Age-related hormonal adaptations, muscle circumference and strength development with 8 weeks moderate intensity resistance training

Sécrétions hormonales, circonférence musculaire et force musculaire : adaptations en rapport avec l’âge après huit semaines de musculation modérée

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Abstract

Objectives. – To examine the response of the endocrine system, strength development and muscle circumference to moderate-resistance training in younger and middle-aged men. Material and methods. – Two groups of men of similar activity background, but differing in age (Y: 21.2 ± 2.2 years and M: 49.7 ± 2.1 years) participated in an 8-week moderate-resistance training program. Blood sampling was obtained at rest before and after training for analysis of serum testosterone, growth hormone, cortisol and ACTH concentrations. One repetition maximum for the bench press (1RMBP) and squat (1RMS); thigh (TC) and arm circumference (AC) were also measured. Both groups underwent a 1-h standardized moderate-resistance training session (three series of 8 to 15 RM; nine exercises with 1–3 min rest between sets) three times a week for 8 weeks. Results. – Both the Y and M groups gained significant improvements in 1RM BP, 1RMS, TC and AC (P < 0.05). Growth hormone and testosterone concentration increased for both groups, while Y men increased greater than M men in resting posttraining testosterone concentration. With training the Y and M men demonstrated significant decreases in ACTH and cortisol concentrations. Conclusion. – These data indicate moderate-resistance training would lead to gains in maximal strength, muscle circumference and increases anabolic hormone secretion for M men and consequently promoting of health, improve daily life and delay negative effects with aging.

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Résumé

Objectifs. – Mesurer la réponse du système endocrinien, la force musculaire et la circonférence musculaire chez des hommes jeunes et d’âge moyen avant et après un programme de musculation modérée. Méthodes. – Un programme de huit semaines de musculation modérée était proposé à deux groupes d’hommes semblables en ce qui concerne leurs niveaux d’activité mais diffèrent par leurs âges : (groupe Y : 21.2 ± 2.2 ans ; groupe M : 49.7 ± 2.1 ans). Chez tous les participants, les taux plasmatiques de la testostérone, de l’hormone de croissance, du cortisol et de l’ACTH étaient mesurés au repos, avant et après le programme de musculation modérée. Ont été mesurées : la force maximale à une répétition du développé couché (1RMBP) et du squat test (1RMS) ; la circonférence mi-cuisse (TC) ; la circonférence brachiale (AC). Le programme de musculation était identique pour les deux groupes : séances d’une heure trois fois par semaine pendant huit semaines (trois séries de huit à 15 répétitions à force maximale ; neuf exercices séparés d’une période de repos d’une à trois minutes). Résultats. – Dans les deux groupes, les résultats montraient une amélioration significative des différentes mesures : 1RMBP, 1RMS, TC et AC (p < 0.05). Les taux plasmatiques de la testostérone et de l’hormone de croissance augmentaient dans les deux groupes. Après le programme de musculation, on notait une augmentation plus importante de la testostérone dans le groupe M que dans le groupe Y et une diminution significative de l’ACTH et du cortisol dans les deux groupes. Conclusion. – Ces résultats suggèrent qu’un programme de musculation modérée pourrait augmenter la force musculaire maximale, la circonférence musculaire et la sécrétion d’hormones anaboliques chez les hommes d’âge moyen et par conséquence améliorer leur santé et vie quotidienne et retarder les effets du vieillissement.

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1. Introduction

Aging is associated with decline in the capacity of the neuroendocrine function and neuromuscular system, resulting in decreases in maximal strength, muscle power and muscle mass (sarcopenia) [1,2]. With aging, serum concentrations of anabolic hormones and growth factors decline along with reductions in anabolic hormone concentrations, which are thought to relate to documented decline in skeletal muscle mass and strength [2,3]. Also, with aging serum concentrations of catabolic hormones increased [1,2,4]. Loss of skeletal muscle mass or muscle strength due to aging, start in middle-age and gradually accelerate thereafter [5,6]. Resistance training increases muscle power, strength and mass through several mechanisms, for example increasing voluntary activation of trained muscles and inducing changes in the muscle cross-sectional area and subtypes of muscle fibers, even when resistance training began in older age [7,8]. Moreover, resistance training can induce increases in anabolic hormones in women, younger and older men [2,4–9]. Therefore, with resistance training, it is possible to prevent or delay the age-related loss of skeletal muscle mass and decreases in muscle strength and power in middle-aged and older individuals [5,10].

There were a large number of studies that examined the effects of resistance training in young, middle-aged, and older men, and compared younger vs. older or middle-aged vs. older men [2,4–9]. For example, Kraemer et al. [2] found younger men to possess more favorable hormonal profiles for cortisol and testosterone after a 10-week of heavy-resistance training at rest compared with older men. They also noted few significant changes in plasma ACTH and serum GH in both younger and older men. Izquierdo et al. [1] found that middle-aged and older men increased maximal strength following 16 weeks of heavy-resistance training. Older men made decreases in cortisol concentration after 16 weeks of resistance training, while middle-age men showed no significant changes in cortisol and testosterone concentrations.

Previous studies examined heavy or high-intensity resistance training on hormonal concentrations in younger, middle-aged and older men [1,2,4]. However, heavy-resistance exercise can be performed in younger men and has been shown to be a potent stimulus for increases in circulating hormones, this intensity maybe induced risk or injury for middle-aged or older men [1,4,11]. Moreover, moderate intensity resistance training can be prevalent in middle-aged men. With this goal, this study was designed to examine the effects of moderate intensity resistance training on hormonal responses in middle-aged men and compared with younger men. Therefore, the purpose of this study was to examine the effects of 8 weeks moderate intensity resistance training on maximal strength, arm and thigh circumferences, anabolic and catabolic hormones in middle-aged and younger men. We hypothesized that moderate intensity resistance training can improve strength and muscle circumference, with elevating in anabolic hormones and decreasing in catabolic hormones in middle-aged and younger men. Also, these responses or changes are greater for younger man compared to middle-aged men.

2. Methods

2.1. Subjects

Ten younger (Y: age; 21.2 ± 2.2 years, weight; 71.9 ± 6.4 kg, height; 177.2 ± 3.3 cm, and percent body fat; 14.6 ± 4) and eight middle-aged healthy men (M: age; 49.7 ± 2.1 years, weight; 80.2 ± 6.0 kg, height; 174.8 ± 3.2 cm, and percent body fat; 19.8 ± 3; [mean ± SD]) volunteered in this study. Subjects were informed as to the experimental procedures and signed informed consent statements and medical history forms in adherence with the human subjects’ guidelines of the University Health Sciences Center before any data collection. Before initiation of the study, subjects had to:

- be medically screened by a physician for orthopedic problems;
- sign statements stating that they had no current or past use of anabolic steroids, human growth hormone, or other pharmaceuticals that affect muscle mass;
- not participate in a structured resistance training program for at least 1 year;
- have not ingested or were currently consuming creatine or other nutritional supplements for an 8-week period before beginning the study.

2.2. Study design

One week before the start of training period, all subjects reported to the laboratory for the familiarization with training and testing procedures. During the familiarization session, subject initial characteristics such as; age, height, weight, and percent body fat via 7-site skinfolds were measured. One day later, thigh and arm circumferences and upper and lower body strength were assessed using one repetition maximum (1RM) bench press and squat exercises. Subjects performed an 8-week resistance training program and blood sampling was drawn 48 hours before the first and 48 hours after the last training session. Participants were instructed to maintain their normal caloric intake throughout the duration of the study.

2.3. Testing procedures

2.3.1. Body composition

Body composition was assessed using skinfolds. All anthropometric measurements were obtained by the same investigator on the right side of the subject’s body. Skinfold thickness was measured with a Lafayette caliper (Skin Fold Caliper, Model 01127 INDIANA) at the chest, midaxilla, abdomen, suprailium, subscapula, triceps, and thigh following the procedures previously described [12]. Repeated trials were performed until two measures within 1 mm were obtained, with the mean of these two measures being utilized. A 7-site skinfold equation was used to estimate percent body fat using the Siri equation [13].

2.3.2. Muscle circumference

The circumferences of mid thigh and mid arm of the right side were assessed during full muscle contraction using tape measure with nearest to 0.1 cm.

2.3.3. Strength

Upper and lower body strength were measured using the one repetition maximum (1RM) bench press and squat exercises. The 1RM testing was performed according to method previously described by Kraemer and Fry [14]. The participants performed a warm-up set of 8 to 10 repetitions at a light weight (∼50% of 1RM). A second warm-up consisted a set of three to five repetitions with a moderate weight (∼75% of 1RM), and third warm-up included one to three repetitions with a heavy weight (∼90% of 1RM). After the warm-up, each subject was tested for the 1RM by increasing the load during consecutive trials until the participants were unable to perform a proper lift, complete range of motion and correct technique. The 1RM test was determined by ∼5 sets of one repetition, with 3–5 minutes of rest among attempts. Spotters and investigators were present to provide verbal encouragement and safety for the subjects. The test-retest reliability coefficient of these test was \( r = 0.97 \).

2.3.4. Hormonal analysis

Resting blood samples were drawn at 48 hours before the start of training (pre) and 48 hours after the last training session (post). The time of blood collection was chosen due to its use in many studies conducted with these procedures for the control of the circadian hormonal range [4]. The subjects reported to the laboratory and were sitting quietly for 10–15 min before giving a blood sample. Venous blood samples were obtained at rest between 8 and 9 AM from the antecubital vein to determine concentrations of serum testosterone, cortisol, growth hormone and ACTH. Blood samples were taken at the same time of day to reduce the effects of diurnal variation on hormonal concentrations. Blood was drawn after 12 hours of fasting and 8 hours of sleeping. The samples for the analyses of hormones were centrifuged, and the serum was removed and frozen at −70°C for later analysis. The assays of serum hormones were performed by radioimmunoassay (RIA) via a gamma counter system (LKB model, Finland). All samples were analyzed in the same assay for each hormone, according to the instructions of the manufacturer. Coefficients of variations for variables (CV) for all the variables were less than 6%.

2.4. Resistance training program

All subjects were carefully familiarized with all the exercise protocols used in the study. In addition, all exercise sessions were individually supervised. The periodized resistance training program consisted of a nonlinear, multiset, multi-exercise periodized program performed three times a week for 8 weeks [15]. On the first day (Sunday), three sets of 8 to 10 RM were performed with 2–3 min of rest between sets. On the second day (Tuesday), three sets of 10 to 12 RM were performed with 1.5–2 min of rest between sets. Finally, on Thursday, three sets of 12 to 15 RM were performed with 1 min of rest between sets.

The program consisted of the following exercises: squats, knee extensions, leg curls, calf raises, lat pull downs, bench presses, seated rows, lower back extensions, and arm curls.

2.5. Statistical analysis

All data are presented as mean ± SD. Data were analyzed using two-way repeated measures Anova, and Bonferroni post-hoc test was used to find differences in the pairwise comparisons when appropriate. The level of significant for this investigation was set at \( P \leq 0.05 \). The statistical tests were performed using the SPSS statistical package version 16 (Chicago, IL, USA).

3. Results

Both the Y and M groups showed statistically significant improvement in thigh (TC) and arm circumferences (AC) after 8 weeks of training (TC; Y, from 54.6 ± 5.3 to 57 ± 4.3 cm [4.5%]; M, from 54.2 ± 5.5 to 56.3 ± 5.1 cm [4%]; AC; Y, from 30.1 ± 3.6 to 31.9 ± 3.7 cm [6%]; M, from 30.9 ± 3 to 32.4 ± 3 cm [5%], \( P \leq 0.05 \)). However, the level of increases were greater for the Y, no significant differences were observed between the Y and M groups in the TC and AC (\( P > 0.05 \)). The 1RM<sub>BP</sub> and 1RM<sub>S</sub> strength increased for the Y and M groups significantly (\( P \leq 0.05 \)). Both the Y and M groups showed similar improvements in the 1RM<sub>BP</sub> strength ∼23% (Y, from 53.5 ± 8.8 to 66 ± 9.3 kg; M, from 53.7 ± 11.2 to 65.6 ± 11.1 kg). The Y group also made greater increases than M in the 1RM<sub>S</sub> strength (22% vs. 15%), but this increase was not statistically significant (Y, from 64.5 ± 9.8 to 78.5 ± 8.5 kg; M, from 67.5 ± 10.3 to 77.5 ± 10.3 kg). No significant differences were observed between the groups in strength level for the 1RM<sub>BP</sub> and 1RM<sub>S</sub>. Fig. 1 presents serum concentrations of testosterone and cortisol. No significant differences were observed in pre training serum hormone concentrations between the groups. During the 8 weeks training period, significant changes were observed for testosterone and cortisol in both groups (\( P \leq 0.05 \)). For testosterone, significant increases were observed in Y than pre training and M group. For cortisol, both groups made significant decreases than pretraining and no significant differences were observed between the groups. The M group had greater plasma ACTH than Y group before and after the training program (\( P \leq 0.05 \)). After 8 weeks resistance training program, plasma ACTH decreased from 2.9 ± 0.7 to 2.1 ± 0.5 pmol/L and from 4 ± 0.9 to 3.3 ± 0.9 for the Y and M groups, respectively (\( P \leq 0.05 \), Fig. 2A). For growth hormone (GH), both the Y and M groups indicated statistically significant increases than pretraining (\( P \leq 0.05 \)). However, the level of increases were higher for Y, these increases were not statistically significant (\( P > 0.05 \), Fig. 2B).

4. Discussion

Decreases in anabolic hormonal concentrations (e.g., testosterone and GH) and increases in catabolic hormonal concentrations (e.g., cortisol and ACTH) with age can influence the reduction in muscle size and strength observed with aging [1].
Restoring an endocrine gland’s function with exercise training remains an attractive hypothesis, which could help ameliorate the age-related declines in muscle tissue mass and strength. In this study we examined strength, muscle circumference and hormonal responses to an 8-week moderate intensity resistance training program in two groups of men of similar activity background, but differing in age. The present resistance training performed three times a week for 8 weeks led to large gains in maximal strength as well as thigh and arm circumferences in both ages. Also, anabolic hormones increased, and catabolic hormones decreased remarkably in the Y and M men.

The primary results of the present study demonstrated that an 8-week resistance training program led to gains in maximal strength of the arms \( \text{1RMBP} \) and legs \( \text{1RMS} \) in the Y and M men. The percent improvement in the \( \text{1RMBP} \) was \( \sim 23\% \), whereas the percent improvement in the \( \text{1RMS} \) was \( 22\% \) vs. \( 15\% \) for Y and M men, respectively. Several previous investigations have reported that, in previously untrained young, middle-aged and older subjects, great initial increases in maximal strength may occur after a few weeks of resistance training [4,7,16]. During the 8-week of training it would appear that middle-aged subjects are equally trainable for maximal strength as are the younger counterparts. However, in the \( \text{1RMS} \), there was difference between Y and M (22% vs. 15%); these differences may be differing in motor unit recruitment and amount of muscle mass during different tests (bench press vs. squat). Training-induced increases in muscle strength of previously untrained young, middle-aged and older men have been shown to result primarily from the increased motor unit activation of the trained muscles [7,17]. Gradually increasing muscle hypertrophy contributes to strength development during the initial stages of resistance training [18,19]. In the present study, the resistance training program promoted muscle circumferences. Accordingly, significant enlargements occurred in the AC and TC in both age groups, supporting the earlier observations that skeletal muscle of middle-aged and older people seems to retain the capacity to undergo training-induced hypertrophy when the volume, intensity, and duration of the training period are sufficient [18–20]. It is also likely that increases in strength may also be related in part by transformation of type II musclefiber subtypes (i.e., alterations in myosin ATPase isomorf and myosin heavy chains) [21]. Nevertheless, as suggested earlier, neural adaptations may have been a more important contributing factor in the present study than that of muscle hypertrophy for strength development [1,4,7].

No significant differences between Y and M men were observed for AC and TC. Both groups, however, also increased with a similar pattern AC and TC. This results is supported by findings in the literature [7,18,20]. The mechanism(s) that mediate increases in AC and TC could be due to increases in myofilaments, actin and myosin filaments, sarcoplasm, and connective tissue and secretion testosterone and GH hormones and signaling pathway [2,4,21].

Both Y and M groups showed significant increases in the resting testosterone and GH concentrations after 8 weeks resistance.
training. Also, Y men had greater increases than M men in testosterone. This result is not supported by findings in literature [4,22,23]. Hakkinen and Pakarinen [22] addressed the importance of biologically active testosterone for trainability in Y men. Testosterone circulates in a bound form in the blood primarily with sex hormone-binding globulin or albumin. The higher testosterone in the blood appears to indicate an improved “bioactivity status” for the Y men [24]. Overall, a greater androgenic environment for the Y men at rest and appears to support the higher overall magnitude of the observed increase in muscle size and strength. These data support the maintenance of an “andropause”, which is characterized by a decrease in testicular Leydig cell numbers, reductions in secretory capacity, and a decrease in resting episodic and stimulated gonadotropin secretion [24]. Staron et al. [25] demonstrated that resting concentrations of total testosterone in men averaging 23.5 years of age increased over baseline values after just four weeks of training. However, other studies have not shown a training-related increase in resting concentrations of testosterone [22,22,23]. This indicates that, in Y men, testosterone may exhibit a dynamic homeostatic hormonal response pattern to resistance training. The mechanism(s) that mediate such an adaptation in exercise-induced serum testosterone concentrations in men could be due to classic increases in luteinizing hormone (LH) pulsatility or production [24]. However, Lu et al. [26] reported that increased testosterone concentrations in male rats during exercise were at least partially the result of a direct (LH-independent) stimulatory mechanism of exercise, with lactate influencing the secretion of testosterone by increasing testicular cAMP production.

It is well known that resistance exercise is a potent stimulus for GH secretion. Increased circulating GH, by enhancing the action of insulin-like growth factor I on muscle protein synthesis, is important to muscle fiber hypertrophy resulting from resistance training [27].

Exercise-induced stimulation of the endocrine system may be a trigger for additive adaptation processes in skeletal muscle cells, leading to increased content of contractile proteins. In fact, testosterone is considered the major promoter of muscle growth and subsequent increase in muscle strength and in response to resistance training in men [28]. It has been suggested that the response of GH to resistance training may be most prominent for tissue remodeling [27]. Nevertheless, the increase of GH to resistance training has been found to correlate with the magnitude of muscle fiber hypertrophy during a period of resistance training. This relationship could indicate that the transient increase in GH during each exercise bout has a positive effect on the cellular adaptations to resistance training. Resistance training programs that elicit the greatest testosterone and GH response are the potent stimulus for increasing tissue remodeling [27] and consequently decreasing in muscle mass and strength can be prevent or delay with aging.

Another important finding of this study was that the amount of ACTH and cortisol produced at resting levels was reduced and the response to the resistance training was lower in the Y men. The M men had significant differences than Y men in ACTH at pre and posttraining. Resistance training decreased cortisol and ACTH concentrations for both Y and M men significantly. This finding supported with previous researchers [2,25]. The decrease in resting concentrations of cortisol throughout the training program in the Y and M men with significant changes in the ACTH concentrations indicates that the ACTH receptors in the adrenal gland may have been “downregulated”. Staron et al. [25] showed a similar response in Y men. These changes in training-induced cortisol responses observed after resistance training are apparently mediated by a reduction in ACTH responses to the resistance training. Cortisol increases protein degradation and decreases protein synthesis in muscle cells resulting in greater release of amino acids into circulation. Furthermore, it has been observed that physiological elevation of cortisol may reduce the activity of the hypertrophy-promoting pathway protein kinases B. Because of its possible role in tissue remodeling, changes or decreases of cortisol during resistance training have been supported [2,25,27]. ACTH has been shown to mediate the secretion of cortisol from the adrenal cortex and it has been established that cortisol secretion and clearance are coupled [29]. The reductions in cortisol have been thought to provide one possible mechanism by which protein accretion via reduced degradation in muscle fibers is enhanced. Middle-aged men may also rely on hypertrophy of type I muscle fibers to elicit total muscle hypertrophy due to a loss of type II muscle fibers with the aging process [30]. Thus, the importance of these changes in cortisol cannot be minimized, especially in the M men, as a mechanism related to tissue hypertrophy and force production abilities. Collectively, these data indicate that the M men can elicit a reduction in the catabolic hormonal responses, resulting in a more favorable anabolic environment for reduced protein degradation or increased protein synthesis.

In summary, the present moderate intensity resistance training performed three times a week for 8 weeks led to gains in maximal strength for the bench press and squat in Y and M men. The strength gains were accompanied by significant increases in the muscle fiber areas (e.g., arm and thigh circumference) of the trained muscles. Systematic changes occurred in the basal concentrations of serum anabolic and catabolic hormones examined during the training period. Training-induced increases of GH and testosterone not only increased in Y men only after the 8-week resistance training but also it enhanced in M men. Both Y and M groups also had significant decreases in secretion of catabolic hormones (cortisol and ACTH) after training period. These results support that moderate intensity resistance training three times a week for 8 weeks is proper for increasing strength, muscle circumference and anabolic hormones with decreasing in catabolic hormones. Thus, it can be recommend for coaches and middle-aged men who use moderate intensity resistance training for promoting of health, improve daily life and delay negative effects with aging.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.
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