JOURNAL OF NUTRITION FASTING AND HEALTH

The Effects of Aerobic Exercise and Salvia on Thyroid Hormones in Male Athletes

Hamidreza Miri[1], Mehdi Baigzadeh[2], Mehran Ghahramani[3]*, Mohammad Ghahramani[4]

1. MA Student Exercise Physiology, Eslamabad-E-Gharb Branch, Islamic Azad University, Eslamabad-E-Gharb, Iran.
2. Department of Exercise Physiology, Eslamabad-E-Gharb Branch, Islamic Azad University, Eslamabad-E-Gharb, Iran.
3. Department of Exercise Physiology, Ker.C., Islamic Azad University, Kermanshah, Iran.
4. Department of Physical Education, Technical and Vocational University (TVU), Tehran, Iran.

A R T I C L E I N F O

Article type:
Research Paper

Article History:
Received: 16 Mar 2025
Accepted: 07 Oct 2025

Keywords:
Exercise
Salvia
Thyroid
T3
TRH
T4

A B S T R A C T

Introduction: This study aimed to compare the effects of a 12-week aerobic training program combined with salvia supplementation on thyroid hormone secretion and the secretion of the stimulating hormone.

Methods: In this quasi-experimental study, 48 young male athletes (aged 20–35 years) were randomly assigned to four groups (n = 12 per group): (1) aerobic training, (2) aerobic training with Salvia supplementation, (3) Salvia supplementation only, and (4) control. The intervention lasted 12 weeks and included three one-hour aerobic training sessions per week. Participants in the Salvia groups received three coated Salvigol tablets daily (100 mg each). Groups without supplementation performed only the aerobic training protocol for 12 weeks. Data were analyzed using descriptive and inferential statistics. The Shapiro–Wilk test was used to assess normality. To test the study hypotheses, a two-way ANOVA was conducted; paired t-tests compared pre- and post-test values within groups, and Tukey's post hoc test was applied for between-group comparisons. All analyses were performed in SPSS version 27, with a significance level of $p < 0.05$.

Results: The findings demonstrated that 12 weeks of aerobic training combined with Salvia supplementation resulted in a significant reduction in serum T3 concentrations and its stimulating hormone ($p = 0.001$). Furthermore, aerobic training with Salvia supplementation significantly increased T4 levels ($p = 0.001$). However, no significant change in TRH concentrations was observed ($p > 0.05$). Pairwise comparisons revealed significant differences in T3 and T4 between the aerobic + Salvia group and each of the aerobic, Salvia-only, and control groups. Additionally, significant differences in T3 and T4 were observed between the aerobic and control groups, whereas no other significant differences were observed among the remaining groups.

Conclusion: Considering the beneficial properties of Salvia supplementation, its combination with aerobic exercise may have a synergistic effect on the regulation of thyroid hormone levels and their stimulating hormone.

► Please cite this paper as:
Miri H, Baigzadeh M, Ghahramani M, Ghahramani M. The Effects of Aerobic Exercise and Salvia on Thyroid Hormones in Male Athletes. J Nutr Fast Health. 2026; 1-. DOI: 10.22038/JNFH.2025.86803.1572.

Introduction

The thyroid gland, a key regulator of basal metabolism, plays a crucial role in governing energy balance, growth, and various physiological processes (1). Thyroid hormones (T3 and T4) and thyroid-stimulating hormone (TSH) exhibit significant fluctuations in response to physical stressors, such as exercise (2). Emerging evidence suggests that aerobic exercise, in particular, can influence these hormone levels by modulating the hypothalamic–pituitary–thyroid (HPT) axis (3). Conversely, antioxidant-rich medicinal plants, such as Salvia, have been shown to mitigate exercise-induced oxidative stress through their bioactive constituents, including carnosic acid and rosmarinic acid (4). Experimental studies further indicate that Salvia may enhance thyroid function by modulating genes involved in hormone biosynthesis (e.g., TPO and NIS) (5). However, clinical data regarding the combined effects of aerobic exercise and Salvia

* *Corresponding author(s):* Mehran Ghahramani, Associate Professor, Department of Exercise Physiology, Ker.C., Islamic Azad University, Kermanshah, Iran Tel: +989188342771, Email: ghahramani@iau.ac.ir.

supplementation on thyroid homeostasis in athletes remain limited and inconsistent. The underlying mechanisms of these interactions, as well as the specific contributions of herbal compounds such as Salvia, have yet to be fully elucidated (6). While some studies have reported reductions in TSH and increases in T3 following aerobic exercise (7), others have found no significant changes (8). These discrepancies may stem from variations in exercise intensity, duration, or participant characteristics. Despite the well-documented antioxidant and anti-inflammatory properties of Salvia (9), its effects on the HPT axis during exercise remain unclear. Evidence from animal studies suggests that Salvia extracts may modulate TSH secretion by reducing lipid peroxidation (10), but translating these findings to human physiology requires further investigation. Young male athletes (aged 20–35 years) are at increased risk of thyroid dysfunction due to accelerated metabolism and oxidative stress induced by intensive training (11). However, most previous studies have focused on sedentary individuals or patients with hypothyroidism (12). Siloglu et al. (2023) reported significant decreases in TSH and increases in T3 levels following 12 weeks of aerobic training in male athletes (13). In contrast, Rahmani et al. (2019) observed only a slight reduction in TSH and no change in T4 after eight weeks of aerobic exercise (14). Similarly, Nasiri and Khalili (2021) found a 20% decrease in TSH and a 15% increase in T3 in rats treated with Salvia extract (15). Rabiei et al. (2020) demonstrated TSH modulation in obese individuals receiving Salvia supplementation, although athletes were not included in their study (16). Fathi et al. (2023) reported improved T3/T4 ratios with a combined exercise–herbal protocol, yet the specific role of Salvia remained unclear (17). While the effects of aerobic exercise alone have been extensively investigated, the interaction between aerobic training and herbal supplementation in athletic populations remains poorly understood. Prolonged aerobic activity may disrupt thyroid homeostasis through oxidative stress, whereas Salvia's antioxidant properties could mitigate these effects. Therefore, the present study aimed to examine whether a 12-week aerobic exercise program combined with Salvia supplementation significantly alters serum T3, T4, and TSH levels in male athletes aged 20–35 years. Clarifying this relationship may help elucidate exercise–herbal interactions and offer practical insights for maintaining thyroid health during intensive training.

Materials and Methods

The present study employed an experimental, applied design with a pre-test–post-test structure and randomized allocation into three experimental groups and one control group. Before participation, the study objectives and procedures were explained to all subjects, and written informed consent was obtained. Baseline anthropometric characteristics and background variables—including height, weight, and body mass index (BMI)—were then measured and recorded. The intervention lasted 12 weeks and consisted of three one-hour aerobic exercise sessions per week. Dependent variables were collected from both the training and control groups at pre- and post-test stages. Before randomization and the initiation of training, participants underwent general health screening to ensure cardiovascular–respiratory fitness, medication compliance, absence of chronic diseases or mobility limitations, and non-smoking status. This assessment was performed through a structured questionnaire and verified by a licensed physician. Participants were subsequently instructed to visit the sports club one day before the study commenced to register demographic information and undergo baseline measurements of the study variables. Afterward, they were randomly assigned to one of the four groups: (1) aerobic training, (2) aerobic training with Salvia supplementation, (3) Salvia supplementation only, or (4) control. All training sessions were conducted under the direct supervision of the principal investigator.

The Salvia group received three coated Salvigol tablets daily, each containing 100 mg of dried extract derived from young Salvia branches. Groups without supplementation performed only aerobic training for 12 weeks. Before the intervention, all participants completed pre-tests, and the results were recorded for later comparison with post-test outcomes. Following 12 weeks of training and supplementation, and 48 hours after the final training session, post-tests were administered.

The study population consisted of male athletes aged 20–35 years with at least six months of consistent exercise experience (minimum of three sessions per week). A total of 48 participants were recruited voluntarily and randomly assigned to four groups (n = 12 per group): (1) aerobic exercise, (2) aerobic exercise with Salvia supplementation, (3) Salvia supplementation only, and (4) control.

Participants were informed that they could withdraw from the study at any stage without penalty. A screening questionnaire was administered to exclude individuals who had used any type of supplements or performance-enhancing substances before the survey. Ultimately, 48 athletes met the eligibility criteria and were selected as the study sample. They were then randomly assigned to four groups (n = 12 per group): (1) aerobic training, (2) aerobic training with Salvia supplementation, (3) Salvia supplementation only, and (4) control. Inclusion criteria included the absence of medical or metabolic disorders, no current medication use, non-smoking status, and no consumption of other sports supplements. Participants were also required to have at least 6 months of continuous training experience (at least two sessions per week) and to be free of acute health conditions. Furthermore, participants needed to demonstrate willingness to participate, ensure accessibility for monitoring throughout the study, and complete all study questionnaires. Exclusion criteria included irregular attendance (missing more than three training sessions), the use of sports supplements during the intervention, illness during the study period, or initiation of any medication regimen. Statistical analyses were conducted using SPSS (version 22), with a significance level of $p < 0.05$.

Salvia Supplement Protocol (18)

- **Supplement**: Standardized salvia extract (containing 240 mg of rosmarinic acid per capsule).
- **Dosage and Administration**: 500 mg daily (two 250 mg capsules) for 12 weeks, taken one hour after breakfast.
- **Placebo**: Identical starch-containing capsules (no active ingredient).
- **Compliance Monitoring**:
  - Weekly supplement distribution under researcher supervision.
  - Daily intake recorded in a logbook by participants.

Blinding: Participants and researchers were blinded to the supplement contents.

Training Protocol

The training protocol consisted of 12 weeks of exercise, with each week including three sessions lasting between 45 and 60 minutes, as follows:

- Weeks 1-4: 40 minutes (10 minutes of warm-up + 25 minutes of main activity + 5 minutes of cool-down).
- Weeks 5-8: 50 minutes (10 minutes of warm-up + 35 minutes of main activity + 5 minutes of cool-down).
- Weeks 9-12: 60 minutes (10 minutes of warm-up + 45 minutes of main activity + 5 minutes of cool-down).

Gradual Progression: An increase of 5% in intensity or 10% in duration every 4 weeks (based on standard principles) (17).

All training sessions were conducted by the researcher and were standardized for the participants (Table 1) (17).

Table 1. Training Protocol

Weeks of Training	Duration of Each Session (Minutes)	Exercise Intensity (% HRmax)
1-4	40	60%
5-8	50	65%
9-12	60	75%

Statistical Analyses

The Shapiro–Wilk test was used to verify the normality of data distribution. To test the study hypotheses, a two-way analysis of variance (ANOVA) was conducted. Paired-sample t-tests were applied to assess within-group differences between pre- and post-test scores, while Tukey's post hoc test was employed for between-group comparisons. All statistical analyses were performed using SPSS (version 27), with a significance level of $p < 0.05$.

Results

According to the study results, the mean serum T3 levels varied across groups before and after the intervention. In the combined aerobic exercise and Salvia group, T3 levels decreased from 13.11 to 9.77 ng/dL, the largest reduction among all groups. A similar, though smaller, decline was observed in the aerobic exercise group (from 12.66 to 10.82 ng/dL). The Salvia-only group also showed a slight decrease (from 10.76 to 9.57 ng/dL), whereas the control group exhibited no significant change (from 10.00 to 9.77 ng/dL).

Regarding TRH, a notable decrease was observed in the combined aerobic exercise and Salvia group (from 178.84 to 165.31 ng/L). The aerobic exercise group showed a comparable reduction (from 179.77 to 168.35 ng/L). In contrast, smaller changes were recorded in the Salvia-only group (from 174.11 to 170.88 ng/L) and the control group (from 179.09 to 176.29 ng/L).

Similarly, mean T4 levels declined in all experimental groups, with the most pronounced decrease observed in the combined aerobic exercise and Salvia group (from 133.94 to 117.54 ng/dL). The aerobic exercise group showed a moderate reduction (from 131.08 to 120.22 ng/dL), and the Salvia-only group exhibited a minimal decrease (from 130.58 to 127.92 ng/dL). No significant variation was observed in the control group, with levels remaining slightly stable at 131.23-129.20 ng/dL.

Assumption Testing for Two-Way ANOVA

The first assumption for conducting a two-way analysis of variance (ANOVA) is that the data are normally distributed. This assumption was examined using the Shapiro–Wilk test. The results indicated that the test statistics and corresponding p-values for all variables across the four groups at both pre-test and post-test stages exceeded 0.05. Therefore, the normality assumption was met, and no significant deviation from normality was observed.

The second assumption involves the equality (homogeneity) of error variances among the study groups. Levene's test was performed to verify this condition. The results showed that the error variances were homogeneous, as the obtained F-values were not significant at the 0.05 level.

The third assumption for applying the two-way ANOVA was the homogeneity of regression slopes. This assumption was also satisfied, as the calculated F-values for all three variables were not significant at the 0.05 level.

In summary, since all assumptions required for the two-way ANOVA were met, the use of this method to test the study hypotheses was appropriate.

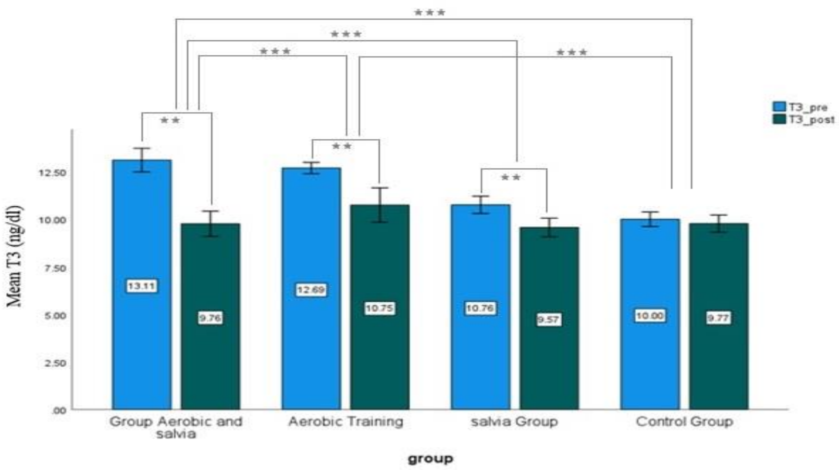

Figure 1. Secretion levels of the T3 hormone across the four groups.
The symbol ** indicates statistical significance based on the t-test, while the symbol *** denotes statistical significance based on Tukey's test.

The results of the two-way ANOVA examining the effects of 12 weeks of aerobic training combined with Salvia supplementation on T3 secretion supported the first hypothesis, indicating a significant influence of the intervention on T3 levels. Significant between-group differences in T3 secretion were observed: for the supplementation group ($F = 4.219$, $p = 0.006$, $\eta^2 = 0.208$), for the training group ($F = 6.741$, $p = 0.001$, $\eta^2 = 0.315$), and for the combined training and supplementation group ($F = 10.07$, $p = 0.001$, $\eta^2 = 0.511$).

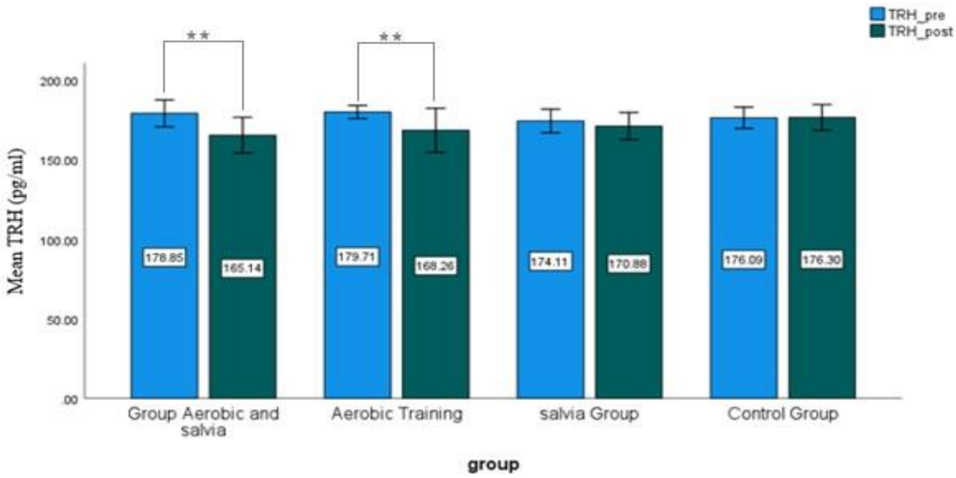

Figure 2. Secretion levels of the TRH hormone across the four groups.
The symbol ** indicates statistical significance based on the t-test, while the symbol *** denotes statistical significance based on Tukey's test.

The results of the two-way ANOVA examining the effects of 12 weeks of aerobic training combined with Salvia supplementation on TRH secretion supported the second hypothesis, indicating a significant influence of the intervention on TRH levels. The findings showed no significant change in the supplementation group ($F = 2.319$, $p = 0.148$, $\eta^2 = 0.045$). However, significant effects were observed in the training group ($F = 3.566$, $p = 0.031$, $\eta^2 = 0.152$) and in the combined training and supplementation group ($F = 4.128$, $p = 0.011$, $\eta^2 = 0.197$).

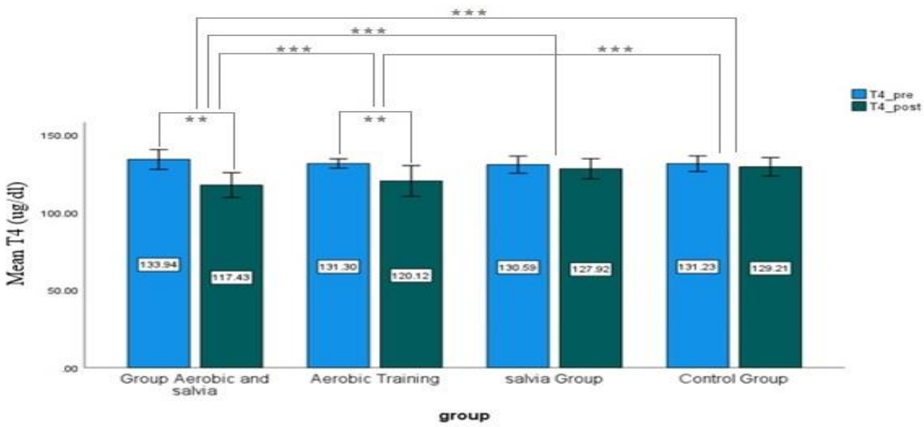

Figure 3. Secretion levels of the T4 hormone across the four groups.
The symbol ** indicates statistical significance based on the *t*-test, while the symbol *** denotes statistical significance based on Tukey's test.

Similarly, the two-way ANOVA results for T4 secretion indicated that the 12-week aerobic training combined with Salvia supplementation significantly affected T4 levels. No significant difference was found in the supplementation group ($F = 2.018$, $p = 0.159$, $\eta^2 = 0.036$). In contrast, significant effects were detected in the training group ($F = 3.714$, $p = 0.023$, $\eta^2 = 0.165$) and in the combined training and supplementation group ($F = 5.188$, $p = 0.002$, $\eta^2 = 0.271$).

Discussion and Conclusion

The present study demonstrated that a 12-week aerobic exercise program alone significantly reduced serum TSH, TRH, and free T3 levels in young male athletes. These results suggest that prolonged aerobic training modulates the hypothalamic–pituitary–thyroid (HPT) axis, leading to lower circulating concentrations of these hormones as part of a physiological adaptation. The impact of aerobic exercise on thyroid hormone levels appears to vary depending on training intensity, duration, and participant characteristics. Previous research indicates that moderate- to high-intensity aerobic exercise tends to reduce TSH and free T3 concentrations, reflecting a transient suppression of HPT axis activity. Such adaptations are thought to represent an energy-conservation mechanism during sustained aerobic activity, given the central role of thyroid hormones in regulating basal metabolic rate and overall energy metabolism. Consistent with earlier findings, endurance athletes frequently exhibit lower TSH and T3 levels, likely resulting from exercise-induced negative energy balance and altered central and peripheral endocrine signals, including leptin-mediated modulation of hypothalamic pathways governing thyroid function. These findings align with evidence suggesting that chronic exercise triggers metabolic adaptations characterized by reduced TSH stimulation and decreased thyroid hormone secretion, thereby optimizing energy expenditure during long-term training (18, 19). The observed decline in TRH, a hypothalamic hormone regulating TSH release, further supports the hypothesis of central downregulation of the HPT axis in response to aerobic exercise. Such hormonal adjustments may enhance endurance performance and metabolic efficiency in trained individuals. Nonetheless, discrepancies in the literature exist, with some studies reporting increases or no significant changes in thyroid hormone levels, likely due to differences in exercise protocols, participant sex, age, or baseline fitness levels (20, 21).

Another key finding of the present study was that 12 weeks of supplementation with Salvia officinal is alone significantly reduced serum T3 concentrations, while TRH and T4 levels remained unchanged in young male athletes. This pattern suggests that Salvia primarily influences peripheral thyroid hormone metabolism rather than central hypothalamic–pituitary regulation or T4 synthesis. Previous research on the thyroidal effects of Salvia has yielded inconsistent results. Some animal studies have reported stimulatory effects of Salvia extract, with increased T3 and T4 levels (22, 23). In contrast, others have demonstrated suppressive actions on T3, likely mediated by modulation of deiodinase enzymes that convert T4 to its active form, T3 (24). The reduction in T3 observed in the present study may therefore reflect alterations in peripheral enzymatic activity that modify thyroid hormone bioavailability, rather than direct changes in glandular secretion or hypothalamic output—an interpretation supported by the stable TRH and T4 concentrations. The unaltered TRH levels suggest preserved hypothalamic regulation. At the same time, the absence of a significant change in T4 indicates that thyroid hormone synthesis and release were largely unaffected by Salvia supplementation under these conditions. This selective decrease in T3 could lead to a modest reduction in basal metabolic rate and energy expenditure, potentially influencing metabolic efficiency and performance in athletes. Salvia contains various bioactive compounds, including rosmarinic acid, with known antioxidant and endocrine-modulating properties (22). However, evidence in humans—particularly in healthy, physically active populations—remains scarce. The direction and magnitude of Salvia's influence on thyroid hormone levels may depend on factors such as dosage, duration of supplementation, and individual metabolic characteristics, warranting further controlled investigations.

A further finding of the present study revealed that a 12-week combined program of aerobic exercise and Salvia officinalis supplementation resulted in significant reductions in serum TSH, TRH, and T3 levels among young male athletes. These results indicate that the combined intervention modulates thyroid hormone regulation. The observed decrease in thyroid hormones (T3 and T4) and TRH is consistent with previously reported effects of both exercise and phytochemical supplementation on endocrine function. Aerobic exercise influences thyroid hormone dynamics primarily through its impact on energy metabolism and overall metabolic rate, while Salvia contains bioactive constituents that can modulate hormone synthesis and peripheral conversion. Earlier studies have reported inconsistent findings regarding the effects of aerobic training alone on thyroid function, with outcomes varying by exercise intensity, duration, and participant characteristics. Salvia supplementation may additionally contribute to hormonal modulation, potentially amplifying the adaptive endocrine responses induced by aerobic training (25, 26). The concurrent reductions in T3, T4, and TRH observed in the present study may reflect a transient downregulation of the hypothalamic–pituitary–thyroid (HPT) axis, representing a physiological adaptation aimed at improving metabolic efficiency and conserving energy during prolonged aerobic activity. Such a response could facilitate optimal energy utilization in athletes exposed to combined physical and biochemical stimuli. However, variability across studies underscores the complex interplay among exercise mode, supplementation type, and individual endocrine status.

Future research should focus on elucidating the underlying mechanisms and assessing the long-term endocrine and metabolic consequences of combined aerobic and Salvia interventions across diverse athletic populations.

Declarations

Ethical Considerations

Compliance with ethical guidelines

This research is derived from the master's thesis of the Sports Physiology Department and was conducted at the student's personal expense, with financial support from the Islamic Azad University, Eslamabad-E-Gharb branch.

Acknowledgments

The authors thank and appreciate all those who helped in this research.

Authors' Contributions

All the authors have the same contributions in the execution and authorship of the study.

Conflict of Interest

The authors declare no conflict of interest in this study.

Financial Support

This study received no funds.

References

1. Brent GA. Mechanisms of thyroid hormone action. J Clin Invest. 2012; 122(9):3035-43.
2. Hackney AC, Dobridge JD. Thyroid hormones and the interrelationship of cortisol and prolactin: influence of prolonged, exhaustive exercise. Endokrynol Pol. 2009;60(4):252-7.
3. Fathi M, Mosaferi Ziaaldini M, Khairabadi S, Hejazi K. Effect of Aerobic Exercise on Thyroid Hormones and Quality of Life in Obese Postmenopausal Women. Mljgoums. 2018; 12 (6) :5-11.
4. Ghorbani A, Esmaeilizadeh M. Pharmacological properties of Salvia officinalis and its components. J Tradit Complement Med. 2017;7(4):433-40.
5. Mirazi N, Abdolmaleki N, Mahmoodi M. Study of Salvia Officinalis Hydroethanolic Extract on Serum Thyroid Hormone Levels in Hypothyroid Male Rat. Avicenna J Clin Med. 2013; 19 (4):27-35.
6. Ozrudi MF. Effect of Resistance Exercises with Salvia Officinalis Supplementation on the Response of Some Bio-Hormones in Overweight Male Students. Ann Clin Med Case Rep. 2021; V6(12): 1-5.
7. Saleem MS, Shirwany TA, Khan KA. Relationship of thyroid-stimulating hormone with metabolic syndrome in a sample of euthyroid Pakistani population. J Ayub Med Coll Abbottabad. 2011; 23(2):63-8.
8. Bastemir M, Akin F, Alkis E, Kaptanoglu B. Obesity is associated with increased serum TSH level, independent of thyroid function. Swiss Med Wkly. 2007; 137(29-30):431-4.

9. Ghorbani A, Esmaeilizadeh M. Pharmacological properties of Salvia officinalis and its components. J Tradit Complement Med. 2017;7(4):433-40.
10. Kiani, L., Byeranvand, S., Barkhordari, A., Bazgir, B. The Effects of Moderate Intensity Aerobic Training on Serum Levels of Thyroid Hormones in Inactive Girls. New Approaches in Exercise Physiology. 2022; 4(7): 107-20.
11. Wheaton CJ, Sullivan KE, Bassiouny E, Burns CM, Smukall MJ, Hendon JM and Mylniczenko ND Investigation of serum thyroid hormones, iodine and cobalt concentrations across common aquarium-housed elasmobranchs. Front Vet Sci. 2025;12:1504527.
12. Ahmad AM, Serry ZH, Abd Elghaffar HA, Ghazi HA, El Gayar SL. Effects of aerobic, resistance, and combined training on thyroid function and quality of life in hypothyroidism. A randomized controlled trial. Complement Ther Clin Pract. 2023;53:101795.
13. Klein I, Ojamaa K. Thyroid hormone and the cardiovascular system. N Engl J Med. 2001;344(7):501-9.
14. Stockigt JR. Free thyroid hormone measurement. A critical appraisal. Endocrinol Metab Clin North Am. 2001;30(2):265-89.
15. Ignacio DL, da S Silvestre DH, Cavalcanti-de-Albuquerque JP, Louzada RA, Carvalho DP, Werneck-de-Castro JP. Thyroid hormone and estrogen regulate exercise-induced growth hormone release. PLoS One. 2015;10(4):e0122556.
16. Berberoğlu M. Drugs and thyroid interaction. Pediatr Endocrinol Rev. 2003; 1(Suppl 2):251-6.
17. American College of Sports Medicine (ACSM). Guidelines for Exercise Testing and Prescription. 2021 (11 ed.). Lippincott Williams & Wilkins.
18. Alaie N, Abdi A. Protective effect of aerobic training with Salvia officinalis consumption on endothelial function indices in postmenopausal women. Daneshvar Medicine. 2023; 31(2): 46-55.
19. Farkhondeh T, Folgado SL, Pourbagher-Shahri AM, Ashrafizadeh M, Samarghandian S. The therapeutic effect of resveratrol: Focusing on the Nrf2 signaling pathway. Biomed Pharmacother. 2020;127:110234.
20. Yeh GY, Eisenberg DM, Kaptchuk TJ, Phillips RS. Systematic review of herbs and dietary supplements for glycemic control in diabetes. Diabetes Care. 2003;26(4):1277-94.
21. Williams SL, Strobel NA, Lexis LA, Coombes JS. Antioxidant requirements of endurance athletes: implications for health. Nutr Rev. 2006;64(3):93-108.
22. Ristow M, Zarse K, Oberbach A, Klöting N, Birringer M, Kiehntopf M, Stumvoll M, Kahn CR, Blüher M. Antioxidants prevent health-promoting effects of physical exercise in humans. Proc Natl Acad Sci U S A. 2009;106(21):8665-70.
23. Zhang C, Han Y, Gao X, Teng W, Shan Z. Thyroid function, physical activity and sedentary behaviour: A bidirectional two-sample Mendelian randomisation study. J Glob Health. 2024;14:04154.
24. de Vito E, et al. Thyroid hormone activation by type 2 deiodinase mediates exercise-induced PGC-1α expression in skeletal muscle. J Physiol. 2016;594(8):2279–2291.
25. Wang Q, Li H, He W, Zhao Q, Huang C, Zhang X, et al. Role of aerobic exercise in ameliorating NASH: insights into the hepatic thyroid hormone signaling and circulating thyroid hormones. Front Endocrinol (Lausanne). 2022; 13:1146843.
26. Forghani Ozrudi M, Ozrudi SF, Rohi A. The effect of 8-week endurance training with sage (Salvia officinalis) supplementation on anabolic and catabolic hormone responses in overweight male students. Research & Investigations in Sports Medicine. 2021;7(5): Article 000671.