INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 4, No. 1, p. 331-339, 2014

RESEARCH PAPER OPEN ACCESS

The acute and chronic effects of continuous and alternative resistance trainings on T3, T4 and TSH serum concentration of active young women

Mohammad Hassan Boostani[1*], Saeed Khatamsaz[2], Mohammad Ali Kohanpour[3], Mohammad Ali Boostani[4]

[1] *Young Researchers and Elites Club, Zarghan Branch, Islamic Azad University, Zarghan, Iran*
[2] *Zarghan Branch, Islamic Azad University, Zarghan, Iran*
[3] *Central Tehran Branch,Young Researchers and Elites Club, Islamic Azad University, Tehran, Iran*
[4] *Zarghan Branch, Islamic Azad University, Zarghan, Iran*

Key words: T4, T3, TSH, continuous and intermittent resistance trainings, resistance exercise.

http://dx.doi.org/10.12692/ijb/4.1.331-339 Article published on January 11, 2014

Abstract

Due to researches shortages about effects of various kinds of resistance trainings on acute and chronic responses of thyroid hormones, the purpose of the present study was comparison of acute and chronic influences of continuous and intermittent resistance trainings on T3, T4 and TSH serums levels of active young women. So, 21 subjects were randomly divided to three continuous resistance training, intermittent resistance training and control groups, and investigated. Two experimental groups participated in 8 weeks progressive continuous and intermittent resistance trainings. Before, immediately then and 2 hrs after first test (48 hr before trainings beginning) blood samples were taken from the subjects. The control group gave blood samples, only at the beginning and ending of the 8 weeks period. In order to investigate variations of under study variant in both continuous and intermittent groups, variance analysis test with repeated measurements was implemented. Considering to the presence of the control group, and in order to compare between the continuous and intermittent training groups, one-way analysis f variance test (ANOVA) was used, at the stage of before activity, and to investigate data at the stages of immediately then and 2 hrs after activity, T-test was utilized. There wasn't observed any significant difference between the continuous and intermittent resistance training groups, among the levels of T3, T4 and TSH serums, in response to one turn resistance exercise, before and after 8 weeks trainings ($P>0.05$). Also, levels of T3, T4 and TSH serums hadn't any significant change neither in continuous nor in intermittent resistance training group, during the research period ($P>0.05$). These results indicate a progressive resistance trainings period, similar to the training protocol of the present study, wouldn't cause any significant metabolic variation in active young women. Also, these results show that this nonbeing significant variation hasn't any relation to whether the resistance exercise is continuous or intermittent.

* **Corresponding Author:** Mohammad Hassan Boostani ✉ boostani_mh@yahoo.com

Introduction

It's certain that physical activity affects on various body systems and causes adaptation of these systems with particular requirements of organism during physical activity and work. Among, the knowledge of these effects and also their controlling mechanism are important to design and set training schedules of sport activity types. Also, because of stressful essences, sport activities and competitions, beside their useful profits, leads to disturb homeostasis temporarily, which might be accompanied with destructive consequences, if training science fundamentals aren't abided (Boostani *et al.*, 2013).

Thyroid gland secrets two major hormones, named Tetraiodothyronine or the same Thyroxine (T4) and Triiodothyronine (T3). Both of these hormones cause increase in metabolism speed and are vital in aspect of performance although, they're different in aspects of speed and intensity of influence. These two hormones are essential for evolution and natural performance of brain and neural system, and preservation of body temperature and energy. Increase in basic metabolism of body is assumed as one of important biological tasks of this vital gland, in a manner that total lack of thyroid secretion could cause 40-50% decrease in basic metabolism and excess of secretion of this gland might lead to around 60-100% increase in metabolism (Peeri *et al.*, 2013). The secretions from this gland are mostly set by thyroid stimulating hormone (TSH) or thyrotropin, which secretes from frontal pituitary. Also, TSH is set by thyrotropin releasing hormone or TRH which secretes from hypothalamus. The axis to axis of hypothalamus-hypophyse-thyroid is famous and activity of thyroid gland is regulated under influence of hypothalamus-hypophyse-thyroid (HPT) axis (Yen, 2001). This axis is influenced by many parameters like; environment temperature, stress, other hormones, chemical compositions and day and night fluctuations. In addition, it seems other physical parameters like physical trainings challenge the above mentioned axis and might cause to regulating changes to preserve its homeostase. One of the under discussion problems in sport physiology is effect of physical training on HPT axis generally and on thyroid gland particularly (Yen, 2001).

Physical training is a stressful situation which challenges body homeostase in a manner that enforces body to retrieve a new dynamic balance in order to minimize cells damages. One of the systems which influenced by physical activity is axis of hypothalamus-hypophyse-thyroid (Fortunato *et al.*, 2008). The metabolic requirement increases during training and higher temperature is set by mechanisms which activated to distribute heat like veins expansions (Fortunato *et al.*, 2008). The axis of hypothalamus-hypophyse-thyroid is affected by intense sport, but resulting mechanisms from variations of thyroid performance after sport, should be required more attentions (Yen, 2001). Sport is a kind of physical stress that occur some changes of endocrine glands following it, to balance its influences on heat releasing and body metabolism (Mastorakos and Pavlatou, 2005). There're different ideas about effect of sport on thyroid performance and it appears, these differences depend on intensity and span of training protocol (Rone *et al.*, 1992). Attention to physical activities and sport, has became to an unavoidable affair. This attention exists in the whole grades of society and with different targets.

Physical activity and sport accompany with physiologic consistencies. Knowledge and investigation of these consistencies, especially in hormonal systems, which have prominent roles in vital reactions of body, is very important and noticeable, because by doing these activities and various sport trainings, hormones involved different changes. Recognition of these variations is effective in interpretation of physiologic mechanisms of body (Peeri *et al.*, 2013).

In the other hand, resisting trainings have been noticed in the aim of fitness by many persons, especially women, recently. These trainings, which contain various types, lead to structural changes and physiologic consistencies, which the most manifest of these matters, could appear in muscular, neural and hormonal systems (Peeri *et al.*, 2013).

Measurement of biochemical and hormonal variables, following various training schedules, could aid better understanding in acute and chronic effects of resisting trainings. Pakarinen *et al.*, (1988) showed nonbeing change of T3 and also significant decrease in thyroxine (T4) and free thyroxine (fT4). Simsch *et al.*, (2002) reported decrease in free T3 and thyroid stimulating hormone (TSH) in company with nonbeing variation of thyroxine (T4) after resisting trainings. Pakarinen *et al.*, (1988) reported significant decreases in T3, T4 and TSH, during one week intense resisting trainings (2 daily sessions) in professional weight lifters. Alen *et al.*, (1993) reported significant decreases in T3, T4 and TSH, during one week intense resisting trainings (2 daily sessions) in professional weight lifters. However, during 1 year trainings periods of athletes, nonbeing changes of the whole thyroid hormones were observed, until the period of before competition. In a manner that mass of training decreased, when significant increase in free T4 and free T3 have been reported. It's appeared, resisting training probably change thyroid performance, although intensities of these variations remain as a matter of thought in the present time. Also, because of accurate control of homeostase on thyroid hormones, no increment during resisting training is expected.

Reviewing the literature shows, few researches have done about effect of resisting trainings on thyroid hormones. Also, incongruous results are seemed in these few studies. Notice to importance and role of thyroid hormones in metabolism during and after trainings and physical activities, vast concerning researches are required to erase existing ambiguities. The purpose of the present study was determination of acute and chronic effects of continuous and alternative resistance trainings on levels of T3, T4 and TSH serums of active young women.

Material and methods

Subjects

The statistical society of this study consisted of the whole active student girls of Tehran city. Fourteen 20-25 years old girls of Tehran city with averages age of 22.571±1.804 years old, 161.19±4.094 cm height, 56.904±6.533 kg weight, maximal oxygen consuming of 38.428±1.567 (ml/kg (body weight)/min) and body mass index (BMI) of 21.879±1.999 kg/height^2 declared their readiness to participate in research, following the announcement. They were purposefully chosen and divided to 2 groups including an alternative resisting training group (7 persons) and a control group (7 persons), randomly. All of the subjects had perfect physical healthiness (physician approval).

Data collecting method

One week before research execution, the subjects became familiar with training protocol and method of study in explanation meeting. In this session, besides making familiar the subjects with resisting movements, characteristics of heights, weights, body mass indices (BMI), maximal oxygen consuming and also maximal power (IRM) for each movement were measured. Then, 48 hr before trainings beginning, the subjects attended in test session and before, immediately after and 2 hr after an alternative resisting activity, bloods samples were taken. This session conducted with 20% intensity of a maximal repetition. Thereafter, the subjects did increasingly their training schedule in span of 8 weeks.

Control group didn't perform any training and only carried out their natural daily activities. After ending of 8 weeks trainings and after 48 hr rest, proportional to rest interval between the first samples collecting day and trainings beginning (48 hr), last session of resisting training activity conducted just like the first day with the same 20% intensity of a maximal repetition. Before, immediately then and 48 hr after this session bloods samples were taken, too.

Trainings schedule

Resisting trainings were in increasing manner and consisted of 8 weeks (3 days weekly (1 day on/1 day off)). A percentage of a maximal repetition and execution speed considered as intensity and mass of trainings. Training masses were kept constant and intensities of trainings increased in an increasing manner. The implemented increasing overload was in a manner that the subjects performed their trainings with 20, 25, 30, 35, 40, 45, 50 and 55 percents of a maximal repetition from the first week to eighth one, during these eight weeks, respectively.

Resisting trainings were designed in circular forms and alternative schemes. Each circle contained chest press, feet press, fore-arms, fore-feet, rear-arms, rear-feet and sidelong tension (or length), which order of movements execution was in the same way, too. Span of each station considered as 2 min 30 sec. The alternative training group was executing 10 sec of each station with speed of 2V and 20 sec of it with speed of V, until 2 min 30 sec of each station finished. Speeds of movements were controlled by metronome. Relaxation interval between 2 successive stations was 1 min and between 2 circles was 2 min. In each training session, 2 circles were considered. Resisting activities also performed with 20% of a maximal repetition, before and after trainings period which counted as test and samples collecting sessions.

Each person started and finished her entire activity session at particular times which were the same for her, during the whole training sessions. The subjects of control group didn't carry out any sport and physical training during activities period of the research and performed their daily usual activities.

Bloods samples collecting and hormonal analysis

Before, immediately then and 2 hr after the first test (48 hr before trainings beginning) and the final one (48 hr after trainings ending) bloods sample we taken from middle veins of the subjects in amounts of 5 cc. The control group only gave bloods samples at the beginning and ending of 8 weeks period (companion with experimental group). Serums of collected samples were separated from plasma by centrifuge pump in duration of 10 min and with revolution of 3500 RPM. All of bloods samples had been preserved in frozen condition and at -20°C temperature until arrived to laboratory and there, lab examination started, immediately. For each sample, T3 serum was measured by immunochemiluminescence assay and using T3 kit of Auto bio Diagnostic Co. with sensitivity of 0.4 (*ngr/ml*), T4 serum was gauged by immunochemiluminescence assay utilizing T4 kit utilizing T4 kit of Auto bio Diagnostic Co. with sensitivity of 0.2 (*μgr/dl*) and TSH serum was measured by immunochemiluminescence assay using TSH kit of Auto bio Diagnostic Co. with sensitivity of 0.08 (*μIU/ml*).

Statistical method

At first, values of under study variables at each samples collecting time were described by average and standard deviations. Then, in order to determine naturality of distribution, Smirnov-Kolmogorov test was used. In order to investigate changes of under study variants in control group, variance analysis test with repeated measurement and Fisher's LSD test were utilized.

Also, Sphericity of data was also investigated simultaneously with execution of variance analysis test, to carry out Greenhouse-Giggs modification on degree of freedom, in necessary cases. Also, in order to investigate variations of control group, T paired test was used. To compare hormones relaxation levels between the training and control groups, independent T test was utilized, too. Level of significance considered as 0.05 for all of statistical tests. And, the statistical software SPSS v.16 was used for performing statistical calculations.

Results

Table 1 presents the statistical results of independent one-way analysis of variance test (ANOVA), which had compared relaxation levels of under study variables between the three groups of continuous resistance training, intermittent resistance training and control, before and after the trainings period.

Table 2 represents results of Tukey's post-hoc test, related to observed significant difference of after exercise relaxation levels, from the independent one-way analysis of variance (ANOVA) (table 1).

Table 3 shows results of T-test, which compared after exercise values of under study variants, between the two continuous and intermittent training groups, before and after the training period.

Table 1. Statistical results of independent one-way analysis of variance (ANOVA) to compare relaxation levels of under study variables between the 3 groups.

Variables	Time of Sampling		Sum of Squares	df	Mean Square	F	P
TSH	Before Training	Between Groups	6.57	2	3.28	2.40	0.11
		Within Groups	24.59	18	1.36		
		Total	31.17	20			
	After Training	Between Groups	10.36	2	5.18	5.08	0.01 *
		Within Groups	18.34	18	1.01		
		Total	28.71	20			
T4	Before Training	Between Groups	205.12	2	102.56	13.87	0.000 *
		Within Groups	133.06	18	7.39		
		Total	338.18	20			
	After Training	Between Groups	170.98	2	85.49	6.43	0.008 *
		Within Groups	239.31	18	13.29		
		Total	410.29	20			
T3	Before Training	Between Groups	0.18	2	0.09	0.52	0.59
		Within Groups	3.22	18	0.17		
		Total	3.41	20			
	After Training	Between Groups	0.51	2	0.25	1.75	0.20
		Within Groups	2.63	18	0.14		
		Total	3.14	20			

*The mean difference is significant at the 0.05 level.

Table 2. Results of Tukey's post-hoc test, related to observed significant difference of after exercise relaxation levels, from the independent one-way analysis of variance (ANOVA).

Variables	Time of Sampling	Comparison of Between Groups	Mean Difference	Std. Error	P
TSH	Before Training	Continuous Groups - Intermittent Groups	-	-	-
		Continuous Groups - Control Groups	-	-	-
		Intermittent Groups - Control Groups	-	-	-
	After Training	Continuous Groups - Intermittent Groups	0.29	0.53	0.85
		Continuous Groups - Control Groups	1.32	0.53	0.06 *
		Intermittent Groups - Control Groups	1.61	0.53	0.02 *
T4	Before Training	Continuous Groups - Intermittent Groups	1.03	1.45	0.76
		Continuous Groups - Control Groups	6.05	1.45	0.002 *
		Intermittent Groups - Control Groups	7.08	1.45	0.000 *
	After Training	Continuous Groups - Intermittent Groups	1.46	1.94	0.73
		Continuous Groups - Control Groups	5.18	1.94	0.04 *
		Intermittent Groups - Control Groups	6.65	1.94	0.008 *
T3	Before Training	Continuous Groups - Intermittent Groups	-	-	-
		Continuous Groups - Control Groups	-	-	-
		Intermittent Groups - Control Groups	-	-	-
	After Training	Continuous Groups - Intermittent Groups	-	-	-
		Continuous Groups - Control Groups	-	-	-
		Intermittent Groups - Control Groups	-	-	-

*The mean difference is significant at the 0.05 level.

Table 4 indicates variance analysis test with repeated measurements that has investigated variations of under study variables, in the two training groups. Table 5 presented results of T-test, which have investigated changes of the control group, in duration of 8 weeks.

The difference in relaxation levels of TSH serum concentrations, between the continuous and intermittent resistance training groups, before and after the 8 weeks trainings, wasn't significant. Also, there wasn't observed any significant difference between TSH serum values, in responses to the two types of continuous and intermittent resistance exercises, before and after 8 weeks resistance trainings (P>0.05). Levels of TSH serum hadn't any significant change, neither in continuous nor in intermittent group, during the study period (P>0.05). There wasn't observed any significant difference in relaxation levels of T4 serum, between the continuous and intermittent resistance training groups, after 8 weeks trainings (P>0.05). Also, there wasn't observed any significant difference between T4 serum values, in responses to the two types of continuous and intermittent resistance exercises, before and after 8 weeks resistance trainings (P>0.05). Levels of T4 serum hadn't any significant change, neither in the continuous nor in the intermittent resistance training group, during the research period (P>0.05).

Table 3. Statistical results of T-test to compare after exercise values of under study variant between 2 training groups.

Variables	Time of Training	Time of Exercise	T	df	P
TSH	Before Training	Immediately After Exercise	0.22	12	0.82
		One Hours After Exercise	0.18	12	0.85
	After Training	Immediately After Exercise	0.65	12	0.52
		One Hours After Exercise	0.35	12	0.72
T4	Before Training	Immediately After Exercise	1.41	12	0.18
		One Hours After Exercise	1.47	12	0.16
	After Training	Immediately After Exercise	1.41	12	0.18
		One Hours After Exercise	1.47	12	0.16
T3	Before Training	Immediately After Exercise	1.39	12	0.18
		One Hours After Exercise	1.04	12	0.31
	After Training	Immediately After Exercise	0.21	12	0.83
		One Hours After Exercise	0.05	12	0.96

About relaxation levels of T3, the differences weren't significant among the three groups, before and after 8 weeks trainings (P>0.05). Also, there wasn't observed any significant variation between T3 serum values, in responses to the two types of continuous and intermittent resistance exercises, before and after 8 weeks trainings (P>0.05). Levels of T3 serum hadn't any significant variation, neither in the continuous nor in the intermittent resistance training group, in duration of the research period (P>0.05).

Table 4. Statistical results of variance analysis test with repeated measurements to investigate variations of under study variables in the 2 training group.

Group	Variables	Sum of Squares	df	Mean Squares	F	P
Continuous Groups	TSH	1.23	5	0.24	1.71	0.16
	T4	19.58	5	3.91	1.10	0.37
	T3	0.25	1.91	0.13	0.67	0.52
Intermittent Groups	TSH	2.04	5	0.40	1.75	0.15
	T4	3.06	2.12	1.44	0.15	0.86
	T3	27.14	1.02	26.45	1.59	0.25

*The mean difference is significant at the 0.05 level.

Discussion

According to understanding of the present study, the difference of relaxation levels of TSH serum concentrations between continuous and intermittent training groups wasn't significant, after the trainings period. Also, there wasn't observed any significant difference between TSH serum values, in responses to the two types of continuous and intermittent resistance activities, after a trainings period. In addition, there wasn't seen any significant difference between TSH serum values, in responses to the two types of continuous and intermittent resistance activities, before beginning of the trainings period.

Table 5. Statistical results of T-test related to changes of the control group during 8 weeks.

Variables	T	df	P
TSH	1.20	6	0.27
T4	0.90	6	0.40
T3	0.45	6	0.66

Pakarinen *et al.*, (1991) reported significant decrease in TSH during one week intense resisting trainings (2 daily working sessions) in professional weight lifter. Alen *et al.*, (1993) reported significant TSH during one week resisting trainings (2 daily working sessions) in professional weight lifters, too. However, in one year trainings periods of athletes, nonbeing change of the whole thyroid hormones and also TSH observed until the period of before competition. It has appeared that resisting trainings probably change thyroid performance, but intensities of these variations remain as a matter of thought at the present time. Because of accurate control of homeostase on thyroid hormones, the increment during resisting training isn't expectable. Lack of compliance of the present founds (nonbeing change of TSH) and previous understandings (decrease in TSH) maybe hidden in various training protocols or durations of trainings. About inconsistency of understandings, the differences in under study societies shouldn't be ignored. Also, according to understandings of the present study, concentration of TSH serum hadn't any significant change, following an activity session before period of trainings.

Based on founds of the present research, the differences in relaxation levels of T4 serum between the three groups were significant, after the trainings period. But, the difference wasn't significant, between the continuous and intermittent groups. Also, there wasn't observed any significant difference between T4 serum values, in response to the types of continuous and intermittent resistance activities, after a period of resistance trainings. In addition, there wasn't seen any significant difference between T4 serum values, in responses to the two types of continuous and intermittent resistance activities, before beginning of the trainings period.

They reported this decrease during one week intense resisting trainings (2 daily working sessions) in professional weight lifters (Pakarinen *et al.*, 1988). But, Simsch *et al.*, (2002), in consistent understandings with founds of the present study, reported nonbeing change of thyroxine (T4) after resisting trainings. Though, Alen *et al.*, (1993) reported significant decrease in T4 during one week intense resisting trainings (2 daily working sessions) in professional weight lifters. However, nonbeing changes of the whole thyroid hormones, during one year periods of athletes' trainings, were observed in their study, until the period of before competition. In a manner that masses of trainings were decreased when significant increase was observed in fT4.

Based on understanding of the present study, the differences in T3 serum between the three groups weren't significant, after the trainings period. Also, there wasn't observed any significant difference T3 serums values, in responses to the two types of continuous and intermittent activities, after a resistance trainings period. In addition, there wasn't seen any significant difference in T3 serum values, in responses to the types of continuous and intermittent resistance activities, before beginning of the trainings period.

Simsch *et al.*, (2002) reported decrease in free T3 after resisting trainings, Also, Alen *et al.*, (1993) reported significant reduction of T3, in understandings which are opposed to the present ones, during one week intense resisting trainings (2 daily working sessions) in professional weight lifters. However, the lack of change in the whole thyroid hormones, during one year period of athletes' trainings was observed in their study, until the period of before competition. In a manner that mass of training decreased when significant increase was observed in free T3.

Conclusion

According to the understandings of the present study, it's concluded 8 weeks progressive continuous and intermittent resistance trainings would cause any significant change in active young women's levels of T4, T3 and TSH serums. In the other hand, it was determined in comparison between continuous and intermittent resistance exercises, the most important aim of the present study, there wasn't any difference between continuous and intermittent types, about the mentioned outcome of resulting from resistance trainings. These results show a progressive resistance trainings period, similar to the implemented training protocol of the present study, wouldn't cause any metabolic variation, among active young women. Also, these results indicate that this nonbeing significant change hasn't any relation whether the exercise is continuous or intermittent. It's recommended, duration of study should increase in another similar research, and further long term consistencies, which are obtained from continuous and intermittent exercise, should compare to each other.

References

Alen M, Pakarinen A, H¨akkinen K. 1993. Effects of prolonged training on serum thyrotropin and thyroid hormones in elite strength athletes. Journal of Sports Sciences **11,** 493-497. http://dx.doi.org/10.1080/02640419308730018

Boostani MH, Peeri M, Kohanpour MA, Barzegaran M, Boostani MA, Zare AH. 2013. Effect of eight weeks alternative resisting trainings on relaxation levels and responses of active young women's thyroid hormones to one turn sport. Advances in Environmental Biology **7(5),** 829-834.

Boyden TW, Pamenter TC, Rotkis RW, Stanforth P, Wilmore JHH. 1982. Evidence for mild thyroidal impairment in women undergoing endurance training. The Journal of Clinical Endocrinology & Metabolism **54,** 53-56. http://dx.doi.org/10.1210/jcem-54-1-53

Fortunato RS, Lea˜o Igna´cio D , lvaro Souto Padron A, Pec¸anha R, Marassi MP, Rosenthal D, Joa˜o Pedro Saar Werneck-de-Castro, Carvalho DP. 2008. The effect of acute exercise session on thyroid hormone economy in rats. Journal of Endocrinology **198,** 347–353. http://dx.doi.org/10.1677/JOE-08-0174

Hackney AC, Hodgdon JA, Hesslink RJ, Trygg K. 1995. Thyroid hormone to military winter exercise in the Arctic region. Arctic Medical Research **54,** 82-90.

Kraemer RR, Blair MS, Caferty RMc, Castracane VD. 1993. Running-induced alterations in growth hormone, prolactin, triiodothyronine and thyroxine concentration in trained and untrained men and women. Research Quarterly for Exercise & Sport **64,** 69-74. http://dx.doi.org/10.1080/02701367.1993.10608780

Kraemer WJ. 1988. Endocrine responses to resistance exercise. Medicine & Science in Sports & Exercise **20(5),** S152–S157.

Mastorakos G, Pavlatou M. 2005. Exercise as a stress model and the interplay between the hypothalamus–pituitary–adrenal and the hypothalamus– pituitary–thyroid axes. Hormone & Metabolic Research **37,** 577–584. http://dx.doi.org/10.1055/s-2005-870426

Pakarinen A, Alen M, Ha¨kkinen K, Komi P. 1988. Serum thyroid hormones, thyrotropin and

thyroxine binding globulin during prolonged strength training. European Journal of Applied Physiology and Occupational Physiology **57**, 394-398.
http://dx.doi.org/10.1007/BF00417982

Peeri M, Boostani MH, Banaeifar A, Kohanpour MA, Erfani M, Abbariki Z. 2013. Effect of eight weeks continuous resisting trainings on relaxation levels and responses of active young women's thyroid hormones to one turn sport. Journal of Basic and Applied Scientific Research **3(4),** 648-653.

Refsum HE, Stromme SB. 1979. Serum thyroxine, triidothyronine and thyroid stimulating hormone after prolonged heavy exercise. Scandinavian Journal of Clinical & Laboratory Investigation **39,** 455.

Rone JK, Dons RF, Reed HL. 1992. The effect of endurance training on serum triiodothyronine kinetics in man: physical conditioning marked by enhanced thyroid hormone metabolism. Clinical Endocrinology **37,** 325-330.
http://dx.doi.org/10.1111/j.13652265.1992.tb02332.x

Simsch C, Lormes W, Petersen KG, *et al.* 2002. Training intensity influences leptin and thyroid hormones in highly trained rowers. International Journal of Sports Medicine **23,** 422-427.
http://dx.doi.org/10.1055/s-2002-33738

Wilber JF, Yamada M. 1990. Thyrotropin releasing hormone: Current concept. In M.A. Green (Eds), the thyroid gland 129-795 P. New York: Raven press.

Yen PM. 2001. Physiological and molecular basis of thyroid hormone action. Physiological Reviews **81**, 1097-1126.