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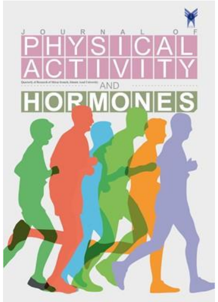

The Effect of Concurrent Aerobic and Pilates Training on Body Composition and Glucose Hemostasis on Obese Non-Menopausal Women

Kimia Poornoruz [1], Sara Jafari [2*]

[1] Master's degree, Faculty of Humanities, Department of Physical Education and Sports Sciences, Islamic Azad University, Rasht Branch, Guilan, Iran.
[2] Master's degree, Faculty of Humanities, Department of Physical Education and Sports Sciences, Islamic Azad University, Rasht Branch, Guilan, Iran.

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Correspondence
E-mail address*:* Sarajafari96@gmail.com

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Abstract

Introduction: The prevalence of obesity and overweight is very high in the north of Iran, it is a signal of serious health problems and should be the focus of special attention. The purpose of this research was to investigate the effect of concurrent aerobic and Pilates exercises on body composition and glucose homeostasis in obese non-menopausal women.

Material & Methods: 28 eligible women were randomly divided into experimental (EG), and control groups (CG). The training protocol consisted of two sessions per week, and each session was 90 minutes of aerobic and Pilates exercises. body mass index (BMI), The Waist-to-hip Ratio (WHR), body fat percent (BF%), fasting blood sugar(FBS), body obesity index, muscle mass, insulin, and Homeostatic Model Assessment for Insulin Resistance(HOMA-IR) were measured before and after 12 weeks exercise training.

Results: The results showed a significant decrease in subcutaneous fat (%), WHR, and Insulin in the experimental group compared to the control group in the post-test ($p<0.05$). However, no significant change was observed in FBS and HOMA-IR ($p>0.05$).

Conclusion: Concurrent aerobic and Pilates training programs probably improve body composition indices, and decrease serum insulin in obese women with normal blood glucose.

1. Introduction

The increasing prevalence of obesity has become a major problem in adults as well as among children and adolescents due to various health-related complications (1). The estimate by 2030 is expected to be 2.16 billion overweight people and 1.12 billion obese in the world (2). Based on published data from 2012 to 2021, Abiri et al. estimated the prevalence of overweight and obesity in the Iranian population according to age and geographical distribution. Accordingly, the total rate of overweight and obesity in Iran was estimated to be 35.09%, which was calculated to be 56.55% for people older than 18 years and 21.11% for people younger than 18 years(3). Obesity is an important public health problem that has been discussed in recent decades worldwide. Although the nationally reported prevalence of obesity in Iran was not considerably diverse, remarkable differences were seen in the sub-national prevalence which must be noticed more in national health programs, especially among women and children (4). The prevalence of obesity and overweight is very high in the north of Iran, hence is a signal of serious health problems, and should be the focus of special attention (5). Yang et al. should that obesity prevalence has risen rapidly in individuals in their 20s and 80s compared with other age groups. Additionally, class III obesity prevalence in both men and women has significantly increased by nearly threefold. The relative risk of developing type 2 diabetes, myocardial infarction, ischemic stroke, and cancers in people with obesity or abdominal obesity is greater than in people without obesity or abdominal obesity. The relative risk was higher in young and middle-aged individuals than in the older population (6).

Overweight and obesity are associated with impaired metabolic homeostasis, reduced insulin sensitivity (7), postprandial lipid metabolism (8), loss of muscle mass, and increased accumulation of visceral adipose tissue (9), largely attributable to physical inactivity (10). Exercise training e.g. Pilates and aerobic training would likely lead to improvements in anthropometric indices and glucose homeostasis (11). (12-14). Although there are studies indicating that aerobic training in women affects body composition, most of those studies examined the combined effect of aerobic exercise and nutrition (15, 16). Špirtović et al. showed that a 12-week program of aerobics mix can be concluded that mix program was efficient in the reduction of subcutaneous fat tissue and visceral fat and also influential on the increase of muscle mass (17). Weight loss is effective in preventing pre-diabetes and T2DM, and the positive effect of exercise bouts on glucose tolerance is well known (18, 19). Exercise without weight loss seems to have a smaller effect on glucose tolerance in participants who are overweight/obese, as the baseline glycemic control tends to be poorer in this population (18). The latest guidelines issued by the American College of Sports Medicine also recommend that T2DM patients perform exercises such as Tai Chi, Pilates, and yoga to enhance their overall health (20). Women with health issues who practiced Pilates reported improvements in physical and psychological health metrics. Additional high-quality research is necessary to determine the impact on other aspects of health and fitness (21).

Few studies have verified the effectiveness of Concurrent Aerobic and Pilates Training on Body Composition and Glucose Hemostasis in Obese non-menopausal women, which is highly time-efficient and based on the same exercise intervention program (e.g., same exercise volume, intensity, time, etc.). In particular, studies that have comprehensively examined the differences in the effects of Concurrent Aerobic and Pilates interventions on body composition, cardiometabolic parameters, and physical fitness factors in women with obesity are lacking. Therefore, it is important to confirm the effectiveness of Concurrent Aerobic and Pilates exercises using the same exercise treatment. Therefore, considering the importance of the topic, the purpose of this research was to investigate the effect of concurrent aerobic and Pilates exercises on body composition and glucose homeostasis in obese non-menopausal women.

2. Materials and methods

This semi-experimental research was conducted as a pre and post-test design in two control and experimental groups. Before and after the end of 12 weeks of exercise training, body composition, and glucose homeostasis indices were measured

2.1. Subjects

Forty-five obese, non-menopausal, non-athletic, middle-aged women from Lahijan city were volunteers to participate in this research. The inclusion criteria were: age (40 – 50 years), obesity (BMI $\geqslant$30), no medication use, and no history of exercising training at least for six months, FBS $\leqslant$120 mg/dl, and insulin between 5 and 15 µU/mL. 30 eligible samples were randomly divided into experimental (EG), and control groups (CG). In a meeting, the benefits and harms of the exercise program were explained to the samples, and a written consent form was obtained from them. One person from each group was removed from the sample due to not regularly participating in the exercise sessions and the other was due to illness. Table 1 shows the demographic characteristics of the samples. The study was approved by the ethical committee Rasht Branch, Islamic Azad University, and was conducted by adhering to the Declaration of Helsinki.

2.2. Measurements

The anthropometric characteristics of the subjects were assessed. Height was determined with a stadiometer, and weight was measured with a digital scale (SECA 786, Germany). The BMI of a subject was calculated by measuring the height in meters and body weight in kilograms (weight / height2). Waist measured at the narrowest area parallel to the ground during normal breathing. Hips: maximum protrusion of the buttocks muscle (gluteus Maximus) was measured in a parallel position over the place. WHR value obtained by dividing waist circumference by hip circumference (WHR = waist circumference/hip circumference). Skinfold thickness was measured with a skinfold caliper (SAEHAN, SH5020) according to standard procedures. Percentage body fat (BF %) was calculated from the equation: 1.089733-0.0009245 (x) + 0.0000025 (x2) – 0.0000979 (y); where x = the sum of triceps, suprailium, and abdominal skinfolds (in mm) for women, and y = age in years (22). Body adiposity index was computed as hip circumference/ (height)1.5 – 18. Skeletal muscle mass(SM) measurement is a method that uses anthropometric characteristics to measure skeletal muscle mass, which replaces expensive methods such as magnetic resonance imaging and CT scanning. SM was measured using the following formula:

SM (kg) = Ht (0.00744 CAG2 + 0.00088 CTG2 + 0.00441 CCG2) + 2.4 sex - 0.048 age + race + 7.8

Sex = 1 for male and 0 for female, race = 2.0 for Asian, 1.1 for African American, and 0 for white or Hispanic; limb circumferences and skinfold thicknesses [Ht: height (in m) and skinfold-corrected upper arm, thigh, and calf girths (CAG, CTG, and CCG, respectively; in cm)].

2.3. Biochemical analyses

Blood samples were collected after an overnight fast (>12 h) in a sitting position and centrifuged at 1500 rpm for 30 minutes at 4o C within 2 h. Serum samples from each participant were stored frozen at -20o C until analyzed. Serum insulin was measured by a commercial chemiluminescence assay kit (Cobas®, USA) (intra-assay CV: 1.9%, inter-assay CV: 2.6%) and serum glucose was measured by a glucose oxidase method kit (Pars Azmoon, IRAN). Moreover, the homeostasis model assessment-insulin resistance (HOMA-IR) index for insulin sensitivity was computed following these equations (when glucose and insulin are both during fasting and applied glucose unit: mg/dl)

HOMA - IR: Glucose × Insulin / 405.

2.4. Exercise training

The training protocol consisted of 12 weeks and two sessions per week and each session was 90 minutes, consisting of 10 minutes of warm-up, 70 minutes of progressive aerobic and Pilates exercises, and 5 minutes of cooling down. Aerobic exercise training intensity gradually increased across the training period. The intensity of aerobic exercise was adjusted based on the percentage of maximum heart rate (MHR). Aerobic exercises started with an intensity of 55% to 60% of the maximum heart rate and continued until 75%-80%. A polar heart rate monitor (Pulse oximeter model A2, China) was used to measure heart rate.

Pilates exercises consisted of 12 movements, each movement was performed in 3 sets of 15 repetitions with 1 minute rest between sets (23).

Table 1. *Aerobic and Pilates exercise training program*

Warm-up (10 min)	Exercise training program(70min)	Cool down(5 min)
Breathing and Stretching training	Aerobic training: Walking, running, rhythmic aerobic movements (march, step, wave, upside down, etc.) in a chain. Pilates training: Bridge, Corkscrew, Tail Wag, Toe Tap, Side Leg Lift, Side Kick, Seated Row, Heel Squeeze Prone, Prone Hip Extension, Prone Back Extension, Cat Stretch, Spine Stretch	Breathing and Stretching training

weeks	First and second	Third and fourth	Fifth and sixth	Seventh and eighth	Ninth-twelfth
Aerobic training intensity (MHR)	55%-60%	60%-65%	65-70%	70-75%	75-80%

2.5. Statistical Methods

All statistical analyses were performed with SPSS program (version 26, SPSS, Inc., Chicago, IL). Values were expressed as mean ± standard deviation (SD). The shapiro wilk test was used to determine the normality of distribution, and variables were found to be normally distributed. Independent sample t-test was used to evaluate homogeneous groups at baseline. Paired t-test was used for comparison of variables before and after exercise. Analysis of covariance (ANCOVA) was used to evaluate differences between control and experimental groups. P-values less than 0.05 were considered statistically significant.

3. Results

The clinical and biochemical characteristics of the study subjects are presented in Table 2..

Table2. *Clinical and biochemical characteristics of experimental (EG), and control groups (CG) (n=14)*

Variable	EG		Paired t-test sig	CG		Paired t-test sig
	Pre-test	Post-test		Pre-test	Post-test	
Age (yr)	45.23±3.58	---	---	44.50±3.10	---	---
Height (Cm)	158.23±4.67	---	---	155.78±2.99	---	---
Weight (Kg)	79.46±7.56	78.11±7.60	---	77.25±5.52	77.60±5.06	---
BMI (kg/m^2)	32.50±2.41	31.21±2.54	---	32.28±2.10	32.00±2.21	---
Subcutaneous fat (%)	31.98±2.45	31.00±1.09	0.001*	33.49±2.21	33.17±1.13	0.24
Body fat index (Index)	36.56±2.98	35.59±1.88	0.01*	38.04±3.77	37.38±3.43	0.90
Waist-to-hip (Ratio)	0.87±0.02	0.85±0.03	0.045*	0.88±0.02	0.88±0.02	0.36
FBS(mg/dl)	93.76±14.34	91.64±13.05	---	100.85±16.02	97.35±13.57	---
Insulin(pmol/L)	10.28±4.10	9.11±3.59	0.55	10.72±4.58	10.86±3.05	0.19
HOMA-IR	2.49±1.20	2.58±1.11	0.67	2.73±1.56	2.38±1.33	0.12

FBS: Fasting Blood Sugar. HOMA-IR: Homeostatic Model Assessment for Insulin Resistance
*P<0.05

The results of Table 2 showed that in the experimental group, there was a significant decrease in subcutaneous fat and body mass in the post-test compared to the pre-test.

Table 3. *The results of the ANCOVA (n=14 in each group)*

Variable		Levene's test		F	Partial Eta squared	Significance
		F	Significance			
Subcutaneous fat (%)	Pre-test	3.74	0.06	34.58	0.58	0.0001*
	Post-test			44.34	0.63	0.001*
Body fat index	Pre-test	2.55	0.14	49.66	0.66	0.0001 *
	Post-test			0.53	0.02	0.47
Waist-to-hip ratio	Pre-test	2.17	0.13	26.19	0.51	0.0001 *
	Post-test			7.80	0.23	0.01*
Skeletal muscle mass	Pre-test	0.87	0.35	313.4	0.92	0.001*
	Post-test			2.50	0.09	0.12
Insulin	Pre-test	0.05	0.81	337.2	51.22	0.67
	Post-test			12.66	1.92	0.07*
HOMA-IR	Pre-test	0.00	0.97	51.12	0.67	0.001*
	Post-test	1		0.97	1.88	0.07

*P<0.05

The results of ANCOVA statistical analysis showed a significant decrease in subcutaneous fat (%), WHR, and Insulin in the experimental group compared to the control group in the post-test.

Since BMI and FBS did not have normal data distribution, the results of Wilcoxon sighed rank and Mann-Whitney- U tests were presented in Tables 4 & 5.

Table 4. *The results of the Wilcoxon signed-rank test to investigate the difference in BMI & FBS*

Variable	Group	Average rank		Z	Significance
		Negative	Positive		
BMI	EG	6.0	0.0	-2.93	0.003*
	CG	6.50	7.43	-.45	.64
FBS	EG	5.75	8.07	-0.77	0.44
	CG	6.88	5.75	-1.25	0.20

BMI: Body mass index, FBS: Fasting blood sugar
*P<0.05

Compared to the pre-test, the results showed a significant decrease in the BMI in the post-test of the experimental group.

Table 5. *The results of the Mann–Whitney U test to investigate the difference in BMI & FBS*

Variable	Average rank		Z	Mann-Whitney U Sig
	EG	CG		
BMI	11.00	18.00	-2.25	0.02*
FBS	16.46	12.54	-1.26	0.21

BMI: Body mass index, FBS: Fasting blood sugar
*P<0.05

The results of statistical analysis showed a decrease in BMI in the experimental group compared to the control group. The results indicated that aerobic Pilates exercises were effective on body composition, but did not affect glucose homeostasis in overweight women.

4. Discussion and Conclusion

The present study was conducted to investigate concurrent Pilates and aerobic exercises on glucose homeostasis and some selected indicators of body composition in obese non-menopausal women. The results of the present study showed that 12 weeks of aerobic and Pilates exercises had a significant positive effect on body composition (BMI, WHR, fat percentage, body obesity index, and muscle mass) In line with our findings, Souza and Lima showed that Yoga practitioners (40 and 65 years, and practiced for at least 5 years) had better anthropometric variables than the physical activity (PA) and sedentary women groups in the same age range(11, 24-27), also had similar results in their study. Obesity is described as an excessive or unusual buildup of fat in adipose tissue, which compromises a person's well-being(28). It is a frequently occurring curable illness of clinical and public health value. Due to a growing sedentary lifestyle of many occupations, high-calorie, high-fat diets, shifting methods of travel, and growing urbanization, obesity is brought on. Exercise in women is related to a remarkable increment in lipolysis of abdominal adipose tissue relative to femoral adipose tissue, suggesting that exercise-driven weight reduction will be concomitant with preferentially diminished abdominal obesity(29). Weight reduction through lowering fat mass decreases the systemic free-fatty acid content in the bloodstream, consequently diminishing its accessibility to skeletal muscle tissue (30). This will restrain the aggregation of intramuscular lipids as well as other fatty acid derivatives that are known to impair insulin signaling in the insulin-resistant muscle, where basal fat oxidation is compromised (31). Adding exercise to calorie-restricted diet regimens improves mitochondrial consistency and skeletal muscle capillarization (32). and initiates enzymes engaged in fatty acid transport and oxidation (33).

In this study, concurrent Pilates and aerobic exercises did not affect glucose homeostasis (FBS, serum insulin, and HOMA-IR). The findings of Souza and Lima (24), Heidary et al.(34), and Jalali et al. support the results obtained in the present study, While in some research, contradictory results were observed (14, 35-38). The positive effect of physical training was more pronounced among people with type 2 diabetes, hypertension, hyperlipidemia, or metabolic syndrome. Indeed, the recorded reductions in total cholesterol, LDL, fasting insulin, and HOMA-IR were not as pronounced in healthy subjects (39). Skeletal muscle mechanisms proposed to mediate training-induced improvements in glycemic control include enhanced capillarization, GLUT4 protein content, glycogen synthesis, and oxidative enzymes coupled with reduced levels of intramuscular lipids (40). Although adult women have a higher percentage of fat mass, there is an increased visceral fat deposition in men. Consequently, there is greater glucose effectiveness and insulin sensitivity among females in comparison with males (41). Reduction in insulin action with aging is related to overall body fat and visceral fat, β-cell function, hepatic insulin action, and total body insulin clearance, and exercise training may mitigate these age-related deficits (42).

The present study suffers from several limitations. First, our intervention's sample size and duration were small and the findings should be interpreted with caution. Second, the control group was not completely sedentary and had their daily activities. Overall obtained data indicated that concurrent aerobic and Pilates training programs effectively improve body composition, and decrease serum insulin in obese females with normal blood glucose.

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References

1. Aranceta-Bartrina, J., Gianzo-Citores, M., & Perez-Rodrigo, C. (2020). Prevalence of overweight, obesity and abdominal obesity in the Spanish population aged 3 to 24 years. The ENPE study. Revista Española de Cardiología (English Edition), 73(4), 290-299. DOI: 10.1016/j.rec.2019.10.002
2. Kolahi, A.-A., Moghisi, A., & Ekhtiari, Y. S. (2018). Socio-demographic determinants of obesity indexes in Iran: findings from a nationwide STEPS survey. Health Promotion Perspectives, 8(3), 187-196. DOI: 10.15171/hpp.2018.29
3. Abiri, B., Ahmadi, A. R., Amini, S., Akbari, M., Hosseinpanah, F., Madinehzad, S. A., et al. (2023). Prevalence of overweight and obesity among Iranian population: a systematic review and meta-analysis. Journal of Health, Population and Nutrition, 42(1), 70. DOI: 10.1186/s41043-023-00426-5
4. Jafari-Adli, S., Jouyandeh, Z., Qorbani, M., Soroush, A., Larijani, B., & Hasani-Ranjbar, S. (2014). Prevalence of obesity and overweight in adults and children in Iran; a systematic review. Journal of Diabetes & Metabolic Disorders, 13, 1-10. DOI: 10.1186/s40200-014-0046-1
5. Veghari, G., Sedaghat, M., Joshaghani, H., Hoseini, A., Niknezhad, F., Angizeh, A., et al. (2023). The prevalence of obesity and its related risk factors in the north of Iran in 2006. Journal of Research in Health Sciences, 10(2), 116-121.
6. Yang, Y. S., Han, B. D., Han, K., Jung, J. H., & Son, J. W. (2022). Obesity Fact Sheet in Korea, 2021: Trends in Obesity Prevalence and Obesity-Related Comorbidity Incidence Stratified by Age from 2009 to 2019. Journal of Obesity & Metabolic Syndrome, 31(2), 169-177. DOI: 10.7570/jomes21045
7. Krogh-Madsen, R., Thyfault, J. P., Broholm, C., Mortensen, O. H., Olsen, R. H., Mounier, R., et al. (2010). A 2-week reduction of ambulatory activity attenuates peripheral insulin sensitivity. Journal of Applied Physiology, 108(5), 1034-1040. DOI: 10.1152/japplphysiol.01163.2009
8. Booth, F. W., Roberts, C. K., & Laye, M. J. (2012). Lack of exercise is a major cause of chronic diseases. Comprehensive Physiology, 2(2), 1143-1211. DOI: 10.1002/cphy.c110025
9. O, R. H. (2008). Metabolic responses to reduced daily steps in healthy nonexercising men. JAMA, 299(11), 1261-1263. DOI: 10.1001/jama.299.11.1261
10. World Health Organization. (2020). Obesity and overweight. Retrieved from https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight
11. Amozadeh, H., Shabani, R., & Nazari, M. (2018). The effect of aerobic training and green tea supplementation on cardio metabolic risk factors in overweight and obese females: A randomized trial. International Journal of Endocrinology and Metabolism, 16(4), e60738. DOI: 10.5812/ijem.60738
12. Malvini, A. (2022). The influence of regular Pilates practice on visceral adipose tissue in postmenopausal women. California State University San Marcos.
13. Sabzevari, F., Mogharnasi, M., & Golestani, F. (2022). Effect of 6 weeks Pilates training along with dill supplementation on serum concentrations of nesfatin-1, lipocalin-2, and insulin resistance in females with overweight and obesity: A randomized controlled trial. Journal of Research in Medical Sciences: The Official Journal of Isfahan University of Medical Sciences, 27.
14. Shabani, R. (2019). Effect of 8 week resistance training on adiponectin, insulin resistance, insulin sensitivity and HbA1c levels in overweight men. Journal of Neyshabur University of Medical Sciences, 7(2), 120-131.
15. Christiansen, T., Paulsen, S. K., Bruun, J. M., Overgaard, K., Ringgaard, S., Pedersen, S. B., et al. (2009). Comparable reduction of the visceral adipose tissue depot after a diet-induced weight loss with or without aerobic exercise in obese subjects: a

12-week randomized intervention study. European Journal of Endocrinology, 160(5), 759-767. DOI: 10.1530/EJE-08-0789

16. Ross, R., Soni, S., & Houle, S. (2020). Negative energy balance induced by exercise or diet: Effects on visceral adipose tissue and liver fat. Nutrients, 12(4), 891. DOI: 10.3390/nu12040891
17. Špirtović, O., Čaprić, I., Stanković, M., Đorđević, D., Murić, B., Kahrović, I., et al. (2023). The effects of preventive aerobics mix on body composition in healthy adult women. Frontiers in Physiology, 14, 316. DOI: 10.3389/fphys.2023.1130747
18. De Strijcker, D., Lapauw, B., Ouwens, D. M., Van de Velde, D., Hansen, D., Petrovic, M., et al. (2018). High intensity interval training is associated with greater impact on physical fitness, insulin sensitivity and muscle mitochondrial content in males with overweight/obesity, as opposed to continuous endurance training: a randomized controlled trial. Journal of Musculoskeletal & Neuronal Interactions, 18(2), 215-224.
19. Jelstad, S., Ditta Valsdottir, T., Johansen, E. I., & Jensen, J. R. (2021). Eight sessions of endurance training decrease fasting glucose and improve glucose tolerance in middle-aged overweight males. Archives of Physiology and Biochemistry, 127(1), 12-19. DOI: 10.1080/13813455.2020.1733632
20. Kanaley, J. A., Colberg, S. R., Corcoran, M. H., Malin, S. K., Rodriguez, N. R., Crespo, C. J., et al. (2022). Exercise/physical activity in individuals with type 2 diabetes: a consensus statement from the American College of Sports Medicine. Medicine and Science in Sports and Exercise.
21. Parveen, A., Kalra, S., & Jain, S. (2023). Effects of Pilates on health and well-being of women: a systematic review. Bulletin of Faculty of Physical Therapy, 28(1), 1-12. DOI: 10.1186/s43161-023-00515-3
22. Naz, H., Mushtaq, K., Butt, B. A., & Khawaja, K. I. (2017). Estimation of body fat in Pakistani adults: A comparison of equations based upon skinfold thickness measurements. Pakistan Journal of Medical Sciences, 33(3), 635-639. DOI: 10.12669/pjms.333.13036
23. Arguz, H., & İribalci, Ş. (2023). The effect of Pilates exercises applied to overweight and obese women on body composition. Turkish Journal of Sport and Exercise, 25(3), 507-516. DOI: 10.5152/turksportexe.2023.222
24. Souza, L. A. C. e, & Lima, A. A. (2022). Anthropometric, biochemical and clinical parameters in climacteric yoga practitioners. Climacteric, 25(3), 293-299. DOI: 10.1080/13697137.2022.2074509
25. Shabani, R., Jalali, Z., & Nazari, M. (2018). Effects of concurrent strength and aerobic training on blood glucose homeostasis and lipid profile in females with overweight and obesity. Zahedan Journal of Research in Medical Sciences, 20(4).
26. Shabani, R., Nazari, M., Dalili, S., & Rad, A. H. (2015). Effect of Circuit Resistance Training on Glycemic Control of Females with Type II Diabetes. International Journal of Preventive Medicine, 6, 34.
27. Salarinia, M., Azizi, M., Tahmasebi, W., & Khalvandi, H. (2023). Effect of eight weeks of vitamin D supplementation and water-based exercise on cardiometabolic profile in women with type 2 diabetes. Science & Sports, 38(3), 283-292. DOI: 10.1016/j.scispo.2022.12.004
28. De Lorenzo, A., Romano, L., Di Renzo, L., Di Lorenzo, N., Cenname, G., & Gualtieri, P. (2020). Obesity: A preventable, treatable, but relapsing disease. Nutrition, 71, 110615. DOI: 10.1016/j.nut.2019.110615
29. Horowitz, J. F., Leone, T. C., Feng, W., Kelly, D. P., & Klein, S. (2000). Effect of endurance training on lipid metabolism in women: a potential role for PPARα in the metabolic response to training. American Journal of Physiology-Endocrinology and Metabolism, 279(2), E348-E355. DOI: 10.1152/ajpendo.2000.279.2.E348
30. Blaak, E. E., Wolffenbuttel, B. H. R., Saris, W. H. M., Pelsers, M. M., & Wagenmakers, A. J. M. (2001). Weight reduction and the impaired plasma-derived free fatty acid oxidation in type 2 diabetic subjects. The Journal of Clinical Endocrinology & Metabolism, 86(4), 1638-1644. DOI: 10.1210/jcem.86.4.7306
31. Krebs, M., & Roden, M. (2005). Molecular mechanisms of lipid-induced insulin resistance in muscle, liver and vasculature. Diabetes, Obesity and Metabolism, 7(6), 621-632. DOI: 10.1111/j.1463-1326.2005.00487.x
32. Hawley, J. A. (2002). Adaptations of skeletal muscle to prolonged, intense endurance training. Clinical and Experimental Pharmacology and Physiology, 29(3), 218-222. DOI: 10.1046/j.1440-1681.2002.03666.x
33. Hoppeler, H., & Fluck, M. (2003). Plasticity of skeletal muscle mitochondria: structure and function. Medicine and Science in Sports and Exercise, 35(1), 95-104. DOI: 10.1249/01.MSS.0000106193.10551.8E
34. Heidary, H., Shabani, R., & Izaddoust, F. (2019). The effect of eight weeks aerobic interval-resistance training combined with chamomile consumption on body composition and glucose homeostasis in overweight and obese women: A randomized clinical trial. Journal of Rafsanjan University of Medical Sciences, 17(11), 1043-1054.
35. Karimnezhad, N., Mahdavi Roshan, M., Izaddost, F., & Shabani, R. (2019). The simultaneous effects of green coffee and combined exercise training on body composition and glucose homeostasis in obese and overweight women. Journal of Medicinal Plants, 18(72), 215-227.
36. Rostami, F., & Shabani, R. (2019). The effect of eight weeks aerobic training on serum irisin, glucose homeostasis and blood lipid levels in untrained women. Journal of Sabzevar University of Medical Sciences, 26(2), 185-193.
37. Shabani, R. (2017). The effect of concurrent aerobic–resistance exercise training on estrogen level and glucose homeostasis of menopausal females with blood glucose impairment. Iranian Journal of Rehabilitation Research, 3(3), 1-10.
38. Jalali, Z., Shabani, R., & Nazari, M. (2018). Effects of concurrent resistance-endurance training on body composition, lipid profile and blood glucose homeostasis in obese girls: A clinical trial. Journal of Pediatric Nursing, 4(4), 24-34.
39. Bondoc, I., Cochrane, S. K., Church, T. S., Dahinden, P., Hettwer, S., Hsu, F. C., et al. (2015). Effects of a one-year physical activity program on serum C-terminal Agrin Fragment (CAF) concentrations among mobility-limited older adults. The Journal of Nutrition, Health & Aging, 19(9), 922-927. DOI: 10.1007/s12603-015-0068-5
40. Richter, E. A., Sylow, L., & Hargreaves, M. (2021). Interactions between insulin and exercise. Biochemical Journal, 478(21), 3827-3846. DOI: 10.1042/BCJ20210356
41. Bruns, C. M., & Kemnitz, J. W. (2004). Sex hormones, insulin sensitivity, and diabetes mellitus. ILAR Journal, 45(2), 160-169. DOI: 10.1093/ilar.45.2.160
42. Basu, R., Breda, E., Oberg, A. L., Powell, C. C., Dalla Man, C., Basu, A., et al. (2003). Mechanisms of the age-associated deterioration in glucose tolerance: contribution of alterations in insulin secretion, action, and clearance. Diabetes, 52(7), 1738-1748. DOI: 10.2337/diabetes.52.7.1738