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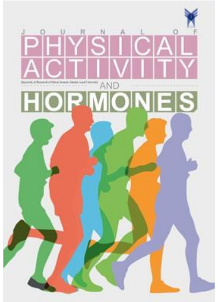

The effect of concurrent aerobic resistance exercise on thyroid hormones, body composition, and maximum oxygen consumption of sedentary overweight and obese women with hypothyroidism

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Abstract

Introduction: This study aimed to investigate the effect of concurrent resistance aerobic training on body composition, maximal oxygen consumption, and thyroid hormones in sedentary overweight, and obese women with hypothyroidism.

Material & Methods: In this quasi-experimental study, 24 women with hypothyroidism were randomly divided into two equal control groups (n =12, body mass index (BMI): 31.33±3.62 kg/m2) and experimental (BMI: 32.33 ± 4.05 kg/m2) were divided. Each session consisted of 30 minutes of aerobic training (55%-85% of maximum heart rate) and 30 minutes of resistance training. Before and after the 8-week exercise training, body composition (weight, BMI, waist-to-hip ratio (WHR), and fat percentage), maximum oxygen consumption (VO2 max), TSH, and T4 were measured. Statistical information was measured by SPSS software version 26 and the statistical level α<0.05 was considered. Data were reported as mean ± SD; data were analyzed using SPSS statistical software (version 26; (IBM Corp) Significance was set at p < 0.05

Results: Compared to the control in the experimental group, there was a significant decrease in weight, BMI, fat %, TSH, and a significant increase in VO2max, and T4 was observed (p<.05), but no significant difference was observed in WHR and TSH(p>.05). compared to the pre-test, there was no significant difference in all the variables in the control group and WHR in the experimental group.

Conclusion: These findings show that resistance aerobic exercise has an effect on body composition, VO2max, and T4 hormone in sedentary, overweight, and obese women with hypothyroidism.

1. Introduction

Hypothyroidism refers to a condition in which an increase in thyrotropin(TSH) is observed. Hypothyroidism is associated with overweight and obesity. Hypothyroidism is expected to increase body weight by reducing thermogenesis, and thus reducing the rate of metabolism. It seems that improving body composition can play an important role in improving hypothyroidism (1). Obesity and thyroid disease have been the subject of research and scientific speculation for years. In both adult and pediatric populations, TSH levels can be affected by obesity conditions. In a prospective re-evaluation of subjects for 7 years, those with higher TSH values showed greater increases in BMI (2). High levels of TSH are associated with an increased risk of developing hyperlipidemia and atherosclerosis, and increased risks of atrial fibrillation, fractures, and death. Some professional thyroid societies recommend screening for thyroid dysfunction in high-risk populations such as women and the elderly to promote early detection and reduce morbidity and mortality and they recommend (3). One of the influential variables in the development of chronic diseases is lifestyle. Lifestyle is the way that people choose during their life and its foundation is laid in the family, which is affected by culture, race, religion, socioeconomic status, and beliefs, as well as eating habits, behavior, stress, and physical activities. , work habits, smoking, and alcohol consumption are among the most important factors related to the lifestyle that improves people's health. In addition, studies show that weight loss causes a significant decrease in the serum level of thyroid-stimulating hormone. Apart from weight loss, it seems that even simple lifestyle changes, which are done by increasing physical activity and improving body composition without simultaneously changing body mass index, cause a decrease in thyroid stimulating hormone (4). Studies have shown that people with thyroid disorders suffer from weight-related problems. Thyroid hormones have a significant effect in increasing metabolism, so a complete lack of thyroid secretion may reduce the basal metabolic rate to about 45 to 50% lower than normal, and excessive thyroid secretion may increase the basal metabolic rate.

Some studies on hypothyroid people have shown a significant relationship between body mass index and thyroid function (5). Evidence has shown that exercise therapy improves health-related quality of life in hypothyroid people. In these studies, 22 middle-aged women with hypothyroidism were asked to do aerobic exercise three days a week for 4 months, and the results indicated that they were able to improve their quality of life (6). Also, studies that investigated aerobic and resistance exercises on the concentration of high-density lipoprotein cholesterol in 25-40-year-old women with hypothyroidism, and exercise may improve the profile of LDL concentration in women with hypothyroidism compared to the control group(7).

It has been shown that physical activity can also play a role in the regulation of thyroid hormones, and therefore it can be expected that physical activity is effective in improving thyroid disorders. However, Based on research findings, very little research has been done on the effects of exercise training on patients with thyroid disorders, especially hypothyroidism. In a study conducted by Garces et al. in 2018 on 20 women with hypothyroidism, it was found that 16 weeks of aerobic exercise has no effect on body weight, BMI, and thyroid hormones (TSH and T4), but improves VO2max (8). In another study, eight weeks of aerobic training(3 sessions/week, 45-85% of the maximum heart rate(HRmax)) can be effective in increasing the levels of TSH and T4 hormones (9).

In another study in women, it has been shown that aerobic resistance training can improve weight and body mass index (10). In another study on women, it has been shown that aerobic resistance training can improve body mass index and fat percentage, but it does not affect the ratio of WHR (11). In another study, it was found that 12 weeks of aerobic resistance training does not change the weight and BMI of women (12).

According to the inconsistencies in the research findings, this study aimed to investigate the effect of concurrent resistance aerobic exercise on body composition, VO2 max, and thyroid hormones in sedentary, overweight, and obese women with hypothyroidism.

2. Materials and methods

2.1. Sample

This research was a clinical trial. The statistical population consisted of sedentary, overweight, and obese women with hypothyroidism living in Shaft City. The samples included 24 female volunteers aged 25 to 45, sedentary, overweight, and obese with hypothyroidism who were taking levothyroxine tablets, these people with inclusion criteria included: not participating in sports activities for at least 6 months, consumption of at least 3 months of levothyroxine sodium tablets, absence of disease except hypothyroidism, absence of skeletal and muscular diseases that affect exercise and exclusion criteria: getting a disease during the research period, the presence of injury during exercise and non-attendance In two consecutive sessions or three alternating sessions. they were selected in this research and randomly divided into two training and control groups. Before and after exercise training protocol, weight, height, WHR, body mass index, VO2 max, and body fat percentage were measured, as well as blood TSH and T4. This study was conducted by the Ethics Committee of the Rasht branch, Islamic Azad University (IR.IAU.RASHT.REC.1401.030).

2.2. Aerobic-resistance exercise program

The duration of the exercises was 75 minutes. Progressive resistance aerobic exercises started with 10 minutes of warm-up (minutes of running, and stretching exercises), then 30 minutes of resistance exercises were performed followed by aerobic exercises for 30 minutes. At the end of the training session, 5 minutes of stretching exercises were done to cool down.

Resistance exercise training in healthy adults includes 3–4 sets, 8–12 repetitions, 30–60 second rest interval between 2 sets, and a 2–3 minute rest between exercises. Each resistance training session consisted of nine exercises that were performed as follows: leg press, chest press, latissimus dorsi pull down, leg extension, leg curl, cable crossover, biceps curl, triceps extension, and abdominal crunches. In session one, the workload for each exercise was equal to 55% of each individual’s one repetition maximum (1RM) consisting of 8–10 repetitions per set. In sessions two and three, the workload was increased to 60% and 65% of 1RM, respectively. Over 2–4 weeks, the workload was increased to 65–70% 1RM, and in the second month, repetitions and load were changed to 10–12% and 70–75% 1RM, respectively. AET included 4–8 rhythmic aerobic step training (which includes A-step, K-step, Across The Top, Around The World, Basic Left, Basic Right, Charleston, Corner to Corner, Flamingo, Indecision, L-step, Repeater, X-step, V-step, Tap Up, Split Basic and Reverse Turn) and running at 60–75% age-predicted maximum heart rate (220 – age). In the first week of the experiment, the participants were trained at 55–

65% of HRmax. The training intensity progressively increased to 70% of HRmax in weeks 2–4. Exercise intensity increased every two weeks to reach 75% of HRmax in the second month(13).

2.3. Measuring Instruments

Height and weight were measured in light clothing without shoes. Waist circumference (WC) was measured using a tape measure placed halfway between the lower border of the ribs and the iliac crest in a horizontal plane. Height, weight, and WC were measured twice and the averages were taken. Height, WC, and weight were measured to the nearest 0.1 cm and 0.1 kg, respectively. Body mass index (BMI) was calculated by dividing the participant's weight (kg) by the square of height (m2).

Body fat percentage was calculated using the three-point method of Jackson and Pollock. In this method, the skin folds of the triceps, upper arm, and thigh areas on the right side of the body were measured with a caliper (SAEHAN, SH5020, Korea) and entered in the following formula.

% Body Fat = (0.41563 × sum of skinfolds) – (0.00112 × square of the sum of skinfolds) + (0.03661 × age) + 4.03653, where the skinfold sites (measured in mm) are abdominal, triceps, and suprailiac.

2.4. Blood test

Blood samples (5 mL/time) were collected from the left vein in the sitting posture before and after the 8-week intervention. Then, they were poured into ethylenediaminetetraacetic acid (EDTA) tubes and were centrifuged at 3000 rpm for 15 min. A part of the serum was stored at −28 °C to measure leptin, and the remaining was used to measure thyroid hormones. An enzyme-linked immunosorbent assay (ELISA) test with a kit (Riachi, Korea) was used to estimate thyroid hormones.

2.5. Statistical Methods

The data were presented using the mean ± standard deviation. In the inferential analysis of the findings, the Shapiro-Wilk test was used to test the normality of the data distribution, and the dependent t and independent t statistical tests were used to test the hypotheses. Wilcoxon and Man-U Whitney tests were used when the variables were not normally distributed.

3. Results

The descriptive characteristics of the two groups are presented in Table 1.

Table 1- *Description of subjects' characteristics*

Variables		Control mean±SD	Experimental mean±SD
weight (kg)	pre-test	80.45±13.26	85.84±11.31
	post-test	81.55±13.40	84.34±10.19
BMI (kg/m)	pre-test	31.33±3.62	32.33±4.05
	post-test	31.83±3. 73	30.75±3.95
WHR (cm)	pre-test	0.84±0.06	0.79±0.08
	post-test	0.84±0.06	0.79±0.08
Fat %	pre-test	0.35±0.04	0.37±0.04
	post-test	0.35±0.04	0.36±0.04
VO2max (ml/kg/da y)	pre-test	27.91±2.19	27. 08±3.98
	post-test	27.25±2. 05	28.00±3.41
	pre-test	6.83±2.34	5.08±3.14
TSH (µu/mL)	post-test	4.29±4.02	2.26±1.16
T4 (µg/mL)	pre-test	5.73±4.89	3.64±2.21
	post-test	7.34±2.84	8.34±.277

The Shapiro-Wilk test results showed that BMI, WHR, and VO2 max had a normal distribution, and other variables (weight, body fat percentage, TSH, T4) had a non-normal distribution.

To compare the post-test results with the pre-test in two experimental and control groups, dependent t-tests (table 2) and Wilcoxon test (table 3) were used.

Table 2- *Dependent t-test (n=12 in each group)*

Variables			standard deviation±mean	t statistic	sig
weight (kg)	control	pre-test	80.45±13.26	-1.72	0.13
		post-test	81.55±13.45		
Fat %	experimental	pre-test	0.37±0.04	2.44	0.03*
		post-test	0.36±0.04		
BMI (kg/m)	control	pre-test	31.33±3.62	-1.483	0.16
		post-test	31.83±3.73		
	experimental	pre-test	32.33±4.05	2.50	0.02*
		post-test	30.75±3.95		
WHR (cm)	control	pre-test	0.84±0.06	0.84	0.06
		post-test	0.84±0.630		
	experimental	pre-test	0.79±0.08	0.84	0.06
		post-test	0.79±0.08		
Vo2Max (ml/kg/day)	control	pre-test	27.91±2.91	1.733	0.104
		post-test	27.25±2.05		
	experimental	pre-test	27.08±3.098	-4.00	0.002*
		post-test	28.00±3.041		

Table 3. *Wilcoxon test tage (n=12 in each group)*

group	experimental		control	
variable	Z	sig	Z	sig
weight (kg)	-2.59	0.01*		
fat %	-1.40	0.16		
TSH (µg/mL)	-2.825	0.005*	-0.866	0.386
T4 (µg/mL)	-2.590	-0.01*	-1.244	0.2

The results of Tables 2 and 3 showed that in the control group, there was no significant difference in any of the variables in the comparison of the post-test results compared to the pre-test, but In the experimental group, a significant decrease in weight, fat%, BMI, TSH and a significant increase in the VO2 max, and T4 were observed in the comparison of the results of the post-test with the pre-test, and no differences were observed in other variables.

In the comparison between groups in the post-test, after reducing the pre-and post-test values, the results of the independent t-test and Man Whitney U testwere shown in Tables 4 and 5.

Table 4. *Mann-Whitney U test (n=12 in each groups)*

Variables	pre-test	post-test

	Man-U Whitney	sig	Man-U Whitney	sig
weight (kg)	57.50	0.40	22.50	0.004*
fat percentage	56.00	0.35	27.00	0.007*
TSH (µg/mL)	56.50	0.37	0.47	0.14
T4 (µg/mL)	53.000	0.291	37.500	0.045*

Table 5. *Independent t-test (n=12 in each groups)*

Variables			standard deviation±mean	t statistic	sig
BMI (kg/m)	pre-test	control	31.33±3.62	-0.63	0.53
		experimental	31.38±3.73		
	post-test	control	-0.50±1.16	-2.90	0.008*
		experimental	1.58±2.19		
WHR (cm)	pre-test	control	0.84±0.06	1.58	0.12
		experimental	0.79±0.08		
	post-test	control	0.001±0.005	-1.34	0.19
		experimental	0.0008±0.001		
VO2max (ml/kg/day)	pre-test	control	0.66±1.30	0.63	0.53
		experimental	0.91±0.72		
	post-test	control	27.91±2.96	3.59	0.002*
		experimental	27.08±3.98		

In the comparison between groups in the post-test, the results showed a significant decrease in weight, BMI, and fat% while a significant increase in VO2 max and T4 in the experimental group.TSH and WHR had no significant change.

4. Discussion

The results of the present study showed that 8 weeks of concurrent aerobic-resistance exercises lead to a significant decrease in weight, BMI, fat%, VO2 max, T4 and TSH in the experimental group. However, it did not affect WHR. Compared to the control group All variables significantly improved except WHR and TSH. The results of the research were in agreement with the present research. Research results that were conducted for 12 weeks of aerobic exercise in women with an average age of 41 years(BMI>25) with hypothyroidism, showed that three sessions a week of aerobic exercise with a 70% HR caused significant weight loss and BMI (15). In another study conducted on 20 overweight and obese postmenopausal women, it was found that resistance aerobic training for three sessions of 60 minutes per week caused a significant decrease in BMI and fat%, but there was a significant change in The WHR was not seen (16). in a research conducted on 32 inactive obese women, it was found that 12 weeks of resistance aerobic exercise (3 sessions/week), caused weight loss and body mass (17).

In contrast, In a research conducted on 31 women with hypothyroidism and hypercholesterolemia, it was found that resistance aerobic exercises did not significantly change weight and BMI. Another research that was conducted on 25 women with hypothyroidism who were taking levothyroxine pills, showed that aerobic exercise(3session/week, 5 months) with low to moderate intensity cannot affect weight, BMI, fat %, and WHR. It seems that the intensity of exercises is one of the factors of discrepancy in research results (18).

In a study that examined the effects of 12 weeks (60 min, 3 sessions/week) of moderate aerobic training on the plasma level of thyroxine and thyroid hormones in 30 inactive obese sedentary women. The results showed that exercise training showed no significant change in weight, BMR, and WHR in the experimental group compared to the control group, but there was a significant change in the fat% in the experimental group. In addition, it was shown that 9 weeks of aerobic training(4 sessions/week), with an intensity of 65-75% of the HR max, decreased the BMI, weight, and fat %, but in contrast to the findings of the present research, it caused a significant decrease in the WHR (19). It was also shown that 6 weeks of combined training (4 sessions/ week) with an intensity of 55-80% of the HRmax, caused a significant decrease in weight and BMI, but in contrast to the findings of the present study, it caused a significant decrease in the WHR(20). It seems that the type, intensity, and duration of exercises are the main factors of the difference in research results. Hypothyroidism can play a role in increasing the BMI by reducing heat generation and reducing the rate of bad basal metabolism, resulting in a higher prevalence of obesity. It has been shown that hypothyroidism causes a significant change in body weight, BMI, WHR, and fat %, and as a result, it is considered a risk factor for overweight and obesity (21). following moderate-intensity aerobic exercise, the amount of Catecholamines, growth hormone, and cortisol increase, which facilitated fat metabolism (22). Therefore, by increasing the consumption of fats after aerobic exercises, by reducing the amount of body fat storage, we see a decrease in weight, BMI, and fat percentage. On the other hand, resistance training stimulates protein production and reduces its degradation. In addition, in resistance exercises, we see an increase in the number of actin and myosin filaments, which increase the body's muscle mass. It is expected that this issue will increase weight and BMI after resistance training (23).

The results of the present study showed that 8 weeks of concurrent aerobic-resistance exercises led to a significant increase in the VO2 max in the experimental group. The results of the Garces et al. study were in agreement with the present research result (24). They found that 12 weeks of exercise (3 sessions/week,60 min) in women with hypothyroidism caused a significant increase in VO2 max. They showed that 9 weeks of aerobic training with an intensity of 50-70% of maximum oxygen consumption in inactive middle-aged women causes a significant increase in VO2 max (25). Contrary to the results of the present study, Amati et al showed that aerobic exercise with an intensity of 75% of the maximum heart rate does not affect the VO2 max in women with hypothyroidism who are overweight and obese (26). It seems that the reason for the difference in results can be attributed to the difference in age, the length of the training period, the physical condition of the subjects, and the duration of the training.

Aerobic training increases metabolic adaptation in both type 1 and type 2 muscle fibers. This adaptation increases the stiffness and lactate threshold of fibers without changing their type. Also, aerobic exercises can increase the capacity of muscles to produce aerobic ATP and also increase the globular protein myoglobin, which plays a role in accelerating the transfer of oxygen to mitochondria (27). Exercise can cause muscle hypertrophy by increasing protein production and reducing its degradation. Also, resistance exercises can increase muscle actin and myosin filaments, which play a role in muscle hypertrophy caused by resistance exercises. Muscle hypertrophy by increasing the cross-sectional area of the muscle can play a role in increasing the force produced by the muscle. On the other hand, increasing the speed of transmission of nerve messages after resistance training can increase the maximum productive force and the speed of its creation (28). In this regard, it is suggested that since three 60-minute sessions of simultaneous aerobic-resistance exercises (including 75 minutes of exercise, half of which are aerobic exercises with an intensity of 55-80% of the HRmax and resistance exercises) lead to a significant reduction in weight, BMI and fat % of women with hypothyroidism, so it is recommended that women with hypothyroidism use exercises similar to the present study to reduce fat%. It is also recommended to the trainers to use a training program similar to this study for women with hypothyroidism. Considering that overweight and obese samples were used together in this research, it is recommended that overweight and obese people be given separate exercises in future research. Gender was another limitation of this research, so it is suggested to compare research variables in two genders.

5. Conclusion

The findings of this research showed that concurrent resistance aerobic exercises improve body composition increase VO2 max and improve plasma thyroid hormones.

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Conflict of interests: The authors declare that they have no conflict of interest relating to the publication of this manuscript.

References

1. Wiersinga, W. M. (2016). Clinical relevance of environmental factors in the pathogenesis of autoimmune thyroid disease. Endocrinology and Metabolism, 31(2), 213. DOI: 10.3803/EnM.2016.31.2.213
2. Biondi, B. (2023). Subclinical Hypothyroidism in Patients with Obesity and Metabolic Syndrome: A Narrative Review. Nutrients, 16(1), 87. DOI: 10.3390/nu16010087
3. Jung, C.-H., Son, J. W., Kang, S., Kim, W. J., Kim, H.-S., Kim, H. S., et al. (2021). Diabetes fact sheets in Korea, 2020: an appraisal of current status. Diabetes & Metabolism Journal, 45(1), 1. DOI: 10.4093/dmj.2021.0020
4. Zare, S., & Alipoor, A. (2019). Comparison of the Resiliency and Health Promoting Lifestyle between Thyroid Dysfunction Disease Patients and Healthy People. Journal of Health Promotion Management, 8(1), 1-14.
5. Hassan, B., Ansari, B., & Farooqui, S. (2021). Effects of Physical Activity on Thyroid Stimulating Hormone Levels in Obese Metabolic Syndrome Patients: A Meta-Analysis. RCT, 15.
6. Gitlin, L. N., Reever, K., Dennis, M. P., Mathieu, E., & Hauck, W. W. (2006). Enhancing quality of life of families who use adult day services: Short-and long-term effects of the adult day services plus program. The Gerontologist, 46(5), 630-639. DOI: 10.1093/geront/46.5.630
7. Masoumi-Ardakani, Y., Najafipour, H., Nasri, H. R., Aminizadeh, S., Jafari, S. J., & Safi, Z. (2022). Moderate endurance training and MitoQ improve cardiovascular function, oxidative stress, and inflammation in hypertensive individuals: the role of miR-21 and miR-222: a randomized, double-blind, clinical trial. Cell Journal (Yakhteh), 24(10), 577. DOI: 10.22074/celljournal.2022.7438
8. Seara, F. A., Maciel, L., Barbosa, R. A., Rodrigues, N. C., Silveira, A. L., Marassi, M. P., et al. (2018). Cardiac ischemia/reperfusion injury is inversely affected by thyroid hormones excess or deficiency in male Wistar rats. PLoS One, 13(1), e0190355. DOI: 10.1371/journal.pone.0190355
9. Shirvani, H., & Sobhani, V. (2016). The effect of a period of selected aerobic training on the response of thyroid and cortisol hormones to exhaustive exercise in women. Journal of Military Medicine, 18(3), 253-261.
10. Dashti, N., Rezaeian, N., Karimi, M., & Kooroshfard, N. (2021). The Effect of high intensity interval training on serum levels of Osteopontin and insulin resistance index in sedentary overweight and obese women. Journal of Sport and Exercise Physiology, 14(2), 115-126.
11. Moravejolahkami, A. R., Hojjati Kermani, M. A., Balouch Zehi, Z., Mirenayat, S. M. S., & Mansourian, M. (2021). The effect of probiotics on lipid profile & anthropometric indices in diabetic nephropathy; a systematic review and meta-analysis of clinical trials. Journal of Diabetes & Metabolic Disorders, 20, 893-904. DOI: 10.1007/s40200-021-00705-7
12. Santos, R. C., Materko, W., Fernandes, D. F., & Da Pureza, D. Y. (2020). Effects of aerobic and resistance training on the high-density lipoprotein cholesterol concentration in women with hypothyroidism. Journal of Physical Education and Sport, 20(4), 1809-1813. DOI: 10.7752/jpes.2020.04193
13. Shabani, R., & Izaddoust, F. (2018). Effects of aerobic training, resistance training, or both on circulating irisin and myostatin in untrained women. Acta Gymnica, 48(2), 47-55. DOI: 10.5507/ag.2018.013
14. Shabani, R., Yosefizad, L., & Fallah, F. (2017). Effects of eight weeks of endurance-resistance training on some inflammatory markers and cardiovascular endurance in sedentary postmenopausal women. The Iranian Journal of Obstetrics, Gynecology and Infertility, 20(1), 23-30.
15. Hu, G., Jousilahti, P., Antikainen, R., Katzmarzyk, P. T., & Tuomilehto, J. (2010). Joint effects of physical activity, body mass index, waist circumference, and waist-to-hip ratio on the risk of heart failure. Circulation, 121(2), 237-244. DOI: 10.1161/CIRCULATIONAHA.109.887885
16. Marandi, S. M., Abadi, N. G. B., Esfarjani, F., Mojtahedi, H., & Ghasemi, G. (2013). Effects of intensity of aerobics on body composition and blood lipid profile in obese/overweight females. International Journal of Preventive Medicine, 4(Suppl 1), S118.
17. Ho, S. S., Dhaliwal, S. S., Hills, A. P., & Pal, S. (2012). The effect of 12 weeks of aerobic, resistance or combination exercise training on cardiovascular risk factors in the overweight and obese in a randomized trial. BMC Public Health, 12, 1-10. DOI: 10.1186/1471-2458-12-1
18. El Gayar, S. L. (2023). Effect of aerobic training on depression and thyroid function in treated hypothyroid women. Revista Pesquisa em Fisioterapia, 13, e5254.
19. Huxley, R., Mendis, S., Zheleznyakov, E., Reddy, S., & Chan, J. (2010). Body mass index, waist circumference and waist: hip ratio as predictors of cardiovascular risk—a review of the literature. European Journal of Clinical Nutrition, 64(1), 16-22. DOI: 10.1038/ejcn.2009.92
20. Wang, Y. H., Hua, Y., Zhang, H. Z., Liang, S., Cao, Z. Z., Chen, L. L., et al. (2024). Ratio of waist circumference to body mass index: A novel predictor of clinical outcome in hypertension patients. The Journal of Clinical Hypertension, 26(1), 24-35. DOI: 10.1111/jch.14749
21. Sanyal, D., & Raychaudhuri, M. (2016). Hypothyroidism and obesity: An intriguing link. Indian Journal of Endocrinology and Metabolism, 20(4), 554-557. DOI: 10.4103/2230-8210.183272
22. Peake, J. M., Tan, S. J., Markworth, J. F., Broadbent, J. A., Skinner, T. L., & Cameron-Smith, D. (2014). Metabolic and hormonal responses to isoenergetic high-intensity interval exercise and continuous moderate-intensity exercise. American Journal of Physiology-Endocrinology and Metabolism, 307(7), E539-E552. DOI: 10.1152/ajpendo.00115.2014
23. Cao, J., Lei, S., Zhao, T., Xie, Y., Zhou, Z., Cheng, S., et al. (2022). Changes in fat oxidation and body composition after combined exercise intervention in sedentary obese Chinese adults. Journal of Clinical Medicine, 11(4), 1086. DOI: 10.3390/jcm11041086
24. Exercise I. (n.d.). Supervised sessions per week for 8 weeks (total of 24 sessions). 5 to 10 minutes of warming up and cooling down. The subjects cycled for.8.
25. Akbarpour Beni, M., & Asheghi, Z. (2022). The Effect of Aerobic Exercise on Angiogenesis Factors in Middle-aged Women. Journal of Vessels and Circulation, 3(4), 173-178.
26. Amati, F., Dubé, J. J., Shay, C., & Goodpaster, B. H. (2008). Separate and combined effects of exercise training and weight loss on exercise efficiency and substrate oxidation. Journal of Applied Physiology, 105(3), 825-831. DOI: 10.1152/japplphysiol.00131.2008
27. Postnikova, G., & Shekhovtsova, E. (2018). Myoglobin: oxygen depot or oxygen transporter to mitochondria? A novel mechanism

of myoglobin deoxygenation in cells. Biochemistry (Moscow), 83, 168-183. DOI: 10.1134/S0006297918020088

28. Aagaard, P., Simonsen, E. B., Andersen, J. L., Magnusson, P., & Dyhre-Poulsen, P. (2002). Neural adaptation to resistance training: changes in evoked V-wave and H-reflex responses. Journal of Applied Physiology, 92(6), 2309-2318. DOI: 10.1152/japplphysiol.01229.2001