Neuroendocrinology Letters No.6 December Vol.26, 2005
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ORIGINAL ARTICLE

Exercise intensity and its effects on thyroid hormones

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Submitted: May 1, 2005 *Accepted: May 13, 2005*

Key words: **exercise; thyroid hormone; thyroxine**

Neuroendocrinol Lett 2005; **26**(6):830–834 **PMID:** 16380698 NEL260605A14 © Neuroendocrinology Letters **www.nel.edu**

Abstract

BACKGROUND: Physical activity influences energy metabolism in human subjects by increasing activity-induced energy expenditure and resting metabolic rate for several hours after exercise. Effects of exercise on circulating thyroid hormone values remain controversial. We have investigated the effect of acute aerobic exercise on thyroid hormone values.
MATERIALS/METHODS: The effect of different intensity levels of acute aerobic exercise on thyroid hormones was investigated in 60 male well-trained athletes by performing bicycle ergometer at 45% (low intensity), 70% (moderate intensity), and 90% (high intensity). These intensities were selected according to their maximum heart rate (MHR). At each intensity level, heart rate, blood lactic acid, serum total thyroxine (T4), free thyroxine (fT4), total triiodothyronine (T3), free triiodothyronine (fT3) and thyroid stimulating hormone (TSH) values were measured.
RESULTS: The results of this study show that exercise performed at the anaerobic threshold (70% of maximum heart rate, lactate level 4.59 ± 1.75 mmol/l) caused the most prominent changes in the amount of any hormone values. While the rate of T4, fT4, and TSH continued to rise at 90% of maximum heart rate, the rate of T3 and fT3 started to fall.
CONCLUSIONS: Maximal aerobic exercise greatly affects the level of circulating thyroid hormones.

Introduction

It is a well-known fact that exercise affects the activity of many glands and the production of their hormones. One of the glands affected is the thyroid. Thyroid gland secretes two separate amino acid-iodine bound thyroid hormones known as 3-5-3’ triiodothyronine (T3) and 3-5-3’-5’ tetraiodothyronine (T4, thyroxine) both of which are also found in the free form (fT4, fT3), whose importance on the regulation of general metabolism, growth, and tissue differentiation as well as gene expression has been known for a long time [7, 22]. It is also known that thyroid hormones act in fatty acid oxidation and thermoregulation [9]. Thyrotropin-releasing hormone (TRH) secreted from hypothalamus stimulates anterior pituitary to release thyrotropin (TSH, thyroid stimulating hormone) [9]. When exercise is repeated at certain intervals, there is a pituitary-thyroid reaction that is properly coordinated by increasing turnover of thyroid hormones [3]. When thyroxine turnover and related hormonal action is increased, this would lead to hyperthyroidism [9, 10]. However, there is no evidence that such a case occurs in trained athletes. For example, in trained athletes the difference between basal metabolic rate and body temperature is rarely abnormal [9]. Thus, it appears that an increase in thyroxine turnover, which occurs with physical training, may have a different mechanism [10, 14].

Training disturbs the athletes' energy homeostasis in an attempt to invoke beneficial adaptations. At the same time, body weight and food intake controlling systems send the signal to save energy. Ignoring this process can result in overtraining and a reduced sensitivity to anabolic hormones and other endocrine signaling [10, 20, 21].

Research on marathon training women brings out very interesting results about thyroid turnover. When a relatively sedentary person starts to train and increases training to 48 km/week – a moderate thyroid disorder develops reflected by increasing T3 and T4 levels [21].

The purpose of this study is to uncover the acute effect of increasing metabolic activity through exercise on thyroid hormones, if an effect is observed – to see whether it is related to the intensity of exercise and which of the thyroid hormones are more intensely affected.

Methods

The ethical consent to study on human subjects was provided by The Ethical Committee of Marmara University according to The Declaration of Helsinki.

Subjects.

Sixty healthy and well-trained male athletes participated in this study. Their ages were between 20–26 (23 ± 3) years; average heights were 176 ± 7,7 cm, and weights were 72 ± 7,8 kg. All subjects were informed about the purpose and procedures of the study.

All subjects were volunteers and selected randomly. They had a medical examination and completed a health status questionnaire.

Study Design.

A total of 9 minutes of exercise was applied to the subjects with a gradually increasing intensity every 3 minutes. Each subject performed in different intensities using bicycle ergometer at the 45%, 70%, and 90%. These rates were calculated of maximum heart rates (MHR). Carvonen method was used for selecting intensity of exercises [1].

Capillary blood was taken from the ear lobe for determination of lactate at the ergometer tests and during the training cycle.

Laboratory analysis.

At the end of each three minutes, they were interrupted for 30 seconds and blood samples were taken. From the blood samples, lactate (Boehringer

Table 1: Values during low, moderate and high exercise intensities (at 45%, 70%, 90% of maximum heart rates)

	Euthyroid adult values*	Percentage of maximum heart rate (Mean value ± standard deviation) 45%	70%	90%
Lactate (mmol/l)		2.86 ± 0.658	4.59 ± 1.75	8.25 ± 2.74
TSH (μIU/ml)	0.5–8.9	1.69 ± 0.55	1.78 ± 0.60	1.89 ± 0.74
T3 (ng/ml)	0.8–2.1	1.47 ± 0.23	1.78 ± 0.42	1.48 ± 0.26
Free T3 (pmol/l)	3.4–7.2	5.30 ± 1.20	6.46 ± 1.62	6.17 ± 1.29
T4 (ng/ml)	42–120	71.10 ± 19.02	84.35 ± 24.86	86.35 ± 28.36
Free T4 (pmol/l)	11–24	16.97 ± 3.86	19.49 ± 3.82	20.16 ± 4.80

* Reference values of kits

Table 2: P-values of thyroid hormones changes in different exercise intensities

	45%–70% of max heart rate	45%–90% of max heart rate	70%–90% of max heart rate
TSH (μIU/ml)	0.200	0.045*	0.204
T3 (ng/ml)	0.025*	0.086	0.021*
Free T3 (pmol/l)	0.047*	0.063	0.038
T4 (ng/ml)	0.012*	0.008*	0.049
Free T4 (pmol/l)	0.023*	0.027*	0.311

Mannheim lactate kit, Boehringer Mannheim 4010 spectrophotometer), T4 (Diatech Diagnostic enzyme immunoassay test kit), T3 (Diatech Diagnostic enzyme immunoassay test kit), free T4 (Amerlex brand RIA kit), free T3 (Amerlex brand RIA kit), and TSH (Biodata Diagnostic brand RIA kit) values were measured.

Statistical analysis.
Differences between values at different time points were tested with one-way ANOVA and Tukey HSD. The assumed level of significance for differences was equal to or less than 0.05 for all tests.

Results

In this study, hormone values at all heart rate categories were compatible with the values of healthy and euthyroid adults (Table 1). In all hormones, with the exception of TSH, the maximum rate of increase was observed at the anaerobic threshold level (70% of maximum heart rate, lactate level 4.59 ± 1.75 mmol/l). The rate of increase of TSH was similar, going from 45% to 70% and from 70% to 90% of MHR (Fig. 1). The increase in TSH level going from 45% to 90% of MHR was statistically significant (Table 2). T4, fT4 continued to increase, going from 70% to 90% of MHR and this rise was statistically significant when compared to the values seen at 45% MHR, but T3 and fT3 began to decrease and for T3 almost to the same level as was seen at the 45% of the MHR (Fig. 2, Fig. 3, Table 2).

Discussion

Some studies performed on animals show that thyroid hormones regulate the transcription of several genes expressed in skeletal muscle, such as the gene coding for Type I myosin heavy-chain (MHC), actin and the sarcoplasmic reticulum (SR) Ca21 ATPase pump [7, 8,11, 18]. Therefore, hypothyroidism and hyperthyroidism states might respectively reduce and increase Ca^{+2} uptakes by the SR [4, 5, 8]. As a result of the effects of thyroid hormones on MHC expression and Ca^{+2} uptake mechanisms, the shortening velocity of skeletal muscles increases with increasing thyroid levels [11]. On the other hand, the slow fibers exhibit a greater sensitivity to thyroid hormones than the fast

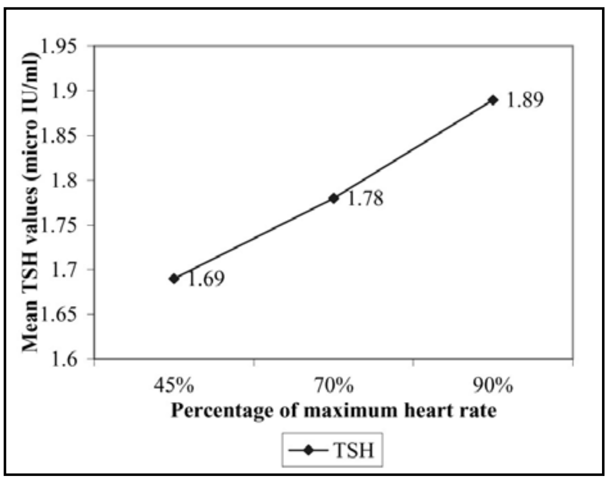

Fig. 1. Change in TSH values with exercise intensity

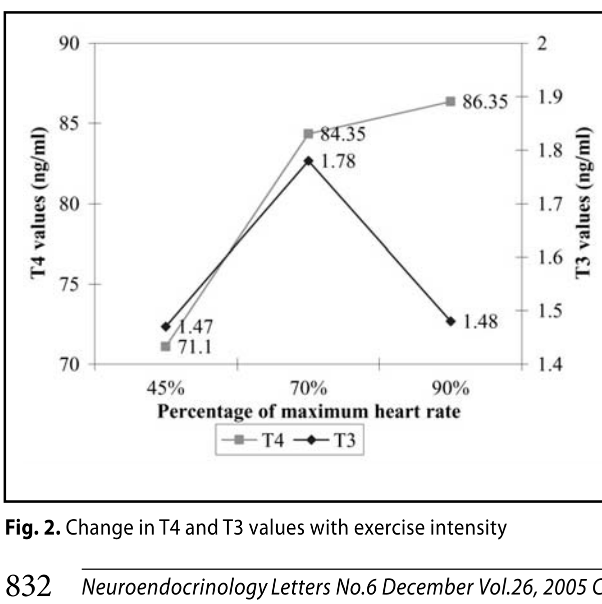

Fig. 2. Change in T4 and T3 values with exercise intensity

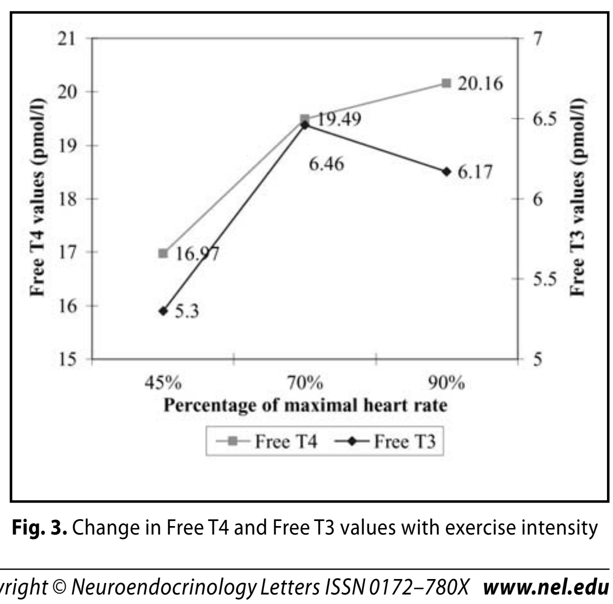

Fig. 3. Change in Free T4 and Free T3 values with exercise intensity

ones. Within physiological limits, increased thyroid activity might be associated with a higher efficiency of the mechanical work performed by exercising muscles [9, 16].

Peripheral metabolism of thyroid hormones can be changed significantly by a number of physiological and pathological conditions, which can alter the deiodination pathway and lead to a change in the circulating level of thyroid hormones. The biological effects of short-term changes in the thyroid hormone levels are not currently completely understood but are potentially important in the body's adjustment to stressful or catabolic states [17]. Compelling evidence also suggests that, if exercise-related energy expenditure exceeds calories consumed, a low T3 syndrome may be induced. In female athletes, four days of low energy availability reduced T3, fT3, increased rT3, and slightly increased T4. Since an adequate amount of the prohormone T4 was available throughout the study, an alteration in the peripheral metabolism of T4 was likely. The increase in rT3 and decrease in T3 are consistent with a decreased activity of hepatic 5'-deiodinase activity, since this enzyme is responsible for the production of T3 and the clearance of rT3. These alterations in thyroid hormones could be prevented solely by increasing dietary caloric consumption without any alteration in the quantity or intensity of exercise [2, 15].

While the role of a hypo caloric diet in producing alterations in thyroid hormones has been demonstrated in several studies, the role of exercise in thyroid hormone metabolism is not very clear. A connection is established between increasing training to 80 km/week and elevated hormone levels [10, 16]. In another study looking at men with six months of endurance training, while T4 and free T4 concentrations reduced a little, no change in thyrotropin was observed [16]. Koistinen *et al.*'s study on unacclimatized top class skiers showed that training at moderate altitude for 12 days resulted in a significant decrease in serum total T3 levels and an increase in fT3 levels with no significant change in TSH, T4, fT4 and reverse T3 (rT3) [14]. Another study done by Deligiannis *et. al.* looking at the thyroid hormone response to swimming for 30 minutes at varying water temperatures showed that TSH and fT4 levels were significantly increased at 20°C as compared to 32°C but no significant effect was seen on T3 [6]. Pakerinen *et. al.* study on the effects of one week of very intense strength training on the thyroid hormones of male weight lifters showed a significant decrease in TSH, T3 and T4 with unchanged fT4, rT3 and thyroid binding globulin (TBG) [19]. Baylor *et al* revealed that over trained athletes show an impaired hormonal response to insulin-induced hypoglycemia with recovery after 4 weeks of rest indicating a hypothalamic dysfunction [2]. In a different study, untrained subjects experienced reductions in cortisol and rT3 and an increase in T3 after exercise. However, trained subjects had an increase in cortisol and rT3 and a decrease in T3 with exercise. Concentration of T4 was unchanged in both groups [6,19]. The confounding results of thyroid hormone levels seen following exercise might be mediated by elevated cortisol levels however; additional research is required to establish this connection.

José L. *et al.*, examined the thyroid hormone levels of professional cyclists during a 3-week stage competition, they concluded that serum T4, FT4 and FT3 levels showed a significant increase by the last week of competition while concentrations of TSH and T3 remained unchanged [13].

Zarzeczny R, *et al.*, studied **e**ffects of thyroid hormone deficit, and triodothyronine (T3) treatment on exercise performance, blood lactate (LA) concentrations and LA threshold (TLA) were studied in trained and untrained rats. They found that T3 treatment markedly increases maximal and submaximal LA levels. This shows some similarities with our studies results [23].

This current study shows that as compared to the thyroid hormone values during low-intensity exercise (45% max. heart rate), there is an increase in TSH values at moderate intensity (70% max. heart rate) and high intensity exercise levels (90% max. heart rate). An increase then a decrease is seen in T3 and fT3 levels at moderate and high intensity exercise conditions respectively and an increase in fT4 and T4 values in moderate intensity with continued increase at high intensity levels. These results partially agree with Schmid *et al* findings of continuous TSH increase until 15 minutes after the end of a sub maximal exercise period with an unchanged or slightly decreased T3, rT3 and fT4 [21]. A possible cause for the increase of TSH levels may be due to pituitary secretion and may serve to fulfill the exercise induced increase in peripheral need for thyroid hormones [12]. But it should be kept in mind that in the current study all the observed changes are within the euthyroid levels and could be realized as a minor physiological response within normal levels. As a conclusion it can be said that a rise in cell metabolism and changes in the internal medium of the organism serves to change the thyroid hormone levels. Thyroid function depends to a certain degree on the exercise intensity and perhaps to other factors such as specific characteristics of the athletes.

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