Testosterone and cortisol in relationship to dietary nutrients and resistance exercise

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Volek, Jeff S., William J. Kraemer, Jill A. Bush, Thomas Incledon, and Mark Boetes. Testosterone and cortisol in relationship to dietary nutrients and resistance exercise. J. Appl. Physiol. 82(1):49–54, 1997.— Manipulation of resistance exercise variables (i.e., intensity, volume, and rest periods) affects the endocrine response to exercise; however, the influence of dietary nutrients on basal and exercise-induced concentrations of hormones is less understood. The present study examined the relationship between dietary nutrients and resting and exercise-induced blood concentrations of testosterone (T) and cortisol (C). Twelve men performed a bench press exercise protocol (5 sets to failure using a 10-repetitions maximum load) and a jump squat protocol (5 sets of 10 repetitions using 30% of each subject’s 1-repetition maximum squat) with 2 min of rest between all sets. A blood sample was obtained at preexercise and 5 min postexercise for determination of serum T and C. Subjects also completed detailed dietary food records for a total of 17 days. There was a significant (P < 0.05) increase in postexercise T compared with preexercise values for both the bench press (7.4%) and jump squat (15.1%) protocols; however, C was not significantly different from preexercise concentrations. Significant correlations were observed between preexercise T and percent energy protein (r = −0.71), percent energy fat (r = 0.72), saturated fatty acids (g·1,000 kcal−1·day−1; r = 0.77), monounsaturated fatty acids (g·1,000 kcal−1·day−1; r = 0.79), the polyunsaturated fat-to-saturated fat ratio (r = −0.63), and the protein-to-carbohydrate ratio (r = −0.59). There were no significant correlations observed between any nutritional variables and preexercise C or the absolute increase in T and C after exercise. These data confirm that high-intensity resistance exercise results in elevated postexercise T concentrations. A more impressive finding was that dietary nutrients may be capable of modulating resting concentrations of T.

Testosterone (T) is a steroid hormone secreted from the Leydig cells of the testes that has both anabolic and anticatabolic effects on muscle tissue (10, 22). Cortisol (C) is a steroid hormone released by the adrenal cortex that has catabolic effects on muscle tissue (10). Previous studies have demonstrated that steroid hormone concentrations are subject to dietary regulation (2, 4, 24). Individuals consuming a diet containing ~20% fat compared with a diet containing ~40% fat (7, 9, 13, 25) have significantly lower concentrations of T. Also, replacement of dietary carbohydrate with protein has been shown to decrease T concentrations (2). These studies indicate that the energy supplied by the different macronutrients has a significant influence on T concentrations. Raben et al. (24) reported a significant decrease in resting T concentrations and an attenuation in the exercise-induced increase in T in male endurance athletes who switched from a meat-rich diet to a lacto-ovo vegetarian diet. Interestingly, both diets contained equal amounts of energy derived from protein, carbohydrate, and fat, indicating that the supply of energy from the different macronutrients was not responsible for the effect on T and that the composition of carbohydrate, protein, and fat may influence T concentrations. Thus both the amount and composition of the energy-providing macronutrients may modify T concentrations.

Few data exist regarding the relationship between nutrients and resting and exercise-induced increases in steroid hormones in young athletic men. Therefore, the primary purpose of this investigation was to examine the relationships among specific dietary nutrients and resting and resistance exercise-induced T and C concentrations.

METHODS

Subjects. Twelve healthy men with at least 1 yr of resistance training experience volunteered to participate in this investigation. Descriptive data for the 12 subjects are presented in Table 1. The subjects had been involved with resistance training ~5 yr, and they trained, on average, five sessions per week. Their workouts involved multiple sets (15–25 per workout) and moderate repetitions (6–15 per set) comprising exercises for two to three muscle groups per session. None of the subjects were coming off any type of high-volume and/or high-intensity cycles, and their workouts were characterized by relatively consistent training volumes 6–10 wk before the study. All subjects were informed as to the possible risks of the investigation before giving their written informed consent in accordance with The Pennsylvania State University Institutional Review Board for use of human subjects.

Exercise protocol. All subjects completed an identical bench press exercise protocol and a jump squat exercise protocol (performed on consecutive days) on two occasions separated by 1 wk. Both testing protocols were performed on a Plyomet-
Table 1. Descriptive characteristics of experimental subjects

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>23.8 ± 1.1</td>
</tr>
<tr>
<td>Resistance training, yr</td>
<td>5.6 ± 0.9</td>
</tr>
<tr>
<td>Height, cm</td>
<td>172.3 ± 2.2</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>75.6 ± 2.4</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>13.3 ± 1.2</td>
</tr>
<tr>
<td>1-RM squat, kg</td>
<td>145.4 ± 11.3</td>
</tr>
<tr>
<td>10-RM bench press, kg</td>
<td>80.7 ± 4.2</td>
</tr>
</tbody>
</table>

Values are means ± SE for 12 subjects. RM, repetition maximum.

Results

The primary finding from this investigation was that dietary nutrients may influence resting concentrations of T in young athletic men. However, the resistance exercise-induced increase in T does not appear to be affected by nutritional variables averaged over 17 days. Because of the variation in nutrient intake from day to day within individuals (especially dietary cholesterol and PUFA/SFA values), 2–3 wk of diet information appears to be required to obtain reliable data (21). Most
other studies have used much shorter time periods to obtain individual food intake information; thus their reliability and accuracy may be questionable. Our results demonstrated that dietary protein, fat, SFA, MUFA, PUFA/SFA ratio, and protein-to-carbohydrate ratio were all significantly correlated with preexercise T concentrations. However, none of these dietary variables were significantly correlated with C concentrations. These data are consistent with the findings of several other investigations that have reported a decrease in T in individuals consuming a diet containing 20% fat compared with a diet containing 40% fat (7, 9, 13, 25). Vegetarians also consume less fat, SFA, and a higher PUFA/SFA ratio compared with omnivores, and vegetarians exhibit lower concentrations of T compared with omnivores (3, 11, 12, 15, 24). These data suggest that alteration in dietary energy and/or dietary composition has the potential to modify T concentrations. The results from several investigations strongly suggest that dietary fat has a significant impact on T concentrations; however, the influence of different types of lipids on T is not as clear. In the present investigation, dietary fat, SFA, and MUFA were the best predictors of resting T concentrations. Interestingly, Tegelman et al. (28) observed a significant positive correlation ($r = 0.76$) between percent energy fat and T in young athletic men, which is very similar to the correlation ($r = 0.72$) obtained in this study. Also, Adlercreutz et al. (1) reported a significant positive correlation between PUFA and T in men and women. The same nutrients were positively correlated with T in the present investigation except for cholesterol, which showed a correlation of $r = 0.53$ ($P = 0.07$) with T. In contrast to the results obtained in this study, Key et al. (15) reported a significant positive correlation ($r = 0.37$) between PUFA and T in men. 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nutritional and metabolic factors. This complexity is illustrated by the findings of Sebokova et al. (26, 27), who reported that alteration in the testicular plasma membrane and changes in the responsiveness of Leydig cells and subsequent T synthesis occur as a result of ingestion of different compositions of lipids.

The significant negative correlation between protein and resting T concentrations is consistent with the findings of Anderson et al. (2), who demonstrated that a low-protein diet (10% of total energy) was associated with higher levels of T compared with a diet higher in protein (44% of total energy). The authors postulated that it was the protein-to-carbohydrate ratio in the diet that influenced either T metabolism or the liver-derived protein sex hormone-binding globulin (2, 14). Interestingly, the protein-to-carbohydrate ratio in the present study was significantly negatively correlated with resting T concentrations. Also, the source from which the protein is derived may influence T concentrations. Raben et al. (24) compared the effects of two diets differing only in the source of protein in male athletes. Results showed a reduced resting and postexercise increase in T concentrations in athletes consuming protein derived mainly from vegetable sources compared with a diet with protein derived mainly from animal sources. Thus not only the percent energy derived from protein in the diet but also the source of protein may influence T homeostasis.

The reason for a lack of a significant relationship between dietary nutrients and resting or resistance exercise-induced changes in C concentrations remains unknown. A number of factors related to the more dynamic nature of this hormone responding to stress and the differential storage, release, and synthesis mechanisms in glands along with differences in regulatory factors (e.g., blood flow) compared with T may partially explain our findings.

The fact that the absolute resistance exercise-induced increases in T and C concentrations were not significantly correlated with any nutritional variables

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**Fig. 2. Correlations between preexercise testosterone and selected nutritional variables.**
indicates that other mechanisms are responsible for the acute hormonal responses to exercise stress. The significant increase in T after both the bench press and jump squat exercise protocols confirms that high-intensity resistance exercise results in elevated concentrations of T (5, 8, 18, 19, 29). The fact that T was increased by ~15% after the jump squat exercise compared with ~7% after the bench press exercise was most likely due to the greater muscle mass used in the jump squat (16, 20). The lack of a significant C response to the resistance exercise protocols may have been due to the time of blood sampling or the amount of rest periods between sets (17). Finally, if blood samples had been obtained further into recovery, the possibility still exists that dietary nutrients may influence testosterone or cortisol concentrations.

In summary, the primary finding of this study was that resting concentrations of T may be partially explained by the amount and composition of dietary macronutrients. Our data suggest that the percentages of energy-providing macronutrients in the diet are important determinants of T homeostasis in healthy athletes. Also, the type of lipid appears to influence circulating T concentrations. In this study, MUFA (g·1,000 kcal−1·day−1) and SFA (g·1,000 kcal−1·day−1) were the strongest predictors of T, accounting for 62 and 59% of the shared variance in T concentrations, respectively. These findings are particularly important for athletes training intensely who may experience a decline in T concentrations due to overtraining. Furthermore, this scenario may be exacerbated by a diet very low in fat, which many athletes (e.g., wrestlers, gymnasts, etc.) consume.

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