ARTICLE IN PRESS

Steroids xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Steroids

journal homepage: www.elsevier.com/locate/steroids

The effect of acute and chronic exercise on steroid hormone fluctuations in young and middle-aged men

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ARTICLE INFO

Keywords:
Total testosterone
Cortisol
Sex hormone-binding globulin
Aging

ABSTRACT

The current study examine the effects of combined sprint and resistance training on serum total testosterone (TT), sex-hormone-binding globulin (SHBG) and cortisol (C), at rest, and in response to the Wingate Anaerobic-Test (WAnT) in 21 and 41 years old men. Forty moderately-trained men were randomly assigned to a young trained (YT), young control (YC), middle-aged trained (MAT), and middle-aged control (MAC) group. Before (P1), and after (P2) training, blood samples were collected at rest and after exercise. At P1, higher C and lower TT was observed in middle-aged groups compared to younger ones ($P < 0.05$). At P2, basal TT increased significantly ($P < 0.05$) in MAT and the age-difference was absent between trained groups ($P > 0.05$). Basal SHBG decreased significantly in YT at P2 ($P < 0.05$) but did not change in other groups from before to after training ($P > 0.05$). Free-testosterone was significantly ($P < 0.05$) higher in young compared to middle-aged groups at P1, but at P2, this age-related difference disappeared between YT and MAT ($P > 0.05$). C post-WAnT increased significantly for MAT only ($P < 0.05$) at P2, whilst no significant changes were observed in the other three groups ($P < 0.05$) at P2. In contrast, resting levels of C did not change in all groups at P2 ($P > 0.05$). The current study demonstrates that this training intervention may help increase steroids hormones in middle-aged men and counteract the negative effect of age on TT and free testosterone.

1. Introduction

The age-related loss of anabolism is characterized by a decrease in muscle protein content and is attributable to an imbalance between muscle protein synthesis and breakdown. Numerous studies have observed alterations in contractile properties of muscle fibers, particularly fast-twitch fibers in older individuals [1,2], which leads to a decline in anaerobic performance [3].

Concomitant with this age-associated decline in muscular function exists a reduction in systemic testosterone concentrations [4]. Furthermore, sex hormone binding globulin (SHBG) increases with age, rendering the bioavailable fraction (i.e. the proportion available for interaction with the androgen receptor) of testosterone decreased [5]. Low testosterone has a number of adverse health consequences, such as loss of muscle mass, increased fat mass, reduced aerobic capacity, and increased cardiovascular disease risk [4,6–8]. Furthermore, significant correlations between testosterone and measures of physical performance in older adults have been observed [9].

Physical inactivity has been shown to decrease testosterone concentrations [10], and well trained older individuals exhibit greater testosterone concentrations than sedentary males [11]. However, this is not widely accepted [12,13]. As such, whether long term exercise training increases testosterone remains a matter of debate. Likewise, the exercise training interventions present heterogeneity in results [13–15]. For example, Lovell et al. [15] observed no perturbation to total testosterone (TT), SHBG, or free testosterone (free-T) in an older cohort (~74 years) following resistance or aerobic training. Conversely, Hayes et al. [13] observed that although highly trained older adults displayed similar TT concentrations to that of sedentary older males, said sedentary participants increased TT following moderate aerobic exercise (150 $\text{min}\cdot\text{wk}^{-1}$). However, SHBG also increased, which rendered free-T unchanged. The same research group however, observed increased free-T following high-intensity interval training (HIIT) in a later study, which may suggest greater exercise intensity is required as a stimulus to increase free-T.

The body of literature concerning the influence of resistance

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https://doi.org/10.1016/j.steroids.2018.01.011
Received 29 September 2017; Received in revised form 16 January 2018; Accepted 19 January 2018

Please cite this article as: Sellami, M., Steroids (2018), https://doi.org/10.1016/j.steroids.2018.01.011

exercise and testosterone generally report increased testosterone following resistance training [16,17]. For example, both Tremblay et al. [18] and Sato et al. [19] reported 12 weeks' resistance training increased basal free-T, 5-dihydrotestosterone (DHT) and dehydroepiandrosterone (DHEA) in young (26 yrs) and older (62 yrs) men. As such, resistance training has been considered an appropriate strategy to counteract the age-associated deterioration of muscle, and androgenic status [20].

There remains considerable ambiguity concerning the influence of exercise training on steroid hormones with age. Therefore, the aim of the present investigation was to compare steroid hormones at rest, and in response to anaerobic exercise, in younger (20 yrs), and middle-aged (40 yrs) men, after13 weeks 'combined sprint and resistance training. We hypothesized *a priori* that a) an age-affect in steroid hormones would exist pre-training, and b) said training period would ameliorate the age-affect in steroid hormones.

2. Experimental procedures

2.1. Participants

Forty healthy, moderately trained men were recruited for participation in the present study. Subjects reviewed and gave their written consent forms approved by the local Ethics Committee for Human Research (ECHR) of the General Direction of the Military Health in accordance with ethical standards of the 1964 Helsinki Declaration (M.D.1369). Training status was assessed using an adapted version of the Baecke questionnaire [21]. To identify those with a medical contraindication (exclusion) to performing specific assessments, participants completed medical history, and dietary, questionnaires. Inclusion criteria included no contraindications to maximal exercise testing such as cardiovascular or pulmonary risk factors, no history of chronic disease, illness, surgeries, hospitalizations, and musculoskeletal or joint injuries.

Eligible participants were subsequently randomized to receive 13 weeks' combined sprint and resistance training (CSRT), or control. Thus, four groups existed: a young trained group (YT; 21 ± 1 yrs, n = 10), a young control group (YC; 22 ± 2 yrs, n = 10), a middle-aged trained group (MAT; 41 ± 3 yrs, n = 10) and a middle-aged control group (MAC; 40 ± 2 yrs, n = 10).

A sports nutritionist conducted the conventional dietary survey to monitor individual diet during the 13 weeks. Participants were asked to abstain from high glycemic loads, saturated and trans fatty acids, caffeine, alcohol, drugs, vitamins or supplements, and low fiber diets for the duration of the experimental period. Because participants belong to the same institution, they were offered the same menu component, which was suitable for "active" status. Before training period, estimated dietary energy intake was not significantly different between groups: YT (total calories per day: 3735 ± 972 kcal·day^{-1}), YC (total calories per day: 3390 ± 144 kcal·day^{-1}), MAT (total calories per day: 3556 ± 75 kcal·day^{-1}), and MAC (total calories per day: 3541 ± kcal·day^{-1}).

After the training period, these results remained stable and no differences were observed between groups: YT (total calories per day: 4132 ± 111 kcal·day^{-1}), YC (total calories per day: 3736 ± 165 kcal·day^{-1}), MAT (total calories per day: 3960 ± 92 kcal·day^{-1}), and MAC (total calories per day: 3943 ± 121 kcal·day^{-1}).

2.2. Exercise training program

Trained subjects (YT and MAT) participated in 13 weeks of CSRT as previously described [22]. Briefly, CSRT consisted of one sprint running, one sprint cycling, and one resistance training session per week, separated by a minimum of 48 h (13 sessions of each training unit). Sessions were performed during the morning and lasted no longer than 70 min, inclusive of 15 min warm-up (jogging and stretching) and 15 min cool-down (jogging and stretching).

Sprint running sessions entailed 3–5 sets of 3–5 short bouts at maximum velocity. A recovery of 2–3 min was permitted between each set. Sprint cycling sessions comprised 3–5 repetitions of 10–30 s. The 10–30 s trials were performed maximally. Subjects recovered actively (at a power output corresponding to 50% VO_{2max}) for 3–5 min between each sprint. Resistance training sessions entailed 5–6 exercises targeting all major muscle groups (squat with Smith machine, machine leg extension, machine leg curl, calf raises over a step, triceps push down with cable machine, bicep preacher curl, and bench press. The load used during exercise was progressively increased from 40% to 65% of 1-repetition maximum (RM)[23]. To produce maximal power output (i.e. velocity × load), the concentric phase of each exercise was performed as fast as possible [24]. Repetitions were maintained at 10–15 per sets and the number of sets increased from 3 to 4 during the training period. Hence, training volume increased progressively during the CSRT program. Rest periods between sets were 3–5 min for upper body muscles [24,25] and a minimum of 1 min for lower limbs [26]. To adjust load during resistance training session and monitor adaptation, we determined strength using a 1-RM for the six resistance exercises, pre-training (P1), during the sixth week, and post-training (P2).

2.3. Exercise testing

Before training, subjects were familiarized with testing procedures to minimize learning effect. Participants avoided physical activity for 48 h preceding each test. Total energy and macronutrient intake per day during the previous three days were monitored to ensure consistency prior to exercise testing. The testing period was divided into two phases: before (P1), and after (P2) training. Each period lasted seven days and included two consecutive laboratory visits separated by 48 h. The second phase (P2) commenced 48 h after training cessation and finished seven days later. Anthropometric measurements were obtained by a single investigator at P1 and P2 on the morning of the first day (Day1). Measurements of body weight (kg) and height were taken from all participants. Body mass was measured to the nearest 0.1 kg, with the subject in light clothing and without shoes, using an electric scale (Model Tanita® BC-418®, Tokyo, Japan). From this scale, body fat and fat free mass (FFM) were recorded for all participants. Total body fat was expressed as percentage body fat and in kg. Fat-free mass was expressed in kg. The height (expressed in cm) was determined to the nearest 0.5 cm with a measuring tape fixed to the wall.

On the first visit, subjects arrived at the laboratory 2 h postprandial, after a standardized breakfast (10 kcal·kg^{-1}, 55% carbohydrate, 33% lipids, and 12% protein). All participants performed a repeated sprint cycling test on a cycle ergometer Monark Ergomedic 894E Peak Bike, Monark, Varberg, Sweden). The test began 5 min after warm-up (15 min at a power output corresponding to 50% estimated VO_{2max}). This test comprised five short trials (6 s) against increasing resistance (2kg each sprint) until the velocity began to decrease during the 6 s trials. Recovery time between each trial was 5 min. The highest pedaling cadence recorded after each trial was collected from a photoelectric cell fixed on the wheel of the cycle ergometer and connected to a computer. The load that permitted the highest peak power output was used for the Wingate Anaerobic Test (WAnT).

48 h later, subjects performed the WAnT on a mechanically-braked Monark cycle ergometer (Monark Ergomedic 894E Peak Bike, Monark, Varberg, Sweden). The test commenced 5 min after warm-up. Subjects were asked to cycle maximally for 30 s. Maximal power during the trial was considered as the highest value (W_{peak}), while average power during the WAnT was considered as mean power (W_{mean}).

A pilot study was carried out to ensure the reproducibility and sensitivity of W_{peak} and W_{mean} indices, using two measurements of 10 subjects in a single day. Both indices showed excellent intraclass correlation coefficients (ICC = 0.91–0.94), small standard error of