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The effects of pilates exercise on lipid metabolism and inflammatory cytokines mRNA expression in female undergraduates

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Hyo-Jin Kim, Jiyeon Kim and Chang-Sun Kim. The Effects of Pilates Exercise on Lipid Metabolism and Inflammatory Cytokines mRNA expression in Female Undergraduates. *JENB*., Vol. 18, No. 3, pp.267-275, 2014 **[Purpose]** The purpose of the study was to verify the effects of Pilates exercise by observing the impact of 8 weeks of Pilates exercise on lipid metabolism and inflammatory cytokine mRNA expression in female undergraduates in their 20s who had no prior experience in Pilates exercise and had not exercised in the previous 6 months. **[Methods]** There were 18 subjects with no prior experience in Pilates exercise. The subjects were separated into the Pilates exercise group (n = 9) and the non-exercise control group (n = 9). The former performed Pilates exercise for 60-70 minutes over 8 weeks with a gradual strength increase of 9-16 in the Rating of Perceived Exercise (RPE). The body composition, creatine kinase in the bloodstream and lipid metabolism (TC, LDL-C, HDL-C, TG) were measured before and after the experiment and Real-Time PCR was used to investigate the mRNA expression of the inflammatory cytokines IL-6 and TNF-α. **[Results]** The creatine kinase (CK) in the blood had significant differences between the groups. The test group showed significant increase compared to the control group after 8 weeks of Pilates exercise ($p = 0.007$). Lipid analysis showed that the level of high-density lipoprotein cholesterol (HDL-C) was significantly different in the two groups ($p = 0.049$), with the Pilates exercise group exhibiting significantly higher levels compared to the control group. No significant differences were observed in the levels of total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C) and triglyceride (TG). IL-6 mRNA expression did not show significant differences between the groups either. Timing and TNF-α mRNA expression showed significant effect in both the exercise and the control groups ($p = 0.013$) but no correlation. **[Conclusion]** It was found from the study that Pilates exercise for 8 weeks affected CK expression (the muscle damage marker) and induced positive changes in the levels of high-density lipoprotein. **[Key words]** Pilates, creatine kinase, lipid metabolism, inflammatory cytokine mRNA.

INTRODUCTION

Pilates is known to strengthen and stabilize the core part of the body by slow and strong muscular contraction repetition with deep breathing. It also enhances the muscles by making the body flexible [36] and balanced while correcting posture [12,16,38]. In addition, Pilates exercise promotes health and beauty [14] and has received particularly high interest among young women [35].

A recent study showed that Pilates exercise enhanced the back muscles for spine stabilization and provided significant benefits in enhancing body flexibility [17]. Another study on pre-menopausal career women reported that the exercise positively improved their bone densities [28] and a musculo-skeletal system study reported that Pilates exercise was an effective training program for ballet dancers with spinal deformation to improve pelvis and spine correction efforts [20]. In addition, a psychological study reported that Pilates exercise boosted physical self-efficacy and concept and positively affected emotion [1,19]. In addition, there has been a substantial number of studies on the effect of Pilates exercise on body composition, blood lipid and muscular strength [5, 29,30,34]. However, it is judged that the results of these studies are insufficient to normalize the changes in body composition, blood lipid and muscular strength from Pilates exercise and additional in-depth research is required.

Creatine kinase (CK) is the enzyme which transforms adenosine di-phosphate (ADP) and creatine phosphate into adenosine tri-phosphate (ATP) and creatine. CK exists in large quantities in the muscle [7]. Generally, the substance

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fluctuates significantly with exercise, is highly correlated with exercise intensity, time and amount and is used as the biochemical indicator of muscular damage [3]. The type of Pilates exercise performed in the study was resistant Pilates using resistant elastic bands and foam rollers. The study investigated the impact of the exercise on muscular damage by measuring fluctuation of the CK index.

In addition, it is known that regular exercise improves blood lipid levels and decreases arteriosclerosis [2]. It has been reported that long-term exercise decreases TG, TC and LDL levels and increases the level of HDL [39]. A combination of muscular and aerobic exercise has been reported to significantly decrease the level of TG [24]. However, the number of studies on the impact of Pilates exercise on blood lipid metabolism including the levels of TG, TC, LDL and HDL are currently insufficient.

It is known that the TNF-α secreted from mastocytes stimulates the secretion of IL-6 and acute reactive protein, causing athermanous arteriosclerosis in the coronary artery [11]. Positive changes in blood lipid through regular physical activities improve the vascular inflammation indicator implicated as a major factor in vascular disease [15]. A recent study [8] reported that IL-6 and TNF-α significantly decreased as a result of judo practice in obese adolescents. Meanwhile, there were prior reports stating that TNF-α concentration did not significantly change despite continuous aerobic exercise [14,42]. Some studies have also reported that exercise did not cause positive changes in the level of IL-6 [31,42]. There are a lot of research results with opposite conclusions and there has been no studies yet comparing the inflammatory cytokine mRNA concentration after Pilates exercise.

Therefore, this study employed 8 weeks of Pilates exercise for female undergraduates in their 20s to evaluate how the exercise affected lipid metabolism, as well as CK and inflammatory cytokine mRNA changes.

METHODS

Research subject

The subjects in the study were healthy female undergraduates with no specific diseases and no experience in systematic exercise for the previous 6 months. A total of 22 subjects were recruited for the study, with the Pilates exercise group and the control group containing 11 subjects each. The total number of subjects included in the final analysis was 18, excluding 4 subjects with poor attendance or dropout. The characteristics of the subjects are in Table 1.

Research procedure

The research team provided specific information on the purpose and overall process of the study to the subjects and all the participants read the documentation on the study, approved their participation and provided written consent. The study team provided Pilates exercise classes and mats for 8 weeks, then compared and analyzed the physical composition, serum lipid and inflammatory cytokine mRNA expression of the subjects.

Pilates exercise program

The Pilates exercise group participated in the exercise program for 70-80 minutes a day, 3 days a week for a period of 8 weeks while the control group enjoyed their everyday lives. The Pilates exercise group was also advised to consume proper nutrition during the exercise period. <Table 2> shows the exercise program. The exercise group performed warm-up with light breathing and stretching for 10 minutes, main exercise for 50-60 minutes and warm down for 10 minutes, for a total of 70-80 minutes. The Pilates exercise program was based on official programs used by the New York Pilates Academy International-Pilates method (PAI) and San Francisco Balanced Body University-Pilates method (BBU) and items were used for the exercise. The exercise intensity was as follows: 1-2 weeks (RPE: 9-12), 3-6 weeks (RPE: 10-14) and 7-8 weeks (RPE: 11-16), with the Rating of Perceived Exertion (RPE) considering individual physical features.

Measured item

Physical composition

The study used the body composition analyzer (In-Body 720 Bio-Space Co., Korea) with bioelectrical impedance

Table 1. Participant's Physical Characteristics (M ± SD)

Group (N)	Age (Yrs)	Height (cm)	Weight (kg)	Fat (%)	BMI (kg/m²)
PEG (n = 9)	21.22 ± 2.39	159.11 ± 9.20	53.56 ± 9.59	27.72 ± 5.03	21.29 ± 2.47
NEG (n = 9)	21.88 ± 3.06	163.06 ± 5.69	53.51 ± 9.03	24.58 ± 4.83	20.18 ± 2.24

BMI: Body Mass Index, PEG: Pilates Exercise Group, NEG: Non Exercise Group

analysis to investigate the height, weight, body fat, muscle quantity and body mass index of the subjects. All the subjects wore clothes as light as possible for accurate examination, removed metallic materials which impeded the current flow and refrained from ingesting water for 2 hours before the examination. The body composition examination measured the weight, body mass index and body fat ratio.

Blood lipid metabolism and CK analysis

The subjects fasted for more than 8 hours before blood analysis. The before analysis was performed before 24 hours of exercise. Also the after analysis was performed after 24 hours of exercise and the analysis was performed after more than 8 hours of fasting. 10ml of blood was sampled from the antecubital vein by an experienced specialist using a disposable syringe. The sampled blood was left at room temperature for 30 minutes and the serum was separated by centrifugation for 15 minutes at 3,500rpm. The separated serum was transferred to a special blood analysis company (SQLab, Seoul) to analyze the total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C) and creatine kinase (CK). The level of low-density lipoprotein cholesterol (LDL-C) was estimated using the equation below.

LDL-C = TC - HDL - TG/5

Cytokine mRNA Expression from PBMC

PBMC isolation

EDTA treated on approximately 4ml of blood sample to PBMC extraction, the same volume of PBS (phosphate-buffered saline) was added to dilute. And layered 4ml of Ficoll-Paque (Pharmacia, Sweden), then centrifuged 400 × g at room temperature for 20 min. The separated PBMC at the boundary between the blood and the Ficoll-Paque was obtained, then phosphate-buffered saline were added 2 times and washed to obtain pure PBMC.

Total RNA extraction

PBMC isolation and total RNA extraction is conducted by modified method of Pacifici *et al*. [35], the entire process was operated in a sterile condition. Total RNA was extracted from separated mononuclear cells through modified acid guanidinium-thiocyanate-phenol-chloroform extraction method [36] using RNAzol Kit (Guadinethiocyanate 4M, 2-metrcaptoethanol 0.1M, Phenol; TEL TEST INC., USA). Briefly, 0.5ml of RNAzol were put in PBMC to dissolve cells, 0.05ml chloroform was added and mixed on ice for 5 minutes, then centrifuged 12,000 × G at 4℃ for 15 minutes. After centrifuge 0.5ml of isopropyl alcohol was added to the supernatant to extract total RNA, the extracted RNA was confirmed using a spectrophotometer. Finally extracted RNA was kept at -80℃ in ethanol until the measurement.

Complementary DNA (cDNA) synthesis by reverse transcription

The cDNA synthesis was conducted using AccuPower RocketScript™ Cycle RT PreMix (Bioneer. KR). Each RNA preserved with 75% alcohol (-80℃) dried at room temperature for 15 minutes, it dissolved with 10 μl of DNase/RNase free double distilled water. According to the manufacturer's instructions, premix including components necessary to cyclic reverse transcription (CTRT) such as reverse transcriptase, oligo (dT) 20, dNTPs, reaction buffer and primers were added in RNA lysate, and DW was added to make the total amount of 20 μl, then cDNA was synthesized. The annealing conditions were at 37℃ for 30 seconds, cDNA synthesis did at 50℃ for 4 minutes, the reverse transcription reaction to remove secondary structure of RNA template was conducted for 30 seconds at 55℃ and repeated 12 times. To confirm DNA extraction, DNA concentration was measured in eluent by A260/A280 ratio using spectrophotometer (ASP-2680, CellTA Gen, KR), then it was kept in -20℃.

Real-time PCR

To analyze cytokine mRNA, we performed cDNA amplifying by Real-time quantitative polymerase chain reaction (Real-time PCR). Cytokines measured in this study were TNF-α, IL-1β, IL-6 and INF-ɣ, and analyzed relative amount with glyceraldehyde 3-phosphate dehydrogenase (GAPDH) mRNA which is housekeeping gene. Forward primer and reverse primer which is react with synthesized cDNA in reverse transcription reaction were designed using Primer Express™ (Applied Biosystems, Foster, CA, USA). Thefollowingis PCR condition, 10 μl of Power SYBR Green PCR Master Mix (Applied Biosystems), 1 μl of 5pMol the forward primer and the reverse primer and 1 μl cDNA were added in each well, finally mixed with Diethylpyrocarbonate (DEPC) treated water, then we performed PCR with total amount of 20 μl solution. Pre-denaturation was done for 5 minutes at 95℃, and denaturation was conducted for 15 seconds at 95℃ each cycle, annealing step was done at 59-60℃ for 60 seconds and repeated 40 times, and then finally reaction at 65~95℃ for 1-5 seconds per each step was performed to melt curve. For SYBR Green analysis, C1000 Thermal Cycler (CFX96 real-time system, Bio-Rad, US) was

Table 2. Pilates Exercise Program

Variable	Pilates Exercise		RPE
Warm Up (10min)	1. breathing	- foamroller	9~10
	2. spine articulation	- roll up/down	
		- neutral/imprint	
		- thoracic massage	
Pilates (50min~60min)	1. half	- foamroller/ball	10~11
	2. roll up	- rolling like a ball	9~11
		- neck roll down	10~11
	3. the hundred	- with small ball	
	4. one leg circle	- straight leg	10~13
	5. swan/superman	- foamroller/ball	11~13
	6. leg stretch series	- single/duble	12~15
	7. leg straight series	- single/duble	12~15
	8. side/ front leg series	- scissors, frog	
		- hip circle/lift	9~16
	9. open leg locker	- roll over/ jackknife	
	10. rotator cuff	- abductor/adductor	10~16
		- external/internal	
	11. push up	- standing	10~16
Cool Down (10min)	1. masage	- neck, spine, leg	10~13
		- QL, IT band	
		- pelvis	
	2. mermaid	- side/front	9~12
	3. side stretch	- shoulder circle	9~10
	4. breathing	- 5 set	9~10

used, the expression level of each target mRNA was corrected by the amount of GAPDH mRNA.

Serum calcium metabolic marker and CK concentration analysis

The serum was isolated from 6ml of blood by centrifuging at 3,000 rpm, and it was stored in a freezer at -80℃. The concentrations of serum Ca, Alb, IP, Mg, ALP and CK was measured by Colorimetry method using Clinimate CA (SEKISUI Chemical Co. Ltd., Japan), ALB plus (Roche Diagnostics, Mannheim, Germany), Clinimate IP (SEKISUI Chemical Co. Ltd., Japan), Roche Integra 800 electrode (Roche Diagnostics, Mannheim, Germany), Modular DDP (Roche Diagnostics, Mannheim, Germany) and Hitachi 7600-110 (Hitachi, Japan), respectively. To correct the Ca concentration which is undervalued by abnormal serum protein, Ca(mg/dl) - Alb(g/dl) + 4.0 formula was used [37]. CK was measured by IFCC method using AU 680 (Beckman coulter, USA).

Table 3. Nucleotide sequence of primer in TNF-α, IL-6 and GAPDH mRNA

		sequence	TM (C°)
TNF-α	(+)	5'- TCC AGA CTT CCT TGA GAC ACG -3'	60
	(-)	5'- CCC GGT CTC CCA AAT AAA TAC -3'	59
IL-6	(+)	5'- GAT GAG TAC AAA AGT CCT GAT CCA -3'	59
	(-)	5'- CTG CAG CCA CTG GTT CTG T -3'	60
GAPDH	(+)	5'- CAA CGA CCA CTT TGT CAA GC -3'	59
	(-)	5'- GGT GGT CCA GGG GTC TTA CT -3'	60

Data processing method

Data processing was performed by calculating the average and standard deviation in the measurements for each group using the Windows statistical program SPSS 18.0. Repeated measures two-way (ANOVA) analysis was used to analyze the differences in the groups, time and to identify group × time interactions. The t-test for matching samples was performed to verify the differences before and after exercise within the exercise group for the interaction analysis. The significant level of all the statistics data is $\alpha = 0.05$.

RESULTS

<Table 4> shows the impact of the 8-week Pilates exercise on blood lipid and inflammatory cytokine mRNA changes.

Table 4. Changes In Body Composition (M ± SD)

Variables	Group	Pre	Post	△(%)	F	P
Weight (kg)	PEG (n = 9)	53.56 ± 9.59	52.60 ± 9.04	-1.63	G:0.007 T:2.332	G: .933 T: .146
	NEG (n = 9)	53.51 ± 9.03	53.39 ± 9.64	-0.33	GT: 1.563	GT: .255
Fat (%)	PEG (n = 9)	27.72 ± 5.03	30.61 ± 3.92	11.71	G:2.502 T:18.274	G: .133 T: .001
	NEG (n = 9)	24.58 ± 4.83	27.10 ± 4.78	11.23	GT: 0.084	GT: .776
BMI (kg/㎡)	PEG (n = 9)	21.29 ± 2.47	20.96 ± 2.43	-1.52	G:0.763 T:1.694	G: .395 T: .211
	NEG (n = 9)	20.18 ± 2.24	20.11 ± 2.43	-0.38	GT: 0.753	GT: .398

△(%) = rate of change, BMI: Body Mass Index
G: Group , T: Time, GT: Group*Time
PEG: Pilates Exercise Group, NEG: Non Exercise Group

Table 5. Changes In Serum Lipid Levels and CK (M ± SD)

Variables	Group	Pre	Post	△(%)	F	P
Cholesterol (mg/dl)	PEG (n = 9)	166.67 ± 15.94	170.55 ± 27.05	2.23	G:4.856 T:0.067	G: .043 T: .799
	NEG (n = 9)	150 ± 30.93	143.22 ± 20.31	-11.95	GT: 0.913	GT: .354
HDL-C (mg/dl)	PEG (n = 9)	53.78 ± 8.07	58.00 ± 8.99	8.55	G:0.104 T:0.023	G: .752 T: .882
	NEG (n = 9)	59.22 ± 14.20	55.56 ± 10.21	-13.95	GT: 4.556	GT: .049
LDL-C (mg/dl)	PEG (n = 9)	96.56 ± 19.45	100.69 ± 27.38	3.33	G:5.836 T:0.245	G: .028 T: .627
	NEG (n = 9)	75.31 ± 19.52	74.93 ± 21.32	-6.60	GT: 0.274	GT: .608
Triglyceride (mg/dl)	PEG (n = 9)	81.67 ± 28.8	59.33 ± 17.85	-20.75	G:0.000 T:4.255	G:1.000 T: .056
	NEG (n = 9)	77.33 ± 37.88	63.66 ± 18.34	-21.33	GT: 0.247	GT: .626
CK	PEG (n = 9)	63.33 ± 19.90	119.11 ± 64.92	95.51	G:2.102 T:4.760	G: .166 T: .044
	NEG (n = 9)	76.89 ± 13.24	67.45 ± 18.79	-19.29	GT: 9.432	GT: .007

△(%) = rate of change
G: Group , T: Time, GT: Group*Time
PEG: Pilates Exercise Group, NEG: Non Exercise Group

Table 6. Chang In Inflammatory Factors (M ± SD)

Variables	Group	Pre	Post	△(%)	F	P
IL-6	PEG (n = 9)	0.48 ± 0.51	0.74 ± 0.46	207.64	G:0.001 T:1.835	G: .978 T: .200
	NEG (n = 9)	0.49 ± 0.76	0.72 ± 0.59	339.32	GT:0.006	GT: .942
TNF-α	PEG (n = 9)	0.14 ± 0.05	0.61 ± 0.32	407.96	G:0.164 T:8.582^{+}	G: .692 T: .013
	NEG (n = 9)	0.16 ± 0.14	0.49 ± 0.59	338.68	GT:0.247	GT: .628

△(%) = rate of change
G: Group , T: Time, GT: Group*Time
PEG: Pilates Exercise Group, NEG: Non Exercise Group

Body composition change

<Table 4> shows the measurements of body composition (weight, body fat ratio, body mass index) for the 8-week Pilates exercise group and the control group. Weight analysis showed the tendency for a decrease in bodyweight in both the exercise and control groups but no significance. Body fat ratio analysis showed a significant increase in both the exercise and control groups ($p < 0.001$) but no interaction effect was observed. The body mass index analysis showed a decrease in both the exercise and control groups but no significant difference.

Blood lipid metabolism and creatine kinase (CK) change

<Table 5> shows the measurement of blood lipid metabolism and CK changes in the exercise and control groups for the 8-week Pilates exercise study. Analysis of blood HDL-C changes showed a group × time interaction effect ($p < 0.05$) and a particular increase in the HDL-C level after Pilates exercise. The blood TC and LDL-C increased significantly in the exercise group ($p < 0.05$) but failed to demonstrate an interaction effect. The change in TG showed no group × time interaction effect either. The blood CK, on the other hand, showed a group × time interaction effect ($p < 0.01$), with a decrease in the control group and a 1.9x increase in the Pilates exercise group.

Inflammatory cytokine mRNA change

<Table 6> shows the result of the blood inflammatory cytokine analysis in the Pilates exercise and control groups after the 8-week Pilates exercise program. Analysis of IL-6 mRNA levels in the blood showed no group × time interaction effect. Analysis of TNF-α mRNA levels in the blood showed a significant increase over time ($p < 0.05$) but no interaction effect was found for group × time.

DISCUSSION

It has been reported that various types of exercise positively affect health and benefit physical improvement. Pilates

emerged recently in the US and has gained popularity with many people in Korea [25,35]. The purpose of this study is to clarify the impact of 8 weeks of Pilates exercise on body composition, blood lipid and inflammatory cytokine mRNA in female undergraduates and to investigate the utility of the Pilates exercise program in the future. The result shows that bodyweight did not change but body fat ratio increased after the 8-week Pilates exercise. However, the body fat ratio increase was found in the control group as well. It may be inferred that the increase was not from the Pilates exercise but was due to poor control of the nutritional and dietary habits of female undergraduates in their 20s during the 8 week period. Park *et al*. [33] reported that there were no significant differences in bodyweight, body fat ratio and Waist Hip Ratio (WHR) during their study on the impact of 12 weeks of Pilates exercise using a mat on the body composition, blood lipid and blood pressure of 30 female undergraduates. Choi *et al*. [9] reported that no significant difference was found in the bodyweight and body fat of subjects participating in Pilates exercise 3 times a week for a period of 16 weeks. These data indicate that the type of exercise affects the results. It is judged that the Pilates exercise in the present study qualifies as highly intensive exercise which may cause muscle damage unlike the aerobic exercise performed in prior studies. A previous study performed by the authors on seniors [6] showed a 1.4x increase in the CK index after one-time Pilates exercise, indicating that the exercise was vigorous enough to cause muscle damage. The current study found that the CK index increased by about 1.9 times after 8 weeks of Pilates exercise. This shows that Pilates exercise is an intensive exercise robust enough to cause damage to muscles. In addition, fascia massage using the foam roller directly stimulates the muscle. It is likely that the muscular stimulation affected the CK index, causing the muscle damage marker index to increase during Pilates exercise, particularly when using the Pilates tool. That is, Pilates exercise with the form roller directly stimulates the muscles and the stimulation results in muscle damage. CK is the major enzyme that controls the ATP-PC system, an indicator that indirectly reflects metabolism in muscle cells and may be used as a marker that indicates the degree of body and muscle damage based on the increase in activation resulting from physical exercise [40]. Kim *et al*. [26] reported that the CK concentration increased significantly after exercise when comparing the concentration before the exercise to the concentration during the restoration period after intensive running. Yoon *et al*. [41] stated that the CK concentration significantly increased right after maximum exercise. The present study confirmed that the CK concentration significantly increased after Pilates exercise, demonstrating that the exercise affected the muscles and caused muscle damage. This means that the Pilates exercise employed in the present study was intensive enough to damage the muscles and the damage led to inflammation and the expression of inflammatory cytokine mRNA. In addition, it was concluded that changes in the experimental environment including poor control over the energy intake, seasonal fluctuation, instrumental error and the menstrual cycle of the female subjects had an effect on body fat, highlighting the importance of strict control over the nutritional intake and experimental conditions.

Meanwhile, Kondo [22] reported that the decrease in body fat ratio positively affected lipid metabolism. Wallace *et al*. [40] reported that increased body fat caused an increase in LDL-C and TG concentrations and a decrease in HDL-C concentration, which is a direct cause of cardiovascular disease. The results of this study confirmed that the exercise group showed significant increases in blood HDL-C concentration despite an increase in the body fat ratio, implying that the Pilates exercise was effective in increasing blood lipid metabolism, particularly with increasing the concentration of HDL-C, despite the body fat ratio increase. However, the study failed to verify that the exercise positively affected the TC, TG and LDL-C concentration decrease. Kim *et al*. [30] reported an interaction effect where TC levels significantly decreased in middle-aged women with more than 30% body fat ratio undertaking Pilates exercise for 90 minutes a day, 3 times a week over a period of 10 weeks and that their TG levels significantly dropped during that time frame. Choi [9] verified the interaction effect with TC, TG and LDL-C concentrations significantly decreasing after 60 minutes of Pilates exercise a day, 5 times a week for 24 weeks. HDL-C levels also increased significantly among the study subjects, who were all senior women. In addition, Kim *et al*. [27] reported that TG concentrations significantly dropped while HDL-C significantly increased in the exercise group consisting of obese female undergraduates undergoing Pilates exercise for 60 minutes a day, 3 times a week for 10 weeks. These results are directly opposite to the results of the current study but it is estimated that the reason for the significant differences in lipid metabolism was due to the studies using obese subjects or providing long-term Pilates exercise for seniors. However, as reported in the previous study, Pilates exercise reduced body fat ratio and positively affected lipid metabolism. Next studies will investigate the use of aerobic Pilates exercise to reduce body fat ratio and focus on the effect of Pilates exercise on blood lipid metabolism.

Meanwhile, the study showed an increase in the concentration of IL-6 mRNA but without statistical significance,

which makes it difficult to conclusively state that the Pilates exercise affected IL-6 levels in the female undergraduates. However, a study by Park *et al*. [33] which provided long-term Pilates exercise for more than 8 weeks reported that IL-6 levels significantly dropped after complex aerobic and muscular exercise for obese women in their 40s. Kim [23] stated that the blood IL-6 concentrations of the exercise group decreased compared to their counterparts in the obese group. As demonstrated by the studies above, there is a possibility that long-term Pilates exercise decreases blood IL-6 concentrations but the studies did not confirm. Considering that prior studies closely linked lipid metabolism to IL-6 concentration, it is expected that the impact of Pilates exercise on the IL-6 concentration of female undergraduates with high body fat ratio would be different. Investigating the impact of Pilates exercise on IL-6 concentration depending on the obesity of the subject will likely provide meaningful results. It is known that the inflammatory cytokine TNF-α significantly influences body fat increase and muscle decrease as it is secreted from the fat and muscle tissues in conjunction with IL-6. Kondo *et al*. [22] reported that the blood TNF-α level was significantly reduced by jogging, walking, muscle exercise, stretching, speed rope and cycling for 30 -60 minutes for 4 - 5 times a week over a period of 7 months with 60 - 70% of the HRR among obese women with an average age of 18. Brunn *et al*. [4] reported that low diet and regular exercise improved inflammation through a significant decrease in the blood TNF-α concentration of 27 highly obese women. Kern *et al*. [21] reported a TNF-α drop as well as body fat decrease by implementing a weight loss program with 39 obese people. Unlike the results of the studies above, this study showed an increase in TNF-α concentration after Pilates exercise. Pedersen *et al*. [23] reported that weight control and mid-level exercise training reduced TNF-α concentration in fat tissue and skeletal muscles and was effective in improving insulin resistance. However, intense exercise caused an inflammatory reaction and increased the blood TNF-α concentration of the test subjects. Petersen *et al*. [35] also reported that the TNF-α concentration rose after extended highly intense exercise. This suggests that the Pilates exercise employed in the present study was intense enough to increase the TNF-α concentration. This conclusion is supported by the observation of significant increase in blood CK concentration after Pilates exercise compared to before the exercise.

In addition, environmental factors and nutritional aspects related to dietary habit were instrumental in increasing body fat ratio after Pilates exercise compared to before the exercise. This suggests that the aerobic component provided by mat Pilates exercise is required. Most people participate in Pilates exercise to lose body fat. A lot of prior studies on Pilates exercise adhere to traditional Pilates programs for rehabilitation or muscle exercise. However, it is suggested that future studies should be performed using a Pilates program that encompasses proper aerobic exercise under thorough analysis for myology.

CONCLUSION

The study which investigated the impact of the 8-week Pilates exercise on the body composition, blood lipid metabolism and inflammatory cytokine expression for the exercise group and control group showed that the Pilates exercise increased the CK and highly affected the muscle to cause damage, did not affect the body fat ratio decrease but was effective in increasing the HDL-C concentration. It is judged that the Pilates exercise in the study was insufficient to improve the obese and blood lipid metabolism due to the failure in exerting positive impact on the TC, TG, LDL-C and inflammatory cytokine mRNA expression. Therefore, it is judged to modify the Pilates exercise program for the exercise purpose and in particular, it is considered that it is required to develop the Pilates exercise program for the purpose of the body fat decrease and lipid metabolism improvement.

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