on heart rate from 40% in the first week to 65% at the end of the eighth week. Table 1.

The training program took place in 3 days a week and for 8 weeks, each day from (9 to 11) o'clock. A blood test in the same condition was taken 24 Hours before the rehearsals and 48 hours after completion of the last session. The training program was followed for eight weeks from simple exercises to difficult and the less severe to the high severe considering the principle of overload and the increase of exercises severity. The endurance, resistance and combined training program was done according to the table 1.

Each endurance training session in the first week includes 45 minutes walking with at most 40% heartbeat rate, with 45% in the second week, 50% in the third week 55% in the fourth week, 60% in the fifth and sixth weeks and 65% at the seventh and eighth weeks. Also in relation to exercise severity control, this work was done by determining the heartbeat of the subjects before starting the exercises, during the exercise, and after performing the activity in each session by using the Polar pulse checker. Each session in the resistance training was performed as a circular strength training which included 9 moves (Shoulders and head press, chest press like (push-ups) abdominal crunch, loosening of the waist, opening the arm, wrapping the arm, opening the legs, closing legs with a device and a weight, and each move lasted 4 sets of 12 times repetition and the severity got 65% in the eighth week from 40%in the first week. The break between each set was 15 seconds and each session was approximately 45 minutes long. Control subjects were asked not to enter any training course during these 8 weeks.

For the purpose of equality of temperature during training, all training sessions in a gym with a temperature of 25 (° C) and a humidity of 40% were conducted.

Table 1. Subjects training schedules

Sessions / Training	First week	Second week	Third week	Fourth week	Fifth and sixth week	Seventh and Eighth Week
Endurance	40% Maximum Heart rate	45% Maximum Heart rate	50% Maximum Heart rate	55% Maximum Heart rate	60% Maximum Heart rate	65% Maximum Heart rate
Resistance	40% Maximum Repetition	45% Maximum Repetition	50% Maximum Repetition	55% Maximum Repetition	60 % one Maximum Repetition	65% Maximum Repetition

The height and weight of the subjects were measured using tape measure and digital scale. Estimation of maximum power: In a session before the start of the main program, after warm up, the maximum power including exercises such as (chest press, Squat, head press, abdominal crunch, lumbar opening, arm loading, arm opening, knee lift and lungs) was measured. To calculate the 1RM of subjects in each movement, the Brzycki formula was used. See table 1.

1RM= replaced weight: [1, 0278 – 0, 0278(10)] [20]

Maximum oxygen consumption Measurement (VO2MAX): For measurement Rockport Test [21] was used. A 1 mile path was specified in a basketball hall. First, how to do the test was instructed to the subjects and after 5 t0 10 minutes of light stretching and warming up, the subjects were asked to walk this path, as fast as possible. Getting the subject's pulse for one minute as soon as the One-mile walk was completed. In this formula, the body weight of a person in pounds, age in years, gender factor (men=1 women=0)

Full time of one mile per minute, heart rate after, after doing this test in multiplying rates in minutes in the formula [22]. (This test is by rate in a minute entered in the formula)

VO2max = 132.853) (weight 0.0769) - (age 0.3387) + (sex 6.315) - (time 3.2649) - (0.1565) heart rate

Maximum Heart Rate: For maximum heart rate, subjects performed this step on the treadmill. During this test, the heart rate was controlled by the instructor and the maximum heart rate of the subjects was obtained in conditions that the subjects were in a state of exhaustion. (Measurement of the concentration of myostatin was operated based on nano grams per liter using biospes kit and the use of ELISA method for the follistatin based on nanograms in liters ,again using a biospes kit. For data analysis, after ensuring that the distribution of data is normal with Shapiro Wilk's test and data homogeneity with Mauchly test, descriptive statistics methods including average and standard deviation, are used to calculate age, height, weight, body mass index, correlation Vo2max of the subjects. To compare the blood test in each group we use t-paired test. And the statistical and covariance analysis was used to compare three groups .If the covariance analysis test were significant, Bonferron's post hoc test was used to find Differences which were applied. A significant level was considered for all statistical data with P≤.0.05. All statistical measurements are done by SPSS software version22.

Results

In table 2 showed mean and standard deviation of descriptive and anthropometric variables.

Table 2. Mean and standard deviation of descriptive and anthropometric variables

Practicing Index	Exercise Group	Number	SD
Age	Endurance	10	55.33±2.75
	Resistance	9	50±3.11
	Control	9	53±2.16
Weight k.g	Endurance	10	54.33±2.41
	Resistance	9	52.81 ±2.17
	Control	9	54.23±1.79
Height c.m	Endurance	10	153.66±3.86
	Resistance	9	158.62 ±3.45
	Control	9	152.4 ±2.45

The result of Two Way ANOVA showed significant interaction effect between 3 groups in myostatin (p =0.036) and follistatin (p =0.008). After post hoc comparisons a significant decrease was found in myostatin serum in resistance exercise group compared to endurance exercise and control groups (respectively, p =0.048 and p =0.004). Also significant increase observed in resistance and endurance exercise groups (respectively, p =0.002 and p =0.009).

Table 3. Within group and between group comparisons of myostatin and follistatin.

group	Process	Resistance	Endurance	Control	P-value between group
Myostatin Serum (ng/ml)	P-test pretest	1.55±0.81	1.63±0.13	1.61 ± 0.019	Group=0.001
	p-test protest	1.37±0.0027	1.60±0.09	1.67 ± 0.014	Time=0.029
	P-value within-groups	0.001	0.16	0.14	Interaction=0.036
Follistatin Serum (mg/l)	P-test pretest	77. 33±26.12	69. 62±12.38	74.56± 22.28	Group=0.001
	p-test protest	111.45 ±20.09	100.9 ±21.39	74.8± 29.32	Time=0.012
	P-value within-groups	0.001	0.001	0.13	Interaction=0.008

Discussion

The purpose of this study was to investigate the effect of eight weeks of endurance and resistance training on to serum levels of

myostatin and follistatin in postmenopausal women. Results showed that resistance levels of myostatin levels decreased significantly. Then, we compared the different training methods. The results showed that both endurance training and resistance training methods significantly reduced serum myostatin levels compared to the control group. Also, a significant decrease in serum myostatin levels in the resistance group compared to endurance was observed, Roth et al. (2003), reported that the expression of myostatin gene in young and old men and women in response to 9 weeks resistance training is reduced, which is consistent with the results of the present study [22, 23]. Also Hittle et al. (2010) reported a decrease in muscle and plasma myostatin protein, after 6 months of moderate intensity aerobic exercise in middle-aged men which was also in agreement with the present study [18]. In contrast to the results of this study Schiffer et al (2011) showed in a 12 weeks strength training with intensity of 70-80% of one maximum repetition and observed a continuous endurance training with the severity of 80 percent the maximum aerobic power percentage for expressing myostatin gene and no significant difference in myostatin gene expression between combined exercise, strength and endurance was observed [24]. While Hulmi et al. (2007) showed that despite strengthening and muscle mass of the subjects, the Myostatin gene expression Increased in 12 resistance strength training week in elderly men, Also the amount of myostatin gene expression in the broader, lateral muscle 4 hours after a knee extension exercise in both in resistance and endurance trained subjects did not change [17]. The main reasons for the discrepancy between the results of various investigations are still not clear. However, the type of protocol, severity and duration of exercise, sex, subjects' characteristics in terms of age, activity rate and body mass index, measurement methods or differences in measurement time. (48-72 hours against 4 hours and a quarter after training) can be the cause of the difference between the various research results.

On the other hand, as a factor influencing the difference in results In most studies, the expression of myostatin gene in response to exercise in skeletal muscle was measured. Since the myostatin protein after synthesis undergoes post-translational modifications, the expression of the myostatin gene can not accurately reflect the levels in the circulation as an active form of myostatin.

On the other hand, in contrast to the current study, one can mention the findings of Kim et al (2005) which observed no myostatin change in elderly women. In response to a similar intensity exercise, elderly women appear to be less effective in reducing myostatin expression [25]. In the case of elderly men, a similar decrease in myostatin compared to young men and women was shown. Previously, many studies reported that elderly women responded with a slow hypertrophy of fibers along 26 weeks resistance training in comparison with older men. The cause of the difference between older men and older women can be attributed to the fact that the resting amount of myostatin plasma in the elderly women is higher than elderly men. The decrease of myostatin basic levels may also be due to decrease in some hormones in women, which are responsible for growth by between the outcome of the present study and previous studies is probably the age of the subjects and reaching the menopause, and on the other hand, it is related to the overweight of the subjects in this research as well as the decrease in weight at the end of the research. Due to the association of myostatin levels with overweight and obesity, the reduction of myostatin in those studies may be related to its anabolic role in adipose tissue. inducing metabolic changes and regulating the negative expression and secretion of myostatin from the Skeletal muscle. Including these important hormones, we can refer to such as testosterone, growth hormone, and insulin-like growth hormone. These hormones are activated by activating various signal paths, especially the b-activating signaling paths, by activating a series of very complex cellular cascade pathways regulates the negative Myostatin expression from muscle cells and subsequently reduces its secretion into blood. It should also be noted that various studies have suggested that obesity is associated with increased expression of myostatin. It has already been shown that the amount of myostatin in both fat and muscle tissue is higher in obese mice. Blood and muscle mass of myostatin was also higher in obese women than in women with normal weight. Conversely, the amount of myostatin muscle and adipose tissue in rats decreases after two weeks of leptin injection and after weight loss in human subjects in obese patients. Studies that surveyed changes in myostatin levels following weight loss reported a decrease in myostatin levels. The main reason for the difference Another main goal of this study were to investigate the effect of different training exercises on serum follistatin levels in postmenopausal women. The results of this study showed that both endurance and resistance training methods significantly increased the levels of follistatin. Also, as a result of comparison between different training methods, both methods of endurance and resistance training increased the serum follistatin level significantly compared to the control group.

Hansen et al [12], Stated that the major regulatory factors of follistatin during different sports activities are not yet properly identified, but are of great importance. Physical activity is an important intervention for the prevention of the age-related sarcopenia phenomenon. So far, various studies of the effect of exercise on follistatin expression in skeletal muscle have been considered and have achieved different results in this regard. According to Dieli et al. [11] follistatin gene expression in skeletal muscles of postmenopausal women after eccentric activity has increased. Moreover in another study Hansen et al. [12] have shown that endurance training leads to an increase in follestatin amount in circulation which is consistent in the increase of follistatin levels after endurance and resistance training with the research results of this study Aoki et al. [19] stated that follistatin is one of the most important inhibitors of myostatin expression

and influenced by the very complex molecular cellular mechanisms prevents the myostatin expression in both muscle and circulation. In addition formerly It has been shown that follistatin can act as a competitive inhibitor of myostatin. In this way follistatin plasma connects to the activin receptor meeting point,and prevents myostatin attachment from its receptor.

Despite a significant reduction after resistance training and no significant difference after endurance training in serum myostatin levels, after both resistances, endurance training follistatin levels significantly increased. Aoki et al [19] suggested that follistatin may play an important role in reducing myostatin signaling. Thus a significant increase in serum follistatin in endurance, resistance groups that was associated with reduction of myostatin in resistance groups, may prevent myostatin signaling and, as a result, muscle catabolism.

In various studies that have already been done Plasma follistatin is attached to myostatin and neutralizes it, thereby increases the skeletal hypertrophy and muscle hyperplasia. Jensky (2000) expression of follistatin in the skeletal muscle of young women in relation to both types of activity acute resistance and Long-term resistivity exercise which was investigated and showed that no activity, neither of The acute motility nor the long-term resistance activity do not regulate the expression of the follistatin gene expression significantly in the skeletal muscle of young women [26].

Additionally, Hulmi et al [17]. One hour and 48 hours after an acute session of resistance activity as well as 21 resistance activity training in elderly men did not observe any changes in levels of follistatin which the results of this study are not consistent with the present study. Therefore, in the present study, after both training methods, significant changes in serum levels of follistatin were observed.

Also another important factor in preventing the effects of fatigue or other interfering resources, the scheduling of the training sessions, requires further investigation. However, in this context we also use the practice of resistance training in the form of a circle, in which the rest conditions are well observed between each move and each circle. Perhaps one of the factors contributing to the difference between our results and the previous research is the appropriate training and arrangement that has been selected which with proper arrangement and proper resting intervals, has provided an anabolic environment.

Conclusions

Resistance training significantly decreased myostatin levels, but no significant change was observed during endurance training of myostatin levels. Also, both endurance and resistance training significantly increased follistatin levels in postmenopausal women.

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Ethics research

This is the subject of the research, required by the master's thesis, and approved by the Sports Physiology Department and the Graduate Committee of the Faculty of Sport Sciences, and the Graduate Committee of Shahid Chamran University of Ahvaz on September 2017 to number of 96/03/30/42751.

Conflict of interest

The authors declare no conflict of interest.

References

1. Parvin N, Kazemian A, Alavi A, Safdari F. Impact on mental health advocacy group therapy in postmenopausal women. Journal of Gorgan University of Medical Sciences. 2007;9(3):23-74.
2. Shouhani M, Rasouli F, HAJI AP, Mahmoudi M. The survey of physical and mental problems of menopause women referred to liam health care centers.
3. Berk J S, Novak. Gynecology. Philadelphia: Lippincott. S 2012. 15 th ed: 1203
4. Stewart CE, Rittweger J. Adaptive processes in skeletal muscle: molecular regulators and genetic influences. Journal of Musculoskeletal and Neuronal Interactions. 2006;6(1):73.
5. Amthor H, Nicholas G, McKinnell I, Kemp CF, Sharma M, Kambadur R, Patel K. Follistatin complexes Myostatin and antagonises Myostatin-mediated inhibition of myogenesis. Developmental biology. 2004 Jun 1;270(1):19-30. doi: 10.1016/j.ydbio.2004.01.046. [Pubmed: 15136138].
6. Miura T, Kishioka Y, Wakamatsu JI, Hattori A, Hennebry A, Berry CJ, Sharma M, Kambadur R, Nishimura T. Decorin binds myostatin and modulates its activity to muscle cells. Biochemical and biophysical research communications. 2006 Feb 10;340(2):675-80. doi: 10.1016/j.bbrc.2005.12.060 [Pubmed: 16380093].
7. Balagopal P, Olney R, Darmaun D, Mougey E, Dokler M, Sieck G, Hammond D. Oxandrolone enhances skeletal muscle myosin synthesis and alters global gene expression profile in Duchenne muscular dystrophy. American Journal of Physiology-Endocrinology and Metabolism. 2006 Mar;290(3):E530-9. doi: 10.1152/ajpendo.00412.2005 [Pubmed: 16263771]
8. Bartoli M, Poupiot J, Vulin A, Fougerousse F, Arandel L, Daniele N, Roudaut C, Noulet F, Garcia L, Danos O,

Richard I. AAV-mediated delivery of a mutated myostatin propeptide ameliorates calpain 3 but not α-sarcoglycan deficiency. Gene therapy. 2007 May;14(9):733.doi: 10.1038/sj.gt.3302928 [Pubmed: 17330087].

9. Lee SJ. Regulation of muscle mass by myostatin. Annu. Rev. Cell Dev. Biol.. 2004;20:61-86. doi:10.1146/annurev.cellbio.20.012103.135836.]pubmed:15473835]
10. Kirchengast S, Huber J. Gender and age differences in lean soft tissue mass and sarcopenia among healthy elderly. Anthropologischer Anzeiger. 2009 Jun 1;67(2):139-51.
11. Dieli-Conwright CM, Spektor TM, Rice JC, Sattler FR, Schroeder ET. Influence of hormone replacement therapy on eccentric exercise induced myogenic gene expression in postmenopausal women. Journal of applied physiology. 2009 Nov;107(5):1381-8. doi:10.1152/japplphysiol.00590.2009.]pubmed:19696363[.]pubmed central:PMC2777804[
12. Hansen J, Brandt C, Nielsen AR, Hojman P, Whitham M, Febbraio MA, Pedersen BK, Plomgaard P. Exercise induces a marked increase in plasma follistatin: evidence that follistatin is a contraction-induced hepatokine. Endocrinology. 2011 Jan 1;152(1):164-71.doi:10.1210/en.2010-0868.[pubmed:21068158]
13. Walker KS, Kambadur R, Sharma M, Smith HK. Resistance training alters plasma myostatin but not IGF-1 in healthy men. Medicine and science in sports and exercise. 2004 May;36(5):787-93.[pubmed:15126711]
14. Wehling M, Cai B, Tidball JG. Modulation of myostatin expression during modified muscle use. The FASEB Journal. 2000 Jan;14(1):103-10.[pubmed:10627258]
15. Welle S, Tawil R, Thornton C A. Sex-related differences in gene expression in human skeletal muscle. PLoS One. 2008;3(1):1385. doi:10.137/journal.pone.0001385.[pubmed:18167544].[pubmed central:PMC2148100]
16. Willoughby DS. Effects of an alleged myostatin-binding supplement and heavy resistance training on serum myostatin, muscle strength and mass, and body composition. International journal of sport nutrition and exercise metabolism. 2004 Aug;14(4):461-72. [pubmed:15467103]
17. Hulmi JJ, Ahtiainen JP, Kaasalainen T, PöLLANEN EI, Hakkinen K, Alen M, Selanne H, Kovanen V, Mero AA. Postexercise myostatin and activin IIb mRNA levels: effects of strength training. Medicine & Science in Sports & Exercise. 2007 Feb 1;39(2):289-97.doi:10.1249/01.mss.0000241450.15006.6e.[pubmed:17277593]
18. Hittel DS, Axelson M, Sarna N, Shearer J, Huffman KM, Kraus WE. Myostatin decreases with aerobic exercise and associates with insulin resistance. Medicine and science in sports and exercise. 2010 Nov;42(11):2023.doi:10.1249/MSS.0b013e3181e0b9a8.[pubmed:20386333].[pubmed central:PMC2975387]
19. Aoki MS, Soares AG, Miyabara EH, Baptista IL, Moriscot AS. Expression of genes related to myostatin signaling during rat skeletal muscle longitudinal growth. Muscle & Nerve: Official Journal of the American Association of Electrodiagnostic Medicine. 2009 Dec;40(6):992-9.doi:10.1002/mus.21426. [pubmed:19705480]
20. Brzycki M. Strength testing—predicting a one-rep max from reps-to-fatigue. Journal of Physical Education, Recreation & Dance. 1993 Jan 1;64(1):88-90.
21. Weiglein L, Herrick J, Kirk S, Kirk EP. The 1-mile walk test is a valid predictor of VO2max and is a reliable alternative fitness test to the 1.5-mile run in US Air Force males. Military Medicine. 2011 Jun 1; 176(6):669-73.
22. Kline CJ, Porcari JP, Hintermeister R, Freedson PS, Ward A, Mccarron RF, Ross J, Rippe J. Estimation of from a one-mile track walk, gender, age and body weight. Med. Sports Exerc.1987;19:2539. [pubmed:3600239]
23. Roth SM, Martel GF, Ferrell RE, Metter EJ, Hurley BF, Rogers MA. Myostatin gene expression is reduced in humans with heavy-resistance strength training: a brief communication. Experimental biology and medicine. 2003 Jun;228(6):706-9. [pubmed:12773702]
24. Schiffer T, Geisler S, Sperlich B, Strüder HK. MSTN mRNA after varying exercise modalities in humans. International journal of sports medicine. 2011 Sep;32(09):683-7.doi:10.1055/s-0031-1279732.[pubmed:21695666]
25. Kim JS, Cross JM, Bamman MM. Impact of resistance loading on myostatin expression and cell cycle regulation in young and older men and women. American Journal of Physiology-Endocrinology and Metabolism. 2005 Jun;288(6):E1110-9.doi:10.1152/ajpendo.00464.2004.[pubmed:15644458]
26. Jensky NE, Sims JK, Dieli-Conwright CM, Sattler FR, Rice JC, Schroeder ET. Exercise does not influence myostatin and follistatin mRNA expression in young women. Journal of strength and conditioning research/National Strength & Conditioning Association. 2010 Feb;24(2):522.