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Original Article:

Examining Effects of Pilates Workout and Jujube Supplementation on Liver Fat Content, Enzymes, and Platelet Count

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Abstract

Introduction: Non-alcoholic fatty liver disease (NAFLD) is one of the fastest-growing health issues worldwide. This study aimed to assess the effect of an eight-week Pilates exercise program and jujube supplementation on liver fat content, liver enzymes, and platelet count in women with NAFLD.

Materials and Methods: The current work is a pretest-posttest quasi-experimental study with a control group. Forty middle-aged women with NAFLD were selected via purposive sampling and allocated randomly to four equal groups, including jujube, Pilates, Pilates+jujube, and control. Liver enzymes measurement, platelet count, and ultrasonography were conducted to determine the fatty liver degree 24 hours before and 48 hours after the intervention. The Pilates protocol was performed three sessions weekly for eight weeks. The jujube supplementation group and the Pilates+jujube group consumed .4 g/kg jujube daily in the morning and evening. The collected data were analyzed in SPSS software, using the Kolmogorov-Smirnov, ANOVA, and dependent t-test. The level of significance was set at $P < .05$.

Results: AST, platelet count, waist-to-hip ratio, and fat levels in the Pilates, jujube, and Pilates+jujube groups changed significantly compared with the control group and baseline values ($P < .05$).

Conclusion: Pilates exercise and jujube consumption can lower serum enzyme concentrations along with fat content of the liver and raise blood platelet count. As a result, they may be regarded as efficient techniques to treat NAFLD.

Keywords: Hepatic fat content, Liver enzymes, Non-alcoholic fatty liver disease, Pilates, Platelet count

1. Introduction

Non-alcoholic fatty liver disease (NAFLD) has attracted considerable attention in recent years due to its high prevalence [1] The liver is the primary organ responsible for metabolism, detoxification, and secretory activities in the body, making it susceptible to a variety of disorders [2] Because of the rising incidence of obesity, NAFLD is now the most common chronic liver disease worldwide [3-6]. The disease is characterized by an abnormal triacylglycerol accumulation, inflammation, and liver damage [7], as well as an increase in liver enzymes, including alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (ALP) [8]. It is a growing public health concern globally [9], affecting roughly 25-35% of people in Western countries and 19-32% in Asian societies [10].

NAFLD is a broad term encompassing a variety of chronic liver disorders, ranging from mild osteoporosis to cirrhosis and hepatocellular carcinoma [11]. It is significantly associated with other conditions such as cardiovascular diseases, type 2 diabetes, and metabolic syndrome. Indeed, NAFLD and its associated complications are linked with substantial health care expenses, owing to a lack of precise and effective therapies.

Notably, the pathogenesis of NAFLD and its determinants are not yet fully understood. However, studies suggest that sedentary lifestyles, obesity, and insulin resistance are the primary risk factors for NAFLD [12]. Few medicinal therapies have been proposed for fatty liver, including insulin-increasing pharmaceuticals, lipid-lowering drugs, and antioxidants. Yet, their prolonged use cannot be recommended given their high costs and adverse effects [13]. Instead, a lifestyle with diet modification and exercise is the most important recommendation for NAFLD patients. In practice, exercise is one of the substantial components of NAFLD treatment [12], as emphasized by the American Digestive Association [14]. Studies indicate that physical activity, especially when accompanied by weight loss, will enhance liver function and resistance to insulin [15]. Industrial drugs should be used as a last resort in treating NAFLD due to their side effects on other body organs. Therefore, lifestyle modification with diet, exercise, and herbal medicines should be the cornerstone of NAFLD management [3].

One of the training methods that has been considered recently is Pilates exercise. Pilates workout is a comprehensive hybrid set of stretching and strengthening movements [16]. It builds on mental concentration and breathing rhythm to strengthen deep muscles with the least possible damage [17]. Unlike traditional resistance exercises where muscles are trained individually, Pilates adopts a holistic approach to activating and coordinating several muscle groups at the same time [18, 19]. Despite some contradictory research findings [20], the majority of studies conducted in recent years reveal the crucial impact of Pilates exercises in enhancing physical health [21], body composition, resistance to insulin, and metabolic disorders [16].

Additionally, jujube is among the best-known medicinal plants in treating liver disorders [3]. The plant's fruits, seeds, and leaves are used as medicine, flavor, and food [22]. The herb is used in traditional medicine to treat several diseases such as gastrointestinal disorders, weakness, liver disorders, obesity, kidney problems, diabetes, fever, anemia, and insomnia [23, 24]. Chinese traditional medicine uses jujube to treat tumors and cardiovascular conditions associated with reactive oxygen species (ROS) caused by oxidative stress [24]. Jujube is known to have analgesic properties. It contains high levels of compounds with antioxidant properties such as polyphenols, tannins, and flavonoids [25]. A number of studies have shown that polyphenols and flavonoids isolated from the plant have anemic, hypolipidemic, and antioxidant effects [22]. Research has also reported that jujube extract induces the expression and production of erythropoietin by activating the hypoxia-1 induction factor and other signaling factors that enhance the hematopoietic process [22]. Jujube fruit extract is demonstrated to improve the activity of antioxidant enzymes in the liver [26]. Hence, the reduction of fat peroxidation in liver cells is presumably due to antioxidant compounds in the jujube extract [23]. Given its anti-fibrotic, anti-apoptotic, and anti-inflammatory effects, jujube is recommended as a complementary food to treat NAFLD and reduce side effects in patients [2].

Liver enzyme concentrations and platelet count are two diagnostic measures used to determine liver damage. Liver enzymes increase in cases of a liver lesion, and platelet count decreases [24]. Besides, blood platelets have a pivotal role in inflammation, coagulation, and wound healing [27]. Platelet measurement seems to be a beneficial approach for evaluating the liver fibrosis severity in NAFLD patients [28]. Peripheral platelet count may reflect the severity of liver damage [29]. In fact, the advancement of liver fibrosis is linked to a decrease in thrombopoietin production by liver cells, whereby platelet generation is reduced [30]. Studies have shown that NAFLD samples have lower platelet counts and higher mean volumes [31].

The literature exhibits very few studies on the impact of Pilates and jujube supplementation on liver enzymes, liver fat content, and platelet count. Only Hagner et al. (2015) have examined the effect of Pilates exercises on the enzymes ALT and AST in postmenopausal and obese women. They reported that despite a significant decline in body weight and body mass index, the ALT and AST enzymes did not show a significant difference after 10 weeks of Pilates exercises [15]. There is little information about the efficacy of Pilates exercises and jujube extract supplementation on NAFLD despite the increasing prevalence of the disease. Hence, with the widespread acceptance of Pilates training and traditional medicine, this study aimed to determine the effect of an eight-week Pilates workout program and jujube supplementation on the fat content of the liver, liver enzymes, and platelet count in women with NAFLD in Khaf city.

2. Materials and Methods

The current research is a pretest-posttest quasi-experimental study with a control group. The population included middle-aged women (31-49 years old) with NAFLD residing in Khaf. They were invited to participate through advertisements placed in medical and administrative centers.

Inclusion criteria consisted of middle-aged women aged between 31 and 49 with body mass index ≤ 30 kg and first or higher degrees of fatty liver who consented to participate. Exclusion criteria comprised the presence of other diseases, alcohol or tobacco use, specific diet/medication, dietary supplements, and regular physical activity six months before the study [32].

The sample size was determined using the formula related to unknown population sizes and based on previous studies by considering a confidence level of 95% and an error margin of ±5%. Thus, 40 eligible volunteers were selected via a lottery method [32, 33] and allocated to study groups using a simple random allocation method. The lottery approach considers the pool of participants as a large block to secure a balanced assignment of participants to each study group. Numbers 1 to 40 were written on cards that were placed in similar envelopes and subsequently in a lottery box. Each participant picked a random card. The first 10 cards were assigned to group A (Pilates), the next 10 ones to group B (Pilates + Jujube), the next 10 ones to group C (jujube only), and the last 10 ones to group D (control group). Candidates were numbered in the order of their referral date and assigned to the groups accordingly.

To perform the study, we first obtained permission from the ethics committee and a letter of introduction from the vice-chancellery of education of Mashhad University of Medical Sciences. We presented them to the officials of the 22nd Bahman Hospital of Khaf and explained the study objectives and procedure to the target group. The participants were informed of any possible consequences of the study protocols and that they could withdraw from the project at any time. Subsequently, they signed written consent forms and completed a health-assessment questionnaire, which examined the history of drug use, alcohol use, and smoking. The participants' diet was also controlled using a 24-hour food recall questionnaire. Participants were requested not to alter their eating habits during the study course and that they would be excluded from the study if their diets were altered. All participants underwent ultrasonography 24 hours before and 72 hours after the intervention to assess their fatty liver. Moreover, liver function tests including ALT, AST, ALP, and blood cell count were performed to determine platelet level [2].

Specifications of data collection tools

Pilates exercise protocol: It included 60 minutes of physical activity, comprising 10 minutes of warm-up, 40 minutes of Pilates exercise, and 10 minutes of cool-down. The protocol was performed three sessions a week for eight weeks. Pilates exercises started from lower levels and gradually developed to include advanced stretching movements, muscular endurance, balance, flexibility, and neuromuscular coordination. The movements were performed by focusing on the large muscles of the upper and lower limbs in standing, sitting, and supine positions without any specialized equipment. In line with the overload principle, the speed and repetition of movements in every session increased compared to the preceding session. The protocol started with 10 repetitions in the first week and gradually increased to 20-25 repetitions in the eighth week. Besides, the maximum heart rate formula (maximum heart rate = 220 – age) and heart rate monitor were used to control the training intensity. The exercises began in the first week with an intensity of 50-55% of maximum heart rate and peaked at 75-80% in the eighth week (nearly 5% enhancement in exercise severity per week). It should be noted that the control and jujube extract groups did not attend any exercise program or sports during these eight weeks [33].

Jujube supplementation protocol: The jujube supplementation and Pilates+jujube groups were advised to ingest .4 grams of jujube fruit per kilogram of body weight daily twice daily [24].

Anthropometric evaluation and body composition: A week before the treatment was initiated, a training class was held for the participants to get acquainted with the tools and procedures of the study. Certain anthropometric and body composition variables were measured 24 hours prior and 48 hours after the Pilates exercise protocol. Participants' height was determined via a Seca stadiometer with an accuracy of 0.01 cm. Waist and hip circumference were also measured using a tape measure, and the waist-to-hip ratio (WHR) was calculated accordingly. Weight and body fat percent were also assessed via the bioelectrical impedance analysis using a physical composition analyzer as per the manufacturer's instructions.

Evaluation of liver fat content, liver enzymes, and platelet count: Fat content, serum levels of liver enzymes, and platelet counts were also measured for all participants 24 hours before and 72 hours after the last Pilates exercise session [2]. After six hours of fasting or longer, a specialist performed ultrasonography in the 22nd Bahman Hospital of Khaf to assess liver fat content. The serum levels of liver enzymes platelets counts were measured after 8-12 hours of fasting in the laboratory of 22nd Bahman Hospital.

Ethical considerations

Before the study commenced, the necessary permissions were obtained from the Iranian Registry of Clinical Trials (Identifier: IRCT20210413050954N1) and the Ethics Committee of Mashhad University of Medical Sciences (Ethics Code: IR.MUMS.REC. 1400.078). The collected information remained confidential and was used only for research purposes. Forms of informed moral consent were given to the participants. Individuals who did not wish to continue participating in the study were free to leave the study.

Statistical analyses

The results are presented using descriptive and inferential statistics. First, the data distribution was examined using the Kolmogorov-Smirnov test. The one-way ANOVA test was used at baseline to ensure a lack of differences between the four groups. When examining the hypotheses, the characteristics of the participants and research data were summarized using descriptive statistics. Subsequently, the hypotheses were tested using appropriate statistical methods. The dependent t-test was utilized to compare within-group differences. Likewise, a one-way ANOVA test was administered to investigate between-group differences after treatment. Significance level was considered for all statistical analyses at P <.05.

3. Results

The data obtained from the groups were summarized, categorized, and presented in tables and diagrams. Tables 1, 2, and 3 report anthropometric

Table 1. Anthropometric characteristics of the participants at baseline

Measured parameters	Group	Number	Mean	Standard deviation	P	F
Age (Year)	Pilates	10	38	6.3	0.572	0.676
	Jujube	10	41.6	6.05		
	Pilates plus Jujube	10	38.8	5.53		
	Control	10	40	6.16		
Weight (kg)	Pilates	10	85.6	7.07	0.228	1.513
	Jujube	10	91.9	7.15		
	Pilates plus Jujube	10	88.8	14.38		
	Control	10	93.8	5.82		
Height (cm)	Pilates	10	158.8	2.48	0.579	0.665
	Jujube	10	161.1	4.17		
	Pilates plus Jujube	10	160.5	4.67		
	Control	10	160.1	3.41		

Table 2. Body composition values in study groups

Parameter	Group	Measurement time	Number	Mean	Standard deviation
Weight (kg)	Pilates	Baseline	10	85.60	7.07
		Post-intervention	10	80.5	6.34
	Jujube	Baseline	10	91.9	7.15
		Post-intervention	10	89.7	6.88
	Pilates plus Jujube	Baseline	10	88.8	14.38
		Post-intervention	10	81.30	13.54
	Control	Baseline	10	93.8	5.82
		Post-intervention	10	94.1	6.46
WHR	Pilates	Baseline	10	0.97	0.03
		Post-intervention	10	0.91	0.03
	Jujube	Baseline	10	0.94	0.05
		Post-intervention	10	0.92	0.06
	Pilates plus Jujube	Baseline	10	0.94	0.03
		Post-intervention	10	0.85	0.04

	Control	Baseline	10	0.98	0.02
		Post-intervention	10	0.98	0.02

Table 3. Values of biochemical variables in study groups

Indicator	Group	Measurement time	Number	Mean	Standard deviation
Platelets	Pilates	Baseline	10	207750.4	9199.5
		Post-intervention	10	215234.6	8288.32
	Jujube	Baseline	10	217129.1	8067.29
		Post-intervention	10	219857.5	8210.09
	Pilates plus Jujube	Baseline	10	215471.7	9989.4
		Post-intervention	10	231826.1	10643.07
	Control	Baseline	10	213048.9	10335.06
		Post-intervention	10	213351.7	10357.42
ALT	Pilates	Baseline	10	56	15.31
		Post-intervention	10	47.63	15.44
	Jujube	Baseline	10	61.80	17.88
		Post-intervention	10	57	17.56
	Pilates plus Jujube	Baseline	10	64.40	17.84
		Post-intervention	10	49.50	16.82
	Control	Baseline	10	65.63	17.07
		Post-intervention	10	65.62	16.40
ALP	Pilates	Baseline	10	165.4	14.26
		Post-intervention	10	159.20	13.96
	Jujube	Baseline	10	160.40	9.44
		Post-intervention	10	156.90	8.72
	Pilates plus Jujube	Baseline	10	162.30	12.21
		Post-intervention	10	144.50	9.76
	Control	Baseline	10	169.51	12.93
		Post-intervention	10	169.90	12.56
AST	Pilates	Baseline	10	47	10.95
		Post-intervention	10	42.10	11.38
	Jujube	Baseline	10	49.70	14.06
		Post-intervention	10	46.50	14.08
	Pilates plus Jujube	Baseline	10	46	9.27
		Post-intervention	10	38.10	8.97
	Control	Baseline	10	48.79	11.73
		Post-intervention	10	48.96	11.51

characteristics and measurement parameters, including body composition and biochemical variables at different measurement times.

Kolmogorov-Smirnov test was utilized to evaluate the normal distribution of data. The findings indicated a normal distribution of the data in all four groups (P> .05) (Tables 4 and 5).

Between-group differences at baseline: As seen in Tables 6 and 7, no significant difference existed between the two groups at baseline, with the Levin test indicating equal variances.

Table 4. Results of Kolmogorov-Smirnov test for biochemical variables

Group	Indicator											
	Pilates			Jujube			Pilates plus Jujube			Control		
	N	Z	P	N	Z	P	N	Z	P	N	Z	P
Platelets	10	0.212	0.200	10	0.204	0.200	10	0.251	0.075	10	0.199	0.200
ALT	10	0.152	0.200	10	0.132	0.200	10	0.144	0.200	10	0.130	0.200
ALP	10	0.147	0.200	10	0.145	0.200	10	0.186	0.200	10	0.115	0.200

AST	10	0.136	0.200	10	0.189	0.200	10	0.127	0.200	10	0.160	0.200

Table 5. Results of Kolmogorov-Smirnov test for anthropometric characteristics and body composition

Indicator		Group			
		Height (cm)	Weight (kg)	Age (Year)	WHR
Pilates	N	10	10	10	10
	Z	0.126	0.233	0.163	0.202
	P	0.200	0.133	0.200	0.200
Jujube	N	10	10	10	10
	Z	0.225	0.257	0.154	0.175
	P	0.164	0.059	0.200	0.200
Pilates plus Jujube	N	10	10	10	10
	Z	0.126	0.239	0.157	0.191
	P	0.200	0.112	0.200	0.200
Control	N	10	10	10	10
	Z	0.131	0.218	0.164	0.175
	P	0.200	0.194	0.200	0.200

Table 6. Results of one-way ANOVA test for between-group comparison of biochemical variables at baseline

Indicator		AST	ALT	ALP	Platelets
Significance	Levin	0.816	0.148	0.235	1.072
	F	0.890	0.601	0.387	0.150
	P	0.494	0.930	0.872	0.373

Table 7. Results of one-way ANOVA test for between-group comparison of body composition and anthropometric characteristics at baseline

Indicator		Height (cm)	Weight (kg)	Age (year)	WHR
Significance	Levin	2.086	6.706	0.112	2.554
	F	0.665	0.228	0.676	2.262
	P	0.119	0.001	0.952	0.071

Testing hypotheses

1. The first null hypothesis

Platelet counts in jujube, Pilates, and Pilates+jujube groups will not change significantly after intervention.

Platelet counts of all four groups were compared using a one-way ANOVA test. Descriptive statistics revealed that the platelet levels increased significantly in all three experimental groups over time. In contrast, platelet count did not change significantly in the control group (Table 8).

Given that the four groups were not significantly different at baseline, post-treatment data were analyzed using one-way ANOVA to examine between-group differences (Table 8). The findings revealed that the platelet values in the three experimental groups were significantly different from that of the control group (P = .001; F = 302.41). Therefore, the null hypothesis is rejected (Figure 1).

2. The second null hypothesis

ALP levels in Pilates, jujube, and Pilates+jujube groups will not change significantly after intervention.

ALP levels of all study groups were compared using a one-way ANOVA test. Descriptive statistics revealed that ALP values did not decrease significantly in any of the study groups (Table 9).

Table 8. Results of one-way ANOVA comparing before-after differences and dependent t-test comparing before-after platelet count data across study groups (mean ± standard deviation)

Variable	Group	Before	After	Dependent t-test		ANOVA results for before-after differences
				t	p	
Platelets	Pilates	207750.4±9199.5	215234.6±8288.32	–17.98	0.001	F = 302.41

Jujube	217129.1±8067.29	219857.5±8210.09	−5.67	0.001	P = 0.001
Pilates plus Jujube	215471.7±9989.4	231826.1±10643.07	−37.57	0.001	
Control	213048.9±10335.06	213351.7±10357.42	−1.148	0.281	

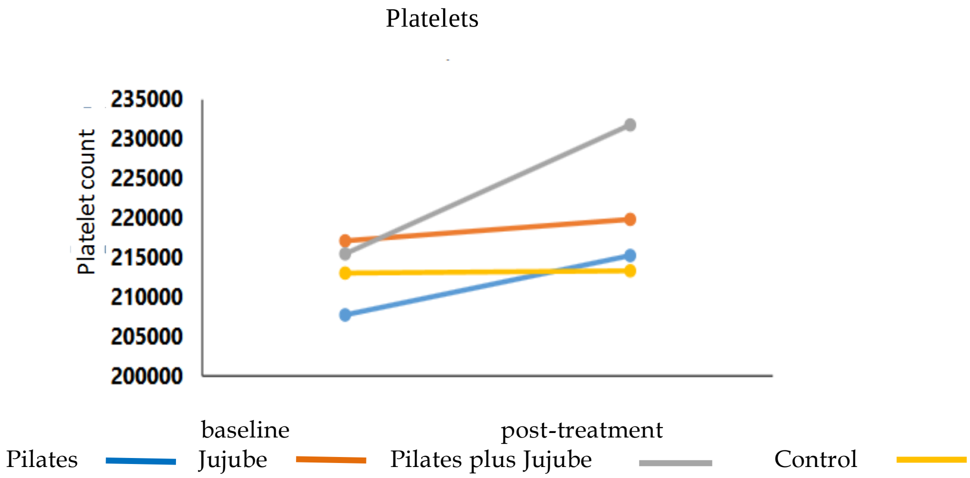


Figure 1. Mean ± standard deviation of platelet values in study groups over time

Table 9. Results of one-way ANOVA comparing before-after differences and dependent t-test comparing before-after ALT levels across study groups (mean ± standard deviation)

Variable	Group	Before	After	Dependent t-test T	Dependent t-test P	ANOVA results for before-after differences
ALP	Pilates	165.4±14.26	159.2±13.96	1.11	0.294	F = 89.91 P = 0.001
	Jujube	160.4±9.44	156.9±8.72	1.92	0.086	
	Pilates plus Jujube	162.3±12.21	144.5±9.76	1.46	0.177	
	Control	169.51±12.93	169.9±12.56	0.466	0.652	

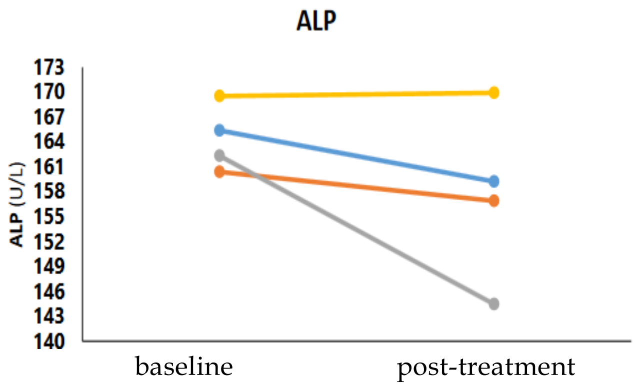
Since no significant difference existed among the four groups at baseline, post-treatment data were analyzed using one-way ANOVA to compare between-group differences (Table 9). The findings indicate a significant difference in ALP levels between the three experimental groups and the control group (P = .001; F = 89.91). Therefore, the second null hypothesis is rejected (Figure 2).

3. The third null hypothesis

ALT levels in Pilates, jujube, and Pilates+jujube groups will not change significantly after intervention.

Baseline ALT levels of all study groups were compared using a one-way ANOVA test. According to descriptive statistics, the ALT value did not decrease significantly in the three experimental groups, nor did it change significantly in the control group (Table 10).

Since no significant differences existed between the four groups at baseline, post-treatment data were

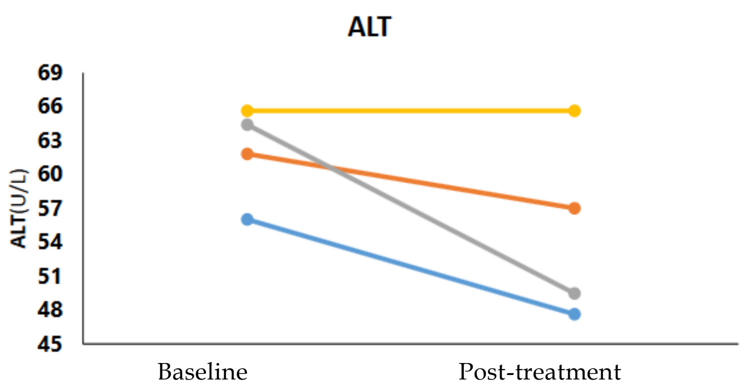


Pilates Jujube Pilates plus Jujube Control

Figure 2. Mean ± standard deviation of ALP levels in study groups over time

Table 10. Results of one-way ANOVA comparing before-after differences and dependent t-test comparing before-after ALP levels across study groups (mean ± standard deviation)

Variable	Groups	Before	After	Dependent t-test		ANOVA results for before-after differences
				t	P	
ALT	Pilates	56±15.31	47.63±15.44	1.57	0.151	F = 208.85 P = 0.001
	Jujube	61.80±17.88	57±17.56	0.863	0.411	
	Pilates plus Jujube	64.40±17.84	49.50±16.82	1.16	0.274	
	Control	65.63±17.07	65.62±16.40	1.05	0.318	



Pilates Jujube Pilates plus Jujube Control

Figure 3. Mean ± standard deviation of ALT levels in study groups over time

analyzed using one-way ANOVA to assess between-group differences (Table 10).

The findings exhibited a significant difference between the experimental and control groups concerning ALT levels (P = .001, F = 208.85). Therefore, the null hypothesis is rejected (Figure 3).

4. The fourth null hypothesis

AST values in jujube, Pilates, and Pilates+jujube groups will not change significantly after intervention.

One-way ANOVA was utilized to compare baseline AST levels in study groups. Based on descriptive statistics, the AST value did not decrease significantly in the three experimental groups, nor did it change significantly in the control group (Table 11).

There was no significant difference between the four groups at baseline; therefore, post-treatment data were analyzed using one-way ANOVA to study between-group differences (Table 11). The findings showed a significant difference between the three experimental groups and the control group in AST levels (P = .001, F = 143.12). As such, the null hypothesis is refuted

(Figure 4).

5. The fifth null hypothesis

WHR values in jujube, Pilates, and Pilates+jujube groups will not change significantly after intervention.

One-way ANOVA was employed to compare baseline WHR levels in study groups. The WHR value dropped significantly in the three experimental groups based on descriptive statistics. However, it did not change significantly in the control group (Table 12).

As there was no significant difference between the four groups at baseline, post-treatment data were analyzed using one-way ANOVA to compare

Table 11. Results of one-way ANOVA comparing before-after differences and dependent t-test comparing before-after AST levels across study groups (mean ± standard deviation)

Variable	Groups	Before	After	Dependent t-test		ANOVA results for before-after differences
				T	P	
AST	Pilates	47±10.95	42.1±11.38	21	0.001	F= 143.12 P= 0.001
	Jujube	49.7±14.06	46.5±14.08	12.82	0.001	
	Pilates plus Jujube	46±9.27	38.1±8.97	22.7	0.001	
	Control	48.79±11.73	48.96±11.51	−0.604	0.561	

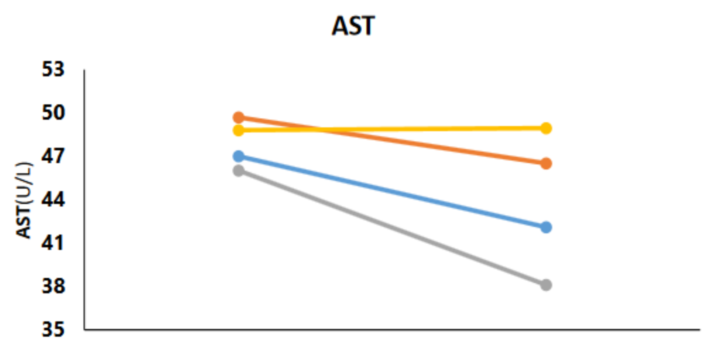
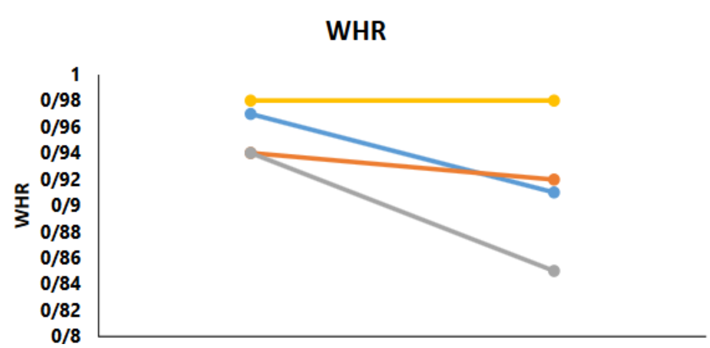


Figure 4. Mean ± standard deviation of AST levels in four groups over time

Table 12. Results of one-way ANOVA comparing before-after differences and dependent t-test comparing before-after WHR levels across study groups (mean ± standard deviation)

Variable	Groups	Before	After	Dependent t-test		ANOVA results for before-after differences
				t	P	
WHR	Pilates	0.97±0.03	0.91±0.03	20.84	0.001	F= 126.41 P= 0.001
	Jujube	0.94±0.05	0.92±0.06	7.21	0.001	
	Pilates plus Jujube	0.94±0.03	0.85±0.04	22.63	0.001	
	Control	0.02±0.98	0.02±0.98	−0.669	0.520	



baseline post-treatment
Pilates Jujube Pilates plus Jujube Control

Figure 5. Mean±standard deviation of WHR in study groups over time

between-group differences (Table 12). The findings indicate a significant difference in WHR levels between the three experimental groups and the control group (P = .001, F = 126.41). Accordingly, the null hypothesis is disapproved (Figure 5).

Data analysis demonstrated significant changes in indices in experimental groups. According to the findings, AST, platelet count, and WHR levels in Pilates, jujube, and Pilates+jujube groups changed significantly compared to baseline and the control group. ALP and ALT enzyme levels in experimental groups did not change significantly compared to baseline. Nonetheless, these changes were significant compared to the changes occurring in the control group.

4. Discussion

The findings of this study demonstrate that eight weeks of Pilates exercise plus jujube supplementation is more effective than Pilates exercise or jujube supplementation administered alone. The combined protocol effectively reduced the serum level of liver enzymes (AST, ALT, and ALP) and increased blood platelet counts. Moreover, WHR significantly decreased more than in other groups. The literature on Pilates exercise and jujube supplementation seems limited. Therefore, more research is needed in this regard. However, among the few related studies is Hagner et al.'s (2015) study, which investigated the effect of Pilates exercises on ALT and AST enzymes in postmenopausal and obese women. The study found that despite a significant reduction in body weight and body mass index, ALT and AST enzymes did not change significantly after 10 weeks of Pilates exercises in postmenopausal and obese women [15]. This is inconsistent with the results of our research, possibly because of the intensity of exercise and lack of jujube supplementation.

In another study conducted by Sharifi et al. (2020), thirty-two non-athlete female volunteers were assigned to four 8-member groups based on body weight. The groups included Pilates, saffron, Pilates+saffron, and placebo. Pilates and Pilates+saffron groups performed Pilates exercises three sessions weekly for 60 minutes per session. The saffron and Pilates+saffron groups took capsules containing 30 mg/day of saffron daily, and the placebo group consumed capsules containing a placebo for eight weeks. The results showed that Pilates training, saffron consumption, and Pilates training+saffron consumption significantly affected fat mass reduction, leading to increased total body water and net body mass. The results also revealed that although Pilates training and saffron consumption alone led to improved body composition, Pilates training+saffron consumption had more favorable effects than either of them alone [34]. This finding is consistent with our results regarding body fat mass reduction assessed via WHR.

In their quasi-experimental study, Nazarieh et al. (2012) examined the effect of eight weeks of resistance training along with Zataria multiflora supplementation on liver enzyme levels in men with NAFLD. The results showed that resistance training, not Zataria multiflora supplementation, may effectively improve liver dysfunction indices (ALP, ALT, and AST) associated with NAFLD [35]. Consistent with our results, lifestyle change, including dietary modification and physical activity, was the most critical advice for patients with NAFLD. Exercise is an essential component of treatment for NAFLD [12], as emphasized by the American Digestive Association [14]. Studies indicate that physical activity, especially with weight loss, enhances the function of the liver and resistance to insulin [15].

In their quasi-experimental study entitled "The effects of dietary weight loss with or without exercise training on liver enzymes in obese metabolic syndrome subjects," Straznicky et al. (2011) examined 63 sedentary and obese men and women who were randomly selected and assigned to intervention and control groups. Exercises were continued for 12 weeks for the intervention group. The results showed that reducing the amount of central body fat and saturated fat consumption are critical stimuli for boosting liver enzymes [36].

Although there are some contradictory findings [20], the majority of studies conducted in recent years indicate the crucial effect of Pilates exercises in boosting physical health [21], body composition, insulin resistance, and metabolic disorders [16]. Pilates exercises involve a comprehensive combination of muscle stretching and strengthening

[16], which strengthen deep muscles with the least possible damage by focusing on the mind and the rhythm of breathing [17]. Keymasi et al. (2017), in their research entitled “Effect of Pilates Training on Hepatic Fat Content and Liver Enzymes in Men with Nonalcoholic Fatty Liver Disease,” randomly allocated 20 middle-aged men with NAFLD into two groups: Pilates and control. The Pilates group participated in a Pilates exercise program for eight weeks. The results revealed that the adipose content of the liver in the Pilates training group significantly decreased compared to the control group. Besides, serum levels of ALT, AST, and ALP enzymes in the Pilates training group decreased compared to the control group. Furthermore, eight weeks of Pilates training significantly reduced body weight, body mass index, fat percentage, and WHR [2], which agrees with our research findings. Among the reasons for the consistency is the similar type of exercise and duration of activity.

The findings of this research are consistent with the study of Beigi et al. (2015), entitled “Effects of aerobic-pilates exercise training on serum levels of liver enzymes and sonography of patients with non-alcoholic fatty liver disease”. In this research, 20 men with NAFLD were selected via purposive sampling and randomly assigned to experimental and control groups. The results demonstrated that serum levels of ALT and AST were significantly reduced in the experimental group. Accordingly, this training protocol seems to significantly affect refining fatty liver disease and its severity and could be utilized as a non-pharmacological approach [37].

A plethora of research has reported that jujube extract induces the expression and generation of erythropoietin by activating the hypoxia-1 induction factor and other signaling factors that enhance the hematopoietic process [22]. Given its anti-fibrotic, anti-apoptotic, and anti-inflammatory effects, jujube can be used as a complementary method to treat NAFLD and reduce side effects in patients [38]. Alongside this, in their study entitled “Effect of Ziziphus jujuba supplementation before one session of acute resistance exercise on the serum glutathione peroxidase and superoxide dismutase activity”, Afzalpour et al. (2017) purposefully and voluntarily selected 24 non-athlete female students of Birjand universities and allocated them randomly to intense resistance exercise and jujube fruit consumption+intense resistance exercise. Individuals in both groups participated in a resistance exercise session consisting of five movements with 90% maximum repetition. The results disclosed that using the jujube supplement enhanced the GPX antioxidant enzyme activity. Nonetheless, this enhancement was not enough to prevent the suppression of these enzymes after resistance training [24].

The findings of our study concerning reduced liver enzymes are consistent with those of Akbulut’s (2020) research entitled “Responses of Uric Acid, Glucose, Thyroid Hormones, and Liver Enzymes to Aerobic and Combined Exercises in University Students”. In this study, 45 male volunteers with a sedentary lifestyle were selected purposively and allocated randomly to aerobic and combined exercise groups. Post-treatment measurements of TSH, T3, T4, AST, ALT, uric acid, and glucose concentrations revealed that aerobic and combined exercise both affect biochemical parameters (thyroid hormones, liver enzymes, uric acid, and glucose). Moreover, combination exercises proved to be more effective than aerobic exercises alone [39].

Lastly, peripheral platelet counts can probably reflect the severity of liver damage [29]. Indeed, the progression of liver fibrosis is associated with liver cells’ reduced thrombopoietin production, which in turn reduces platelet production [30]. In this regard, studies have demonstrated that NAFLD specimens have lower platelet counts and higher mean volumes [31].

5. Conclusion

Overall, very few studies have investigated the effect of Pilates exercises and jujube supplementation on liver enzymes, liver fat content, and platelet count. When put together, lifestyle and diet modifications can positively affect NAFLD. Indeed, exercise especially Pilates workout plus jujube supplementation can reduce the serum concentration of liver enzymes (AST, ALT, and ALP) and raise the number of platelets in the blood.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Mashhad University of Medical Sciences (Ethics Code IR.MUMS.REC.1400.078 and Clinical trial code IRCT20210413050954N1).

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Author's contributions

All authors contributed to the ideas, design, initial draft, and revision of the article. All authors assume responsibility for the correctness of the contents of the article.

Conflict of interest

The authors have no conflict of interests to declare.

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References

[1] Kantartzis K, Rettig I, Staiger H, Machann J, Schick F, Scheja L, et al. An extended fatty liver index to predict non-alcoholic fatty liver disease. Diabetes Metab. 2017; 43(3):229-39. [DOI:10.1016/j.diabet.2016.11.006] [PMID]

[2] Keymasi Z, Sadeghi A, Pourrazi H. Effect of Pilates Training on Hepatic Fat Content and Liver Enzymes in Men with Non-alcoholic Fatty Liver Disease in Qazvin. J Shahrekord Univ Med Sci. 2020; 22(1):22-28. [DOI:10.34172/jsums.2020.05]

[3] Mahady SE, George J. Exercise and diet in the management of nonalcoholic fatty liver disease. Metabolism. 2016; 65(8):1172-82. [DOI:10.1016/j.metabol.2015.10.032] [PMID]

[4] van der Windt DJ, Sud V, Zhang H, Tsung A, Huang H. The effects of physical exercise on fatty liver disease. Gene Expr. 2018; 18(2):89-91. [DOI:10.3727/105221617X15124844266408] [PMID] [PMCID]

[5] Orangi E, Ostad Rahimi A, Mahdavi R, Somi MH, Tarzemani MK. Oxidative stress-related parameters and antioxidant status in non-alcoholic fatty liver disease patients. Iran J Endocrinol Metab. 2011; 12(5):493-9. http://ijem.sbmu.ac.ir/article-1-797-en.html

[6] Celikbilek M, Gürsoy S, Deniz K, Karaman A, Zararsiz G, Yurci A. Mean platelet volume in biopsy-proven non-alcoholic fatty liver disease. Platelets. 2013; 24(3):194-9. [DOI:10.3109/09537104.2012.688898] [PMID]

[7] Donnelly KL, Smith CI, Schwarzenberg SJ, Jessurun J, Boldt MD, Parks EJ. Sources of fatty acids stored in liver and secreted via lipoproteins in patients with nonalcoholic fatty liver disease. J Clin Invest. 2005; 115(5):1343-51. [DOI:10.1172/JCI23621] [PMID] [PMCID]

[8] St George A, Bauman A, Johnston A, Farrell G, Chey T, George J. Independent effects of physical activity in patients with nonalcoholic fatty liver disease. Hepatology. 2009; 50(1):68-76. [DOI:10.1002/hep.22940] [PMID]

[9] Younossi ZM, Koenig AB, Abdelatif D, Fazel Y, Henry L, Wymer M. Global epidemiology of nonalcoholic fatty liver disease—meta-analytic assessment of prevalence, incidence, and outcomes. Hepatology. 2016; 64(1):73-84. [DOI:10.1002/hep.28431] [PMID]

[10] Damor K, Mittal K, Bhalla AS, Sood R, Pandey RM, Guleria R, et al. Effect of progressive resistance exercise training on hepatic fat in Asian Indians with non-alcoholic fatty liver disease. J adv Bmed 2013; 4(1):114-24. [DOI:10.9734/BJMMR/2014/4845]

[11] Arshad T, Golabi P, Paik J, Mishra A, Younossi ZM. Prevalence of nonalcoholic fatty liver disease in the female population. Hepatol Commun. 2019; 3(1):74-83. [DOI:10.1002/hep4.1285]

[12] Kistler KD, Brunt EM, Clark JM, Diehl AM, Sallis JF, Schwimmer JB, et al. Physical activity recommendations, exercise intensity, and histological severity of nonalcoholic fatty liver disease. Am J Gastroenterol. 2011; 106(3):460-8. [DOI:10.1038/ajg.2010.488] [PMID] [PMCID]

[13] Hallsworth K, Fattakhova G, Hollingsworth KG, Thoma C, Moore S, Taylor R, et al. Resistance exercise reduces liver fat and its mediators in non-alcoholic fatty liver disease independent of weight loss. Gut. 2011; 60(9):1278-83. [DOI:10.1136/gut.2011.242073] [PMID] [PMCID]

[14] Suspected NB. American gastroenterological association medical position statement: nonalcoholic fatty liver disease. Gastroenterology. 2002; 123:1702-4. [DOI:10.1053/gast.2002.36569]

[15] Hagner-Derengowska M, Kałużny K, Budzyński J. Effects of Nordic Walking and Pilates training programs on aminotransferase activity in overweight and obese elderly women. J Educ Health Sport. 2015; 5(12):563-80. [DOI:10.5281/zenodo.44249]

[16] Aladro-Gonzalvo AR, Machado-Díaz M, Moncada-Jiménez J, Hernández-Elizondo J, Araya-Vargas G. The effect of Pilates exercises on body composition: a systematic review. J bodyw Mov Ther. 2012; 16(1):109-14. [DOI:10.1016/j.jbmt.2011.06.001] [PMID]

[17] Mir P, Mir Z. Effect of 8 weeks pilates exercise on plasma visfatin and insulin resistance index in obese women. NJV. 2016; 3(8):1-12. http://njv.bpums.ac.ir/article-1-735-en.html

[18] Conte JM, Jacobs RR. Validity evidence linking polychronicity and big five personality dimensions to

absence, lateness, and supervisory performance ratings. Human Performance. 2003; 16(2):107-29. [DOI:10.1207/S15327043HUP1602_1]

[19] Kloubec JA. Pilates for improvement of muscle endurance, flexibility, balance, and posture. J Strength Cond Res. 2010; 24(3):661-7. [DOI: 10.1519/JSC.0b013e3181c277a6.] [PMID]

[20] Marinda F, Magda G, Ina S, Brandon S, Abel T, Ter Goon D. Effects of a mat pilates program on cardiometabolic parameters in elderly women. Pak J Med Sci. 2013; 29(2):500-4. [DOI:10.12669/pjms.292.3099] [PMID] [PMCID]

[21] Lim HS, Yoon S. The effects of Pilates exercise on cardiopulmonary function in the chronic stroke patients: a randomized controlled trials. J Phys Ther Sci. 2017; 29(5):959-63. [DOI:10589/jpts.29.959] [PMID] [PMCID]

[22] Mohebbati R, Kamkar-Del Y, Shafei MN. Effect of ethyl acetate and aqueous fractions of Ziziphus jujuba extract on biochemical and hematological parameters in rat. J Pharm Sci. 2019; 8(2):224-28. [DOI:10.4103/jrptps.JRPTPS_61_18]

[23] Taati M, Alirezaei M, Meshkatalsadat MH, Rasoulian B, Kheradmand A, Neamati SH. Antioxidant effects of aqueous fruit extract of Ziziphus jujuba on ethanol-induced oxidative stress in the rat testes. Iran J Vet Res. 2011; 12(1):39-45. [DOI:10.22099/IJVR.2011.39]

[24] Afzalpour ME, Abtahi Eivari H, Rezazadeh A, Soluki A. Effect of Ziziphus jujuba supplementation before one session of acute resistance exercise on the serum glutathione peroxidase and superoxide dismutase activity. Horizon Med Sci. 2015; 21(2):97-104. [DOI:10.18869/acadpub.hms.21.2.97]

[25] Zhang H, Jiang L, Ye S, Ye Y, Ren F. Systematic evaluation of antioxidant capacities of the ethanolic extract of different tissues of jujube (Ziziphus jujuba Mill.) from China. Food Chem Toxicol. 2010; 48(6):1461-5. [DOI:10.1016/j.fct.2010.03.011] [PMID]

[26] Akbari M, Moradi L, Abbassi Daloii A. The effect of endurance training and Ziziphus jujube extract consumption on apoptosis of cardiac tissue in male Wistar rats. Feyz. 2018; 22(6):547-54. http://feyz.kaums.ac.ir/article-1-3625-en.html

[27] Abbaspour N, Nazari M, Shabani R. Effect of a period of concurrent endurance training and Pilates on the reactive protein, fibrinogen and Blood cell count of obese and normal weight girls. NUMS. 2018; 6(1):22-32. https://www.semanticscholar.org

[28] Yoneda M, Fujii H, Sumida Y, Hyogo H, Itoh Y, Ono M, et al. Platelet count for predicting fibrosis in nonalcoholic fatty liver disease. J Gastroenterol. 2011; 46(11):1300-6. [DOI:10.1007/s00535-011-0436-4] [PMID]

[29] Garjani A, Safaeiyan A, Khoshbaten M. Association between platelet count as a noninvasive marker and ultrasonographic grading in patients with nonalcoholic fatty liver disease. Hepat Mon. 2015; 15(1):1-6. [DOI:10.5812/hepatmon.24449] [PMID] [PMCID]

[30] Kaneda H, Hashimoto E, Yatsuji S, Tokushige K, Shiratori K. Hyaluronic acid levels can predict severe fibrosis and platelet counts can predict cirrhosis in patients with nonalcoholic fatty liver disease. J Gastroenterol Hepatol. 2006; 21(9):1459-65. [DOI:10.1111/j.1440-1746.2006.04447.x] [PMID]

[31] Ozhan H, Aydin M, Yazici M, Yazgan O, Basar C, Gungor A, et al. Mean platelet volume in patients with non-alcoholic fatty liver disease. Platelets. 2010; 21(1):29-32. [DOI:10.3109/09537100903391023] [PMID]

[32] Hoseini Z, Behpour N, Hoseini R. The Effect of Aerobic Training and Vitamin D Supplementation on Blood Pressure in Elderly Women with Nonalcoholic Fatty Liver and Vitamin D Deficiency. J Fasa Univ Med Sci.2019; 9(2):1335-45. [DOI:20.1001.1.22285105.2019.9.2.16.1]

[33] Keymasi Z, Sadeghi A, Pourrazi H. Effect of pilates training on hepatic fat content and liver enzymes in men with non-alcoholic fatty liver disease in Qazvin. J Shahrekord Univ Med Sci. 2020; 22(1):22-8. [DOI:10.34172/jsums.2020.05]

[34] Sharifi S, Hassanpour G. The Effect of Pilates Training along with Saffron Consumption on Body Composition of Female. Res Sport Sci Med Plants. 2020; 1(1):58-66. http://78.38.220.161/article_678439_8a81e7c59455c2ad3f4672e044545221.pdf

[35] Nazarieh E, Ghaedi H, Taghipour-Asrami A. Effect of 8 Weeks Resistance Training with Zataria Multiflora Supplementation on Liver Enzymes, Hepatic Steatosis Index in Men with Non-Alcoholic Fatty Liver. Int J Appl Exerc Physiol. 2020; 16(31):115-26. [DOI:10.22080/JAEP.2020.18178.1931]

[36] Straznicky NE, Lambert EA, Grima MT, Eikelis N, Nestel PJ, Dawood T, et al. The effects of dietary weight loss with or without exercise training on liver enzymes in obese metabolic syndrome subjects. Diabetes Obes Metab. 2012; 14(2):139-48. [DOI:10.1111/j.1463-1326.2011.01497.x] [PMID]

[37] Beigi S, Hematfar A, Kheiri Y, Beigi M. Effects of aerobic-pilates exercise training on serum levels of liver enzymes and sonography of patients with non-alcoholic fatty liver disease. JPSBS. 2020; 8(16):102-15. [DOI:10.22077/JPSBS.2019.1689.1426]

[38] Salem NA, Hamza A, Alnahdi H, Ayaz N. Biochemical and molecular mechanisms of platelet-rich plasma in ameliorating liver fibrosis induced by dimethylnitrosurea. Cell Physiol Biochem. 2018; 47(6):2331-9.[DOI:10.1159/000491544] [PMID]

[39] Akbulut T. Responses of Uric Acid, Glucose, Thyroid Hormones and Liver Enzymes to Aerobic and Combined Exercises in University Students. Higher Education

Studies. 2020; 10(1):109-14. [DOI:10.5539/hes.v10n1p109]