

Thyroid Hormone Responses During an 8-Hour Period Following Aerobic and Anaerobic Exercise

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Summary

The purpose of this study was to compare the daytime hourly responses of total thyroxine (T₄) and triiodothyronine (T₃) during an 8-hour recovery period following aerobic and anaerobic exercise to an equivalent non-exercise, control period. The data were examined for hourly mean differences as well as by determination of the integrated area under the curve (AUC) responses. Significant persistent elevations (hourly concentrations and AUC) from control levels in total T₄ following both aerobic and anaerobic exercise were found. Total T₃, however, was transiently elevated (only in the hourly concentration immediately following exercise) compared with the control following aerobic exercise, but remained unaffected by anaerobic exercise. No significant changes in the total T₃ AUC responses were found due to exercise. The present findings demonstrate that exercise, aerobic and anaerobic, disrupts the daytime hourly pattern for total T₄ in the blood, but apparently has minimal effect on total T₃.

Key Words

Thyroid hormones – Circadian rhythms – Physical activity – Male subjects

Introduction

The thyroid hormones are key effectors of the body's metabolic rate, substrate oxidation, and muscular function. A careful review of the research literature reveals that the influence of exercise upon the thyroid hormones is still somewhat controversial, as the results of many studies contradict one another. For example, Terjung and Tipton (1971) reported that 30 min of submaximal cycle ergometer exercise produces an acute rise in total thyroxine (T₄) concentration in the blood. Galbo *et al.* (1977), however, indicated that several hours of submaximal exercise have no significant effect on circulating levels of total T₄ or triiodothyronine (T₃). Yet, Hackney and Hodgdon (1992) report that prolonged, repetitive bouts of low intensity exercise (several hours daily) result in a reductions of total blood T₄ and T₃ levels. Some of the possible reasons for these contradictions include a lack of controls, e.g. the subjects' prior diet, time of day for blood sampling, their training status, as well as environmental factors. Furthermore, many studies have attempted to assess the impact of exercise upon the thyroid hormones *via* the use of isolated blood

sampling protocols. These studies have used infrequent blood sampling and thus have not accounted for the circadian release of thyroid hormones into the circulation.

Additionally, it would seem that the available research studying exercise and the thyroid has been focused primarily upon the effects of continuous-duration, aerobic-based physical activity. Thus, the effects of anaerobic physical activity thyroid hormones has not been studied. Due to the short-comings in the existing research, we designed the present study so as to investigate the relationship between the thyroid hormones and exercise. Our purpose was to compare the daytime hourly responses of total T₄ and T₃ during an 8-hour recovery period following aerobic and anaerobic exercise to an equivalent 8-hour non-exercise, control period.

Methods

The subjects for this study were six males of varied physical training backgrounds (they had been

competitive runners, soccer players and tennis players at the club level as youth). Currently, all subjects exercised similarly on a recreational basis 3 to 5 times a week for approximately 30–60 min *per* session and had done so for several years. Each subject signed an informed consent prior to participation in the study. The physical characteristics of the subjects (mean \pm S.E.M.) were: age = 27.1 \pm 2.5 years, height = 179.0 \pm 3.5 cm, weight = 72.5 \pm 3.1 kg. Their maximal oxygen consumption (VO_{2max}) was assessed with a standard clinical cycle ergometer protocol (VO_{2max} = 3.51 \pm 0.25 l/min or 48.8 \pm 3.4 ml/kg/min).

Each subject participated in three experimental sessions which consisted of a control aerobic, and an anaerobic session. The experimental sessions took place on separate days and the order of the sessions was assigned randomly. For each of the sessions, the subject reported to the laboratory (temperature 21 \pm 3 °C) at 0630 h in a 12-hour fasted state, and after 24 hours of abstaining from any physical or sexual activity. A catheter was inserted in a antecubital vein and the subject was allowed to rest for 30 min. Starting at 0700 h a pre-experimental session blood sample (pre) was taken, then again immediately in the postexperimental session (post) and thereafter hourly (1–8 h of recovery) until the completion of the experimental session. For the control session, the subject remained in the laboratory and rested quietly (upright position) for an hour between 0700 to 0800 h. For the aerobic session, the subject rode a cycle ergometer at 65 % of VO_{2max} for the hour between 0700 to 0800 h. Finally, for the anaerobic session, the subject performed interval training on a cycle ergometer. The intervals consisted of 2 min at 110 % of VO_{2max} followed by 2 min at 40 % of VO_{2max} . The intervals were arranged in sets of 5 with 5 min passive rest between them. The number of interval sets completed was assigned so that the total work output in kilogram-meters of the anaerobic and aerobic sessions were equated. Furthermore, the time to complete the anaerobic session was kept approximately between 0700 to 0800 h (\pm 6 min).

During the 8-hour period of recovery from the experimental sessions the subjects were allowed to perform normal duties/activities (e.g. reading, studying, working with computers) and to ambulate minimally. However, no exercise training was allowed and all activity patterns were replicated exactly for the three experimental sessions. A controlled-standardized meal was consumed by all the subjects at the same time during the 8 hours' recovery period in each of the sessions and this comprised the subject's only food intake. Water consumption was allowed *ad libitum* throughout the experimental sessions. The sessions occurred during a 5-week period and were separated by approximately 7–13 days for each subject. The three experimental sessions took place in the same season (winter) for all subjects.

All blood sampling was done with the subject in an upright position and the samples were handled with appropriate clinical laboratory procedures to ensure their reliability. Extracted serum was analyzed for total T₄ and total T₃ concentrations by radioimmunoassay procedures utilizing commercially available kits (DPC Inc., Los Angeles, CA, USA). The coefficients of variation for the within-assay and between-assay variances were less than 10 %.

For purposes of statistical analysis the data were assessed *via* two formats. First, mean hormonal concentrations at each hourly sampling (pre, post, 1–8 h) under the three experimental sessions were examined with repeated measures ANOVA. Secondly, the overall effect of the experimental sessions during the 8-hour recovery period (1 through 8 h) was examined by measuring the integrated area under the curve (AUC) of responses for the 8 hours. The integration involved hourly hormone concentrations which were plotted in a standardized fashion for each subject and these graphs were digitized for the determination of total area (Jandel Scientific Inc., Los Angeles, CA, USA). The AUC results were also examined with repeated measures ANOVA. Subsequent post-hoc testing for mean difference comparison was performed with a Fisher LSD procedure with the probability level set at $p < 0.05$ (Winer 1962).

Results

First, it should be noted that all hormonal concentrations in each of the three experimental sessions were within normal physiological ranges and comparable to the results previously obtained from these assay procedures. The hormone concentrations at pre, for total T₄ and T₃, respectively, were not significantly different in the experimental sessions. Yet, some session to session variability (see Figs 1 and 2) was observed. Therefore, the hourly hormone data were also analyzed with repeated measures ANCOVA, with the respective pre-experimental session hormone concentration serving as the covariate. The results of this analysis, however, did not change the data interpretation outcome from the ANOVA analysis.

Fig. 1 shows the results for total T₄ over the entire time period at each experimental session. Both aerobic and anaerobic exercise produced significant ($p < 0.05$) elevations in total T₄ from the control session. For the anaerobic exercise recovery hours 1 through 8 were significantly different from concentrations at comparable control times. Following aerobic exercise, the post and 1- through 8-hour recovery concentrations were all greater than the concentrations at corresponding control session times. Furthermore, the aerobic post and 1- through 6-hour recovery concentrations were greater than the concentrations at respective anaerobic session times.

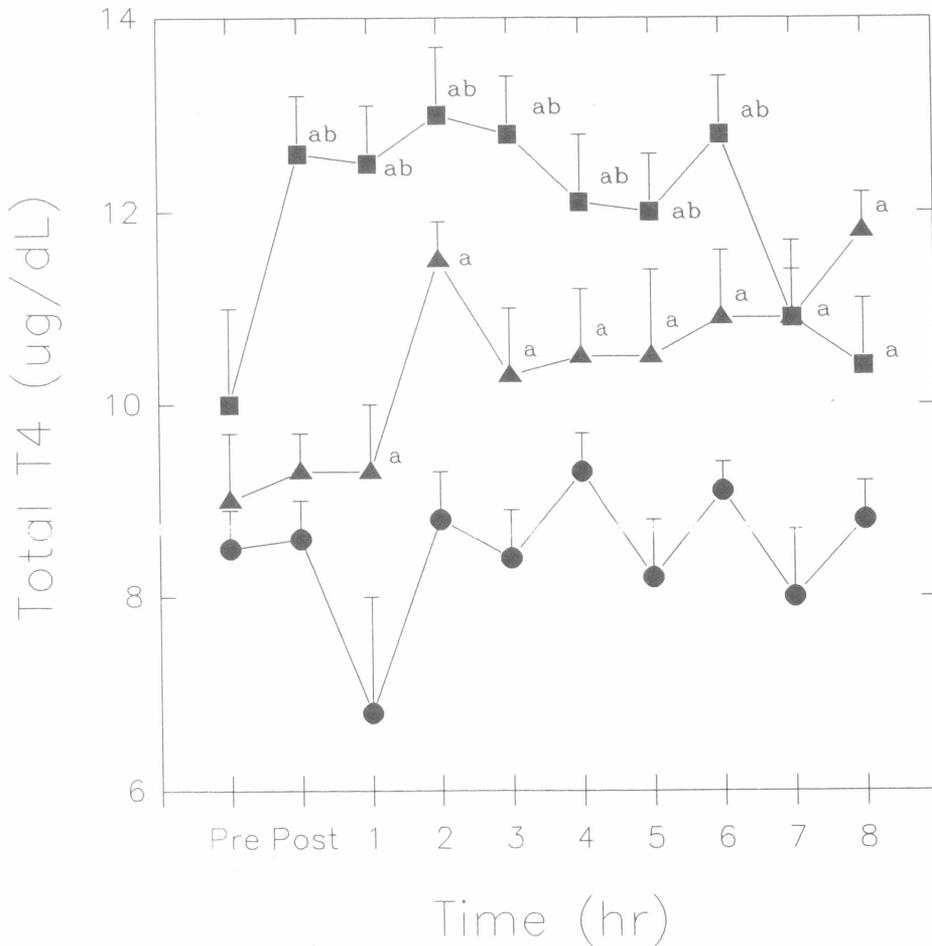


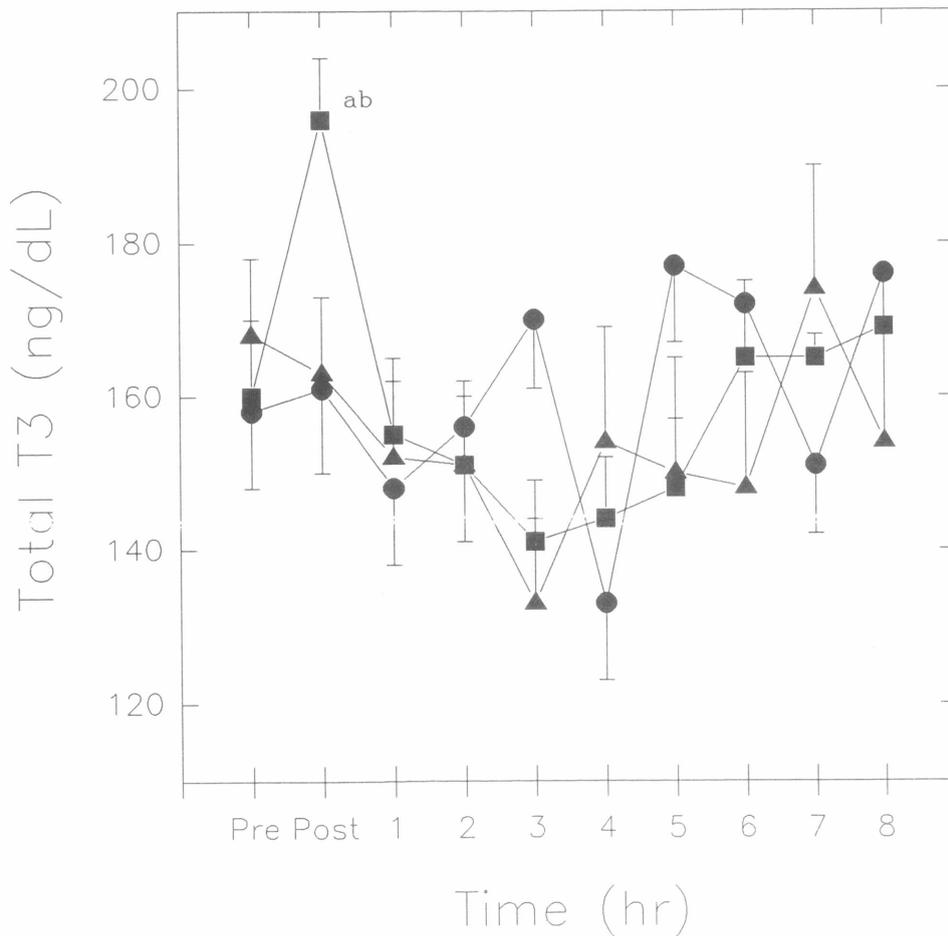
Fig. 1

Mean responses of total T₄ during the three experimental sessions. PRE and post on time axis represent the hormone concentrations immediately before and after the experimental session and the numbers 1 through 8 are the hours of recovery. Circle symbols represent controls, triangle symbols represent anaerobic exercise and square symbols represent aerobic exercise. The "a" letter denotes that the mean for anaerobic and/or aerobic exercise is significantly different from the corresponding control session mean. The "b" letter denotes that the aerobic exercise means differ from the respective anaerobic means.

When the AUC results were compared, the aerobic exercise ($98.2 \pm 7.5 \mu\text{g/dl} \times \text{h}$) and anaerobic exercise ($84.5 \pm 6.7 \mu\text{g/dl}$) were significantly greater ($p < 0.01$) than that of the control session ($67.9 \pm 5.6 \mu\text{g/dl} \times \text{h}$). The anaerobic AUC mean, however, was not statistically significant ($p > 0.05$) from the aerobic mean. Omega squared values were calculated from the AUC ANOVA results to determine the strength of association between the dependent and independent variables (Winer 1962). A moderately robust experimental effect was found to exist as $w^2 = 23.2\%$

The results for total T₃ over the entire time period for the experimental sessions are shown in Fig. 2. The aerobic exercise experimental session produced a significant ($p < 0.05$) change from the

control session in total T₃, but the anaerobic exercise had no statistical significant effect ($p > 0.05$) on the hormone concentrations. The aerobic post concentration was greater than the corresponding control and anaerobic post concentrations. No other individual hourly means during either of the exercise sessions differed from comparable control session concentrations. Furthermore, no significant ($p > 0.05$) differences were noted in the AUC total T₃ means among the experimental sessions (1287 ± 97 , 1243 ± 73 , and $1219 \pm 138 \text{ ng/dl} \times \text{h}$ for control, aerobic, and anaerobic, respectively). The omega squared showed a weak experimental effect relative to the T₃ AUC results ($w^2 < 1.0\%$).

**Fig. 2**

Mean responses of total T₃ during the three experimental sessions. For other legend see Fig. 1.

Discussion

Our purpose was to compare the daytime hourly responses of total T₄ and T₃ during an 8-hour recovery period following aerobic and anaerobic exercise to an equivalent non-exercise, control period. As noted, we found significant, persistent elevations from control levels in total T₄ following both aerobic and anaerobic exercise. In addition, we saw that total T₃ was only transiently elevated from the control following aerobic exercise but unchanged by anaerobic exercise. We feel that the present findings clearly demonstrate that exercise, aerobic and anaerobic, disrupts the daytime hourly pattern (0700 h to 1600 h) for total T₄ in the blood, but apparently has a minimal effect on total T₃. Earlier research established a similar effect of exercise on the nocturnal circadian patterns of thyroid hormones (Hackney *et al.* 1989).

The acute (pre to post) total T₃ changes observed following aerobic exercise seem to be due to

a haemoconcentration effect as the magnitude of the T₃ increase corresponded (approximately +19%) very closely with the plasma volume reductions encountered (-15 to -19%). These plasma volume shifts were estimated from the haematocrit and haemoglobin changes (method of Dill and Costill 1974), and are reported elsewhere (Hackney *et al.* 1992). The anaerobic exercise did not produce an immediate post exercise haemoconcentration effect because the subjects appeared to hydrate substantially better during this exercise session (the rest intervals between the sets facilitated water consumption). The haemoconcentration hypothesis also seems feasible because of the significant total T₄ elevation immediately (post) after the aerobic exercise. However, this explanation does not support the later persistent elevations in total T₄ following both types of exercise during the 8-hour recovery period, as during that time the plasma volume returned to pre-exercise levels. Because of the limited nature of this study's

design and the data obtained it is difficult, if not impossible, to determine the mechanism behind the T₄ changes noted. We propose that part of the total T₄ increase following both exercise sessions was due to a glucocorticoid blockade of T₄ conversion to T₃ (Schimmel and Utiger 1977), thereby maintaining a larger circulating pool of total T₄. Previously published data from this study showed that cortisol was substantially and persistently elevated following each of the exercise sessions (Hackney *et al.* 1992). It is doubtful, however, that the exercise-induced significant elevations in total T₄ from control levels were due to this proposed mechanism alone; and, other physiological events most likely contributing to these findings (e.g., alterations in thyroid hormones production/release, the target tissue metabolic clearance rate, or possibly altered hormonal binding to carrier proteins). Unfortunately we could not measure the indices of hormone turnover (production *versus* clearance) rates or hormonal binding (e.g., free fractions) in this study.

Most interesting to us was the paradoxical finding of exercise (anaerobic and aerobic) which affected total T₄ levels but not T₃ levels in the blood during the 8-hour recovery period. This finding has perplexed us and at present we are uncertain as to what is the exact physiological mechanism responsible for its occurrence. Further research work is necessary to elucidate the aspects of exercise that brought about these disparate responses in circulating thyroid hormones. We are pursuing this question at present in our laboratory.

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