Muscle power increases after resistance training in growth-hormone-deficient adults

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Abstract

COELHO, C. W., C. R. VELLOSO, R. R. DE LIMA OLIVEIRA BRASIL, M. VAISMAN, and C. G. SOARES DE ARAÚJO. Muscle power increases after resistance training in growth-hormone-deficient adults. Med. Sci. Sports Exerc., Vol. 34, No. 10, pp. 1577–1581, 2002. Purpose: To measure the effects of a resistance training (RT) program over muscle function and body composition of adults with GH deficiency without replacement. Methods: 11 GH-deficient patients (39 ± 11 yr) were evaluated in four occasions (two pretraining and at 6 and 12-wk of training). We performed anthropometric measurements and physical tests. Muscle power was measured by a specific tensiometer (Fitro, Bratislava, Slovakia) in five different exercises: seated chest press, rear lat pull-down, knee extension, standing upright row, and triceps press down. Muscle endurance was assessed by maximum number of sit-ups and maximum static strength by measurement with a handgrip dynamometer. A 12-wk home-based RT program was individually prescribed and consisted of 13 exercises, performed each other day, using simple material. Results: No significant differences occurred in body weight or limb circumferences (P > 0.05), although the sum of central skinfolds decreased with RT (111 ± 9 vs 100 ± 9 mm; P < 0.05). RT induced significant gains in four of five exercises: rear lat pull-down (141 ± 19 vs 198 ± 20 W), standing upright row (134 ± 22 vs 157 ± 24 W), triceps press down (85 ± 14 vs 123 ± 21 W), and seated chest press (114 ± 20 vs 143 ± 21 W; P < 0.05). Sit-up results also showed significant improvements, while handgrip did not (P > 0.05). Conclusion: GH-deficient adults without GH replacement may improve their maximum muscle power when submitted to an individualized, simple, and short home-based RT program. Considering that limb girths did not significantly change, the gains were most likely due to improvements in neuromuscular components. Key Words: EXERCISE, MAXIMUM MUSCULAR POWER, BODY COMPOSITION, HOME-BASED PHYSICAL TRAINING, STRENGTH.

Growth hormone (GH) is a natural hormone protein released by adenohypophysis throughout life (24,25). Appropriate levels of GH are necessary for normal child development and for maintenance of body composition, including fat, muscle, and bone, during adulthood. GH deficiency in infancy or acquired GH deficiency during adult life causes radical changes in body composition, mainly observed as a decrease in fat free mass (FFM) (2,3,19). Analyzing patients that acquired GH deficiency at adult age, it was found that their FFM was about 9% lower than standards established for age, sex, height, and weight (19). Patients with this deficiency also tend to present a low physical capacity, lack of strength, and reduced muscle power, suffering frequently from general fatigue (16,17,20). According to Cuneo et al. (2), these symptoms likely result from a decrease in muscle mass.

Cuneo et al. (3,4), in two double-blind studies, assessed 24 patients who were randomized for GH replacement or placebo. After 6 months, those receiving GH increased FFM, strength, and maximum cycling functional capacity. In reality, various studies have shown benefits of GH-replacement therapy in adults with deficiencies (3–7,10,11,16), especially concerning body composition, through FFM increase and fat reduction, and in improving muscular function.

Many studies (22,27,28) investigated the benefits of GH replacement therapy associated with resistance training (RT) on individuals 60 yr or older, finding distinct results from previous trials with GH-deficient adults. For instance, Yarasheski et al. (27) studied 23 healthy and previously sedentary old men, comparing GH replacement therapy and placebo. All the men were submitted to an RT program that prioritized major muscle groups, with exercises performed at 75–90% of one maximum repetition (1RM), four times a week. FFM, total body water content, and protein synthesis/degradation ratio were higher in those receiving GH replacement therapy, whereas similarities were found in creatine kinase excretion and muscle strength. These authors (27) considered that FFM increase was primarily due to water retention, because strength was similar in both groups. In a recent review of nine articles on aging and GH replacement therapy, Zachwieja and Yarasheski (28) observed that four of these studies showed significant changes in muscular strength. However, in six studies, there were significant side effects, mainly insulin resistance and carpal tunnel syn-
drome. These results can be a minus for the routine use of this type of procedure in this population.

It has been accepted for many years that regularly performed RT improves muscular function (8,13,26). Studies have shown that RT promotes changes in body composition by primarily increasing muscular mass. RT stimulates myofibrillar protein synthesis, thus increasing muscle size (14). Muscle hypertrophy can be observed early in the course of RT, and there is a direct relationship between cross-sectional muscle area and strength. Another RT effect is a neuromuscular coordination improvement that usually occurs in its initial phase (18). It has been considered that RT is an effective method for increasing power strength, stamina, and muscle mass (18,23). In addition, RT has been utilized in various situations in different populations with the following major objectives: improving sport skills, prevention and rehabilitation of motor skill problems, increasing functional capacity, and improving quality of life.

Typically, a population affected by chronic GH deficiency is the most devoid of muscle strength and power, thus presenting limitations for work, and even for simple tasks of everyday life. So far, at best of our knowledge, there are no data available about potential RT benefits applied as a single intervention for GH-deficient adults without replacement therapy. Considering the high cost of GH-replacement therapy, it may be worth providing RT to GH-deficient patients for whom this kind of therapy is not feasible. We aimed to assess the effects of a simple home-based RT program on chronically GH-deficiency adults not being simultaneously submitted to GH-replacement therapy. The effects were assessed by measuring body composition, general flexibility, maximum muscle power, and strength and localized muscular stamina.

METHODS

Sample. Eleven patients (7 men and 4 women), with an age span of 22–54 yr (39 ± 11 yr), had pituitary illness and/or a history of GH deficiency since infancy. Body weight ranged from 37 to 101 kg and stature from 152 to 182 cm. The patients were being followed at outpatient clinics and had not received GH for at least 1 yr before the beginning of this study. Although quite small, the number of patients in our study exceeded the previously determined sample size, because a large training effect was expected. All subjects voluntarily accepted to participate in this study, and a written informed consent was obtained before data collection. In addition, the study protocol was approved by the University Hospital Ethics Committee. The anthropometric data and hormonal profiles of the patients are listed in Table 1.

For selecting the sample, we performed two stimulation tests, insulin tolerance (0.1–0.15 U of regular insulin·kg⁻¹·body weight) and glucagon (1 mg IM) in patients with clinical diagnosis of GH deficiency whose GH level did not exceed 5 ng·dl⁻¹. Those patients with multiple hormonal deficiencies had to be in substitution therapy with sexual steroids, glucocorticoids, and L-thyroxine, in a steady dose for at least 3 months before our study. To prevent fluctuations in plasma testosterone levels, male patients were evaluated approximately 10 d after intramuscular administration of 250 mg of testosterone enanthate (Table 1). Exclusion criteria were the following: associated mental disorder, pregnancy, uncontrolled diabetes, severe arterial hypertension, severe acute illness, liver or renal chronic disease, and history of malignancy.

Protocol. Each patient was submitted to following measurements at our research lab: 1) body composition, 2) maximum muscle power, 3) muscle strength, and 4) muscle endurance. The measurements were made at four occasions during the study: 1) 2 wk before initiating RT, 2) immediately before starting RT, 3) 6 weeks after RT started, and 4) 12 wk on RT. Before each evaluation session, patients were questioned in order to detect any recent clinical contraindication for muscle testing.

In the first visit, patients were instructed about how to perform the muscle functional tests, to avoid or to minimize eventual errors induced by learning or experience that could affect the actual tests that were done 2 wk later at their second visit. On the patients’ second visit, they also received a set of materials (ankle weight, bar bells dumbbell, and a small rubber ball) and specific instructions on how to conduct their individually prescribed home-based RT program. This RT program was to be performed at the patient’s home, every other day, for 12 wk. The third and fourth visit to our research lab occurred at 6 and 12 wk after beginning of RT program, respectively.

For body composition evaluation, the following measurements were made: 1) height, in mm; 2) weight, in kilograms; 3) girths of relaxed arm, contracted flexed arm, forearm, wrist, chest, waist, hip, thigh, calf, and ankle, in mm; and 4) skin-fold thickness—triceps, subscapular, supra-iliac, supraspinale, abdominal, anterior thigh, and medial calf, in tenths of mm, using standard procedures.

Maximum muscular power was evaluated in five exercises: 1) seated chest press, 2) rear lat pull-down, 3) knee extension, 4) standing upright row, and 5) triceps press down. They were performed on a standard exercise machine following load increments of 1- or 5-kg intervals. Mean muscle power expressed in watts, velocity times load, in

| TABLE 1. Anthropometry and hormonal characteristics of the patients’ studied. |
|-----------------|---|---|---|---|---|---|
| Patients | Sex | Age (yr) | Height (cm) | Weight (kg) | BMI (kg/m²) | GH Deficiency |
| 1 | M | 24 | 167 | 84.0 | 30.1 | AH |
| 2 | M | 22 | 159 | 36.8 | 14.5 | IH |
| 3 | F | 54 | 157 | 63.7 | 25.7 | AH |
| 4 | F | 49 | 158 | 87.5 | 35.1 | AH |
| 5 | M | 44 | 182 | 101.0 | 30.5 | AH |
| 6 | M | 36 | 152 | 48.2 | 20.8 | IH |
| 7 | F | 51 | 158 | 61.0 | 24.4 | AH |
| 8 | M | 38 | 166 | 81.5 | 29.6 | AH |
| 9 | M | 32 | 143 | 53.9 | 26.4 | IH |
| 10 | M | 37 | 160 | 50.2 | 20.2 | IH |
| 11 | F | 47 | 156 | 69.0 | 28.4 | AH |

Mean | 39 | 161 | 67.0 | 25.9 |
SD | 11 | 19.6 | 19.6 | 5.8 |

BMI, body mass index; M, male; F, female; IH, idiopathic hypopituitarism; AH, acquired hypopituitarism.
each repetition was measured by a specific device (Fitrodyne, Bratislava, Slovakia) that reads mean velocity and was fixed on the stacks of exercise machine. The mean power value during concentric phase of each repetition for each load was recorded. Muscle power tests were ended when further load increases did not produce increase in maximum power (Fig. 1). This testing protocol has been shown to be highly reliable in a previous study (21).

Muscle endurance was estimated by an adapted sit-up exercise test, consisting in the maximum number of sit-ups performed, keeping a 4-s pace to each repetition. Muscle strength was evaluated using a handgrip dynamometer (Therapeutics Instruments, Clifton, NJ); each hand was tested twice, alternately, and the highest reading was adopted as the final measure.

Static flexibility was determined by the Flexitest (1). Briefly, Flexitest consists in measuring and evaluating the maximum passive mobility of 20 articular movements prioritizing the larger body joints. Eight movements are at the lower limbs, three at the trunk, and the remaining nine at the upper limbs. Each movement is measured by an increasing and discontinuous scale of integers, from 0 to 4, a total of five possible values, with a score of 2 representing the mode for young adults. The measurement is slowly performed until the maximum range is obtained, and then visual comparisons are made between assessment standard charts and this maximum range. Typically, the maximum range of motion is easily identified by the considerable mechanic resistance to the continuation of the movement and/or by the assessed person’s report of feeling discomfort. A global score called Flexindex is obtained by adding the 20 movement scores. In addition, Flexitest’s age- and gender-reference norms are available. The method is highly reliable and has been in use for decades in our lab (1).

The RT program was initiated after the second evaluation, in which the patients received detailed information and practiced with the material (ankle weight, barbells, and a small rubber ball) and the exercises to be performed at home. The load was individually selected for each exercise based on muscle power test results. The concentric phase of the movements was executed as rapid as possible, allowing a 15- to 30-s interval between each exercise set and 30 to 60 s between each different exercise. The RT program was made up of 13 exercises for all the patients: elbow flexion and extension, knee flexion and extension, lateral raise, squat, shoulder press, curl-up, standing upright row, wrist flexion and extension, hand compression of the small rubber ball, and chest press. The exercises were performed following the above sequence, and patients received a monthly training-control form, with exercise names and drawings, the number of sets and repetitions for each exercise, and the days RT should be performed. In all the exercises, except for the curl-up exercise and compression of the small rubber ball, 12 repetitions were performed divided in two sets of six repetitions. For the curl-up and the compression of the small ball exercises, they had to perform 30 repetitions divided in 3 sets of 10 repetitions.

RT program was performed in the patients’ home, without supervision, every other day, during 12 wk, using very simple material. After 6 wk of training, the patients were reevaluated and exercise prescription readjusted accordingly, to keep muscular overload stimulation. All patients received a new set of material, where each device was increased in 1 kg; the training continued for 6 more weeks, using the same approach except for the curl-up and hand compression of the small ball, which changes to 6 sets of 10 repetitions each. There were no specific recommendations about aerobic or stretching exercises.

**Statistical analysis.** For data analysis, a repeated-measurement ANOVA was used and when appropriate post hoc analyses were performed by Bonferroni’s least significant difference test. Significance level was set at 0.05 and data reported as mean and standard error of mean, unless specifically mentioned.

**RESULTS**

Four of 11 patients had GH deficiency since childhood (idiopathic), whereas GH-deficiency onset for the remaining seven occurred at adult age. No relevant clinical complications were reported in conjunction with RT. One of the patients suffered of cervical pain, probably aggravated by incorrect execution of an exercise. Two other patients, due to locomotor system limitations, were unable to participate in the muscle power evaluation in some exercises, and their data were excluded for these exercises. Training compliance rate was about 85%, and none of the patients missed more than two consecutive exercise sessions.

Throughout the study, body weight and waist girth remained quite stable (P > 0.05). Analyzing body composition, we were able to find some significant albeit modest changes in the sum of central skinfolds—scapula, supra-iliac, supraspinale, and abdomen—during RT intervention (112 ± 9 vs 100 ± 9 mm) (Table 2), most likely due to the significant decreases seen at supra-iliac (31 ± 2 vs 26 ± 2 mm) and abdominal (31 ± 2 vs 27 ± 2 mm) sites. Patients showed about average flexibility when compared with appropriate age- and gender-reference norms. No major
changes were seen in Flexindex scores with the intervention ($P = 0.45$).

The maximum muscle power increased slightly from the first to second evaluation and major gains were found after the 40-session RT program in the following exercises: 1) seated chest press ($N = 10$) (114 ± 20 vs 143 ± 21 W); 2) rear lat pull-down ($N = 9$) (141 ± 19 vs 198 ± 20 W); 3) standing upright row ($N = 9$) (134 ± 22 vs 157 ± 24 W); and 4) triceps press down ($N = 10$) (85 ± 14 vs 123 ± 21 W) ($P < 0.05$) (Fig. 2). For knee extension ($N = 10$), despite a trend to muscle power increase (196 ± 27; 209 ± 20; 223 ± 23 and 230 ± 22 W), there were no significant differences among the values ($P = 0.12$). Similarly, the adapted sit-up test showed a small increase in number of repetitions between the second and third evaluation, but it was not statistically significant. RT did not influence handgrip strength.

**DISCUSSION**

At best of our knowledge, this is the first study to quantify RT results in relation to a specific population of GH deficient patients. These patients often have low muscle strength and power (15–17,20). Considering the importance of GH in protein anabolism (9), one could speculate that without its presence there would not be any positive results from a RT program. Interestingly, the results of this study showed significant improvements in maximum muscle power, for adults with GH deficiency after only 12 wk of a quite simple RT. Considering that our 12-wk RT program consists of 40 sessions of 12 repetitions in 13 exercises lasting about 20 min or less per session, it is worthwhile to observe that significant improvements may be achieved with a total of less than 500 repetitions per exercise.

Despite the relative similarities seen in the two pre-RT test results, there was a trend for some positive changes from the first to second evaluation of the patients, indicating some learning effect. Notwithstanding, we believed that learning did not play a significant role in the gains that were found with RT training. There are two major arguments to support our view: a) magnitude of the gains substantially exceeded the differences seen between the two pre-RT measurements, exactly the opposite behavior that it could be expected from learning curves; and b) patients did not train in the exercise machines used for testing purposes.

In only one of the five exercises, muscle power did not change with RT, likely because of the small sample size and the large variability within the sample. Comparing pre- and post-RT, the smallest gain in maximum muscle power observed was 17%, and the two highest occurred in triceps press down (50%) and rear lat pull-down (40%). This may be due to the emphasis put on these muscle groups by the training protocol. The magnitude of these muscle power gains is considerably high when compared with a typical response seen in healthy adults undergoing RT program. These results were, at least in part, achieved due to very low muscle power level of the patients before initiated the RT program, although the simplicity and the use of maximal speed of execution in our RT program may had contributed to the gains seen (8,12). The mean maximum muscle power increase for the five exercises was about 30%, despite the fact that no significant changes were observed in muscle mass. At this point, one can speculate whether distinct or more extensive RT protocols could have induced different responses.

It was observed that most of the gains in maximum muscle power were achieved in the first 6 wk (third evaluation) of RT, and the small differences seen later did not have statistical significance. This lack of gain in maximum muscle power between the third and fourth evaluations may be attributed to insufficient overload muscle stimulation after 6 wk of our simple RT, or maybe these GH deficient patients do not have the capacity to improve their maximum
muscle power beyond a certain point. Another possibility is that these patients may also have lost their motivation in performing their home RT program because GH-deficient patients are typically apathetic. Further studies should be carried out in which these variables would be better controlled.

The RT program studied in this article was simple and practical, and with mass appeal. Simplicity comes from the material needed to perform the exercises (ankle weight, bar bells dumbbell, and rubber ball) and the relatively short time needed to do the exercises. Practicality lies in the fact that patients were able to perform the exercises at home. These simple and safe exercises could then be incorporated into their lives as a healthy habit at a very favorable cost-effectiveness ratio.

In short, our results showed positive benefits from a very simple and inexpensive 12-wk RT program performed every other day. Significant benefits were observed in maximum muscle power and in body composition, particularly in decreasing the amount of fat available in the central skinfold sites. This particular RT program could be used in the treatment of patients afflicted with GH deficiency that are not yet receiving hormone replacement therapy, and it is capable to greatly improve the patients functional capacity, thereby, improving their quality of life. Further studies are needed associating simple RT programs and GH replacement therapy, to assess their combined effectiveness in this particular clinical setting.

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REFERENCES


