

ORIGINAL ARTICLE

William J. Kraemer · Keijo Häkkinen
Robert U. Newton · Matthew McCormick
Bradley C. Nindl · Jeff S. Volek · Lincoln A. Gotshalk
Steven J. Fleck · Wayne W. Campbell · Scott E. Gordon
Peter A. Farrell · William J. Evans

Acute hormonal responses to heavy resistance exercise in younger and older men

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Abstract The purpose of this investigation was to examine the acute responses of several hormones [total and free testosterone (TT and FT, respectively), adrenocorticotrophic hormone (ACTH), cortisol (C), growth hormone (GH), and insulin (INS)] to a single bout of heavy resistance exercise (HRE). Eight younger [30-year (30y) group] and nine older [62-year (62y) group] men matched for general physical characteristics and activity levels performed four sets of ten repetitions maximum (RM) squats with 90 s rest between sets. Blood samples were obtained from each subject via an indwelling cannula with a saline lock pre-exercise, immediately post-exercise (IP), and 5, 15 and 30 min post-exercise. Levels of TT, FT, ACTH, C and lactate significantly increased after HRE for both groups. Pre-HRE pairwise differences between groups were noted only for FT, while post-HRE pairwise differences were found for TT, FT, GH, glucose and lactate. Area under the curve analysis showed that the 30y group had a significantly higher magnitude of increase over the entire recovery period (IP, 5, 15, and 30 min post-exercise) for TT, FT, ACTH and GH. Few changes occurred in the INS response with the only change being that the 62y group demonstrated a decrease IP. Lactate remained elevated at 30 min post-HRE. This investigation demonstrates that age-related differences occur in the endocrine response to HRE, and the most striking changes appear evident in the FT response to HRE in physically active young and older men.

Key words Aging · Neuroendocrine · Resistance exercise · Growth factors

Introduction

Heavy resistance exercise (HRE) has been shown to be a potent stimulus for acute increases in circulating hormones in younger men (Bunt 1986; Kraemer et al. 1987, 1989a, 1989b, 1990, 1991). In contrast, it has been shown that HRE does not elicit the same magnitude of hormonal changes in older men (i.e. men over 64 years of age, Craig et al. 1989b; Häkkinen and Pakarinen 1995; Vermeulen et al. 1972). The importance of circulating hormones resides in the fact that a lower amount of circulating anabolic hormones may contribute to the age-related decline in muscle mass (i.e. sarcopenia) and strength observed in the sixth decade of life (Craig et al. 1989b; Häkkinen et al. 1993b; Newton et al. 1995). A question remains as to whether these changes are attenuated in older subjects who remain physically active. Few data are available on the responses of an entire ensemble of anabolic and catabolic hormones to a single HRE stimulus in younger and older men who are both physically active and similar in body size and body composition. (Bunt et al. 1986) The purpose of this investigation, therefore, was to examine the acute responses of several hormones [total and free testosterone (TT and FT, respectively), adrenocorticotrophic hormone (ACTH), cortisol (C), growth hormone (GH) and insulin (INS)] to a single bout of HRE in younger versus older men.

Methods

Subjects

Eight younger (30 years old; 30y group) and nine older (62 years old; 62y group) men volunteered to participate in this investigation. Each subject was informed as to the risks of the study and signed a consent document that was approved by The Pennsylvania State

W.J. Kraemer (✉) · M. McCormick · B.C. Nindl · J.S. Volek
L.A. Gotshalk · S.J. Fleck · W.W. Campbell · S.E. Gordon
P.A. Farrell · W.J. Evans
Noll Physiological Research Center and Laboratory for Sports
Medicine, Pennsylvania State University, 21 REC Bldg,
University Park, PA 16802, USA

K. Häkkinen
Department of Biology of Physical Activity, The University
of Jyväskylä, Jyväskylä, Finland

R.U. Newton
Department of Exercise Science and Sport Management,
Southern Cross University, Lismore, NSW, Australia

University Institutional Review Board for the use of human subjects. All volunteers were physically active but had not been involved in any previous structured resistance training programs. Activity questionnaires were utilized and all subjects were active in recreational sports and jogging. The mean (sd) characteristics of the subjects were as follows. 30y group: age 29.8 (5.3) years, body mass 90.1 (12.8) kg, height 177.2 (5.3) cm, body fat 18.3 (4.6)%, one repetition maximum squat (1RM) 138.2 (24.1) kg; 62y group: age 62 (3.2) years, body mass 84.3 (13.4) kg, height 177.0 (7.3) cm, body fat 20.4 (4.6)%, 1RM 84.8 (28.9) kg. The only significant ($P \leq 0.05$) difference in subject characteristics was observed for age and 1RM. Prior to the study, all subjects were screened by a physician for orthopedic, endocrine, or medical problems that would confound their participation in the study. None of the subjects were on any medications during the study. Maximal strength was assessed using a concentric-only 1RM squat test on the Plyometric Power System (PPS; Norsearch, Lismore, Australia) from a 90° knee angle (Newton et al. 1995). Test-retest reliabilities for the 1RM squat strength measurements were $R = 0.872$ for the 30y group, and $R = 0.902$ for the 62y group. Body composition was determined via skinfold measurements, as described previously by Kraemer et al. (1991).

Experimental protocol

Each subject was familiarized with the experimental HRE protocol. The HRE consisted of performing four sets of ten RM (10RM) squats with 90 s rest between sets. The initial 10RM load was calculated as $\approx 70\%$ of their squat 1RM. If, due to fatigue on any given set, the subject failed to perform ten repetitions, the load was subsequently adjusted (i.e., lightened) to allow the completion of ten repetitions on the following set. The squats were performed with the Plyometric Power System (PPS) (Norsearch) described previously (Newton et al. 1995). Blood was obtained pre-, immediately-post (IP), and at 5, 15, and 30 min post-exercise via an indwelling cannula with a saline lock. The IP blood sample was obtained within 1 min of the termination of the last set of squats. Since only the acute hormonal responses were examined, blood was sampled at various times throughout the day. Blood was centrifuged at 1500 *g* and at -4° for 15 min. All serum and plasma samples were then distributed to appropriate preservative tubes and stored at -84°C until analysis. Serum was obtained for TT, FT, C, GH, glucose, and serum lactate (L) analysis, while a heparinized plasma was obtained for ACTH and insulin (I) analysis.

Biochemical analyses

Hematocrit was determined in duplicate using a standard microcapillary technique and the hemoglobin was determined in duplicate colorimetrically by the cyanmethemoglobin method (Sigma Chemical, St Louis, Mo., USA). All hormones were analyzed in duplicate using various radioimmunoassay techniques. To eliminate interassay variance all samples were analyzed within the same assay batch, and intraassay variance was $< 5\%$. Serum TT, FT and C were analyzed by single-antibody (solid phase) ^{125}I radioimmunoassays, while a double-antibody was used for plasma ACTH (Diagnostics Products, Los Angeles). Serum GH was analyzed by single-antibody (solid phase) ^{125}I radioimmunoassay (Diagnostics Products, Calif., USA). Serum glucose concentration was determined in duplicate colorimetrically by the hexokinase enzymatic method (Sigma Chemical). Plasma INS was analyzed by methods described previously (Engdahl et al. 1995). A LKB Model 1272 Cline gamma counter with on line data reduction capabilities (Pharmacia LKB Nuclear, Gaithersburg, Md., USA) was used to determine immunoreactivity. Blood L concentration was measured in duplicate using a L analyzer (SI model 1500, Yellow Springs, Ohio, USA). Plasma volume changes were calculated using hematocrit and hemoglobin values and the methods described by Dill and Costill (1974). Hormone concentrations were not corrected for plasma volume changes since the target tissues see the actual molar

concentrations. The plasma volume changes in this study IP of -11.4 and -14.0% did not differ between the 30y group and the 62y group, respectively, pre- to IP.

Statistical analysis

Appropriate statistical assumptions for each analysis were tested prior to evaluation of the data and showed the data to be normally distributed. The data were analyzed using alpha level corrected dependent and independent *t*-tests using a CSS: Statistica statistical package (Statsoft, Tulsa, Okla., USA). The area under the curve (AUC) was also calculated for selected hormonal data using a standard trapezoidal method. The criterion level for significance in this study was set at $P \leq 0.05$.

Results

Figure 1 overviews the acute changes in serum TT, FT, C, and plasma ACTH that occurred in response to HRE. For TT (Fig. 1A) a significant increase above resting concentrations was observed IP for both the 30y and 62y groups and it remained elevated for both groups for 30 min into recovery. A significant pairwise difference between the 30y and 60y groups was observed for TT at 5, 15 and 30 min post-exercise. AUC analysis also demonstrated that the 30y group had a significantly higher integrated concentration of TT over the 30 min of recovery. Serum FT (Fig. 1B) demonstrated a significant exercise-induced increase with HRE in both the 30y and 62y groups. This elevation in FT was maintained over the entire 30-min recovery period for both groups. Pairwise differences between the two groups were observed at each of the time points measured. AUC analysis showed that the 30y group had a significantly higher magnitude of increase over the entire recovery period. Plasma ACTH (Fig. 1C) demonstrated exercised-induced increases IP, 5 and 15 min post-exercise for the 30y group, and IP for the 62y group. While no pairwise differences between groups were observed, AUC analyses showed that the 30y the group demonstrated a higher response over the recovery period compared to the 62y group. Both the 30y and 62y groups had significant exercise-induced increases at all post-exercise time points in plasma C (Fig. 1D) with no pairwise differences into recovery, nor any differences in AUC analyses.

The changes in serum GH, plasma INS, glucose, and serum L are presented in Fig. 2. The pattern of increase differed between the 30y and 62y groups for serum GH (Fig. 2A). The 30y group demonstrated significant increases at 5, 15 and 30 min post-exercise, while the 62y group showed an increase IP and 5 min post-exercise. The 30y group GH response at 30 min post-exercise was significantly higher than the 62y group at the same time point. Integrated AUC analyses demonstrated a higher GH response for the 30y group compared to the 62y group. Few changes occurred in INS responses (Fig. 2B), with only the 62y group demonstrating a significant decrease IP. No other changes were observed.