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복합 운동과 오메가-3(Ω-3PUFA) 보충이 비만 여성의 체성분, 혈청 지질 프로필, 염증 매개체, 근육 성능 및 인지 능력에 미치는 영향

The Effects of Omega-3 (Ω-3PUFA) Supplementation in Combination with Exercise Training on Body Composition, Serum Lipid Profile, Inflammatory Mediators, Muscular Performance, and Cognition Capacity in Obese Women

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요약

본 연구의 목적은 복합운동과 오메가-3 섭취가 중년 비만 여성의 체성분, 혈중 지질, 근 기능, 염증 지표, 인지기능에 미치는 영향을 알아보는 데 있다. 총 21명의 비만 여성(46.14±5.01세, BMI = 28.54 ± 2.26 kg/m2)을 위약(C), ω-3(S) 및 ω-3와 운동을 포함하는 3개 그룹(각 그룹당 7명)으로 구분하였다. ω-3그룹과 COMBI 그룹은 매일 2000mg의 ω-3 보충제를 섭취하였으며, COMBI 그룹은 복합운동을 하였다. 수집된 자료는 SPSS 25.0 통계 프로그램을 이용하여 반복측정에 의한 이원변량분석을 하였으며, 상호작용이 있을 경우 집단 내 차이검증은 대응표본 t-test를 실시하였다. 그 결과 COMBI 그룹은 체성분이 개선되었고, 혈중 지질이 감소하는 긍정적 결과가 나타났다. 또한, COMBI 그룹은 염증 수치가 감소하고, 근 기능에 긍정적 효과를 나타냈으며, 인지기능 검사에서 BDNF 수치가 증가하였다. 이러한 긍정적인 효과는 복합운동과 ω-3 섭취가 중년 비만 여성의 혈중 지질을 조절하여 체지방을 낮추고, 염증성 바이오마커를 완화하고, 혈청 BDNF 수준을 촉진하고, 근육 성능에 긍정적인 영향을 미쳐 중년 비만 여성의 건강을 증진하고 비만 예방에 도움이 될 것이다.

Abstract

The purpose of this study was to investigate the effects of combined exercise and omega-3 intake on body composition, blood lipids, muscle function, inflammatory markers, and cognitive function in middle-aged obese women. A total of 21 obese women (46.14 ± 5.01 years old, BMI = 28.54 ± 2.26 kg/m2) were placed into 3 groups (7 in each group) including placebo (C), ω-3(S) and ω-3 plus exercise. separated by The ω-3 group and the COMBI group consumed 2000mg of ω-3 supplement daily, and the COMBI group performed compound exercise. The collected data were subjected to two-way analysis of variance by repeated measurements using the SPSS 25.0 statistical program, and a paired-sample t-test was conducted to verify differences within groups in the case of interactions. As a result, in the COMBI group, body composition improved and blood lipids decreased. In addition, the COMBI group showed a decrease in inflammation level, a positive effect on muscle function, and an increase in BDNF level in cognitive function tests. These positive effects suggest that combined exercise and ω-3 intake lowered body fat by regulating blood lipids in middle-aged obese women, alleviated inflammatory biomarkers, promoted serum BDNF levels, and had a positive effect on muscle performance, thereby reducing middle-aged obesity. It will improve women's health and help prevent obesity.

Key words : Omega-3, Muscle performance, Cognitive, Inflammatory, Obese women

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Ⅰ. Introduction

Recently, the prevalence of obesity and the incidence of comorbidities in Korea has increased continuously for 11 years. Particularly, it has been reported that the risk of cardiovascular disease and metabolic syndrome is relatively high for middle-aged people with abdominal obesity (Yang et al., 2022). Moreover, obesity shows a correlation with inflammation, muscle loss, cognitive decline, and depression, possibly via excessiveexpansion of adipose tissue, development of insulin resistanceand activation of macrophages in adipose tissue (Mulugeta et al., 2018; Kawai et al., 2021; Chang & Kim., 2022; Russo & Lumeng, 2018; Willams et al., 2020; Lee & Park., 2021; Ko & Jung., 2021; Barazzoni et al., 2018).

Specifically, obesity appears more vulnerable in women, reporting that middle-aged women increasing visceral fat by decreasing estrogen and hormonal changes, are more likely to impaired fat cell metabolism than man (Damsgaard et al., 2016).

Therefore, some studies suggested that the pathological effect of obesity and overweight, there is a different pharmacological and non-pharmacological method for obesity managements. Among non-pharmacological strategy, food intakes containing ω-3 fatty acids were recommended because ω-3 supplementation reduced inflammation by positively changing body composition, lowering blood lipids and deactivating autoimmune diseases in obese women (Barsky et al., 2020; De & Carmujo, 2018; Brinton & Mason et al., 2017; D'Angelo et al., 2020; Flachs et al., 2009; Simopoulos., 2008; Del et al., 2019; Ravaut et al., 2020; Simopoulos., 2002; Gonzalez et al., 2013) and exercisetraining attracted a lot of attention because of its role in combating obesity related disorders, increase lipid oxidation and insulin sensitivity (Davis et al., 2022; Zheng et al., 2017; Kulie et al., 2011; Pan et al., 2014).

More importantly, meta-analysis studies suggested that combination of aerobic exercise and resistance exercise positively changes body composition, neurophysiological performance, lowers blood lipids and deactivating inflammation and autoimmune diseases possibly via regulating appetite-hormones and enzymes in obese women (Wen & Tsai, 2020; Battista et al., 2021). Therefore, this study was to investigate synergetic effects of ω-3 supplementation alone and ω-3 supplementation in combination with exercise training on serum lipid profile, inflammatory bio-maker, muscular performance, cognition capacity and body composition in obese women.

Ⅱ. Methods

1. Ethical approval

The study was approved by the Bioethical Committee of KNSU and conducted according to the Declaration of Helsinki. After

Table 1. Physical characteristics

Group	Placebo (C, n=7)	omega-3(n=7)	COMBI (n=7)
Age (yr)	46.14±5.01	45.71±4.15	44.00±3.37
Height (cm)	161.00±4.16	162.14±4.67	162.57±4.83
Weight (kg)	70.81±2.96	71.86±4.06	75.47±2.76
Body fat	26.29±3.01	26.16±1.44	27.64±1.53
BMI	28.54±2.26	27.84±1.39	29.67±2.29

Values are mean±(SD), OEX: erercise+omega-3 group, OEX: omega-3 group, CON: control group

Table 2. 12 Week combined exercise program

	Contents	Time/Rep	HRR%
Warm-up	Prepare body stretching	5 min	
Aerobic Training	Treadmill exercise	30 min	60%
Resistance exercise	4 Week intensity 40% 20 rep Bench press, Shoulder press, Push up, Dumbbell curl Squirt, Leg press, Push-up, Crunch, sit-up, Rowing Machine, Plank, Arm curl.	Time&Set 30min 3set 40% of 1RM × 20 rep 60% of 1RM × 15 rep 80% of 1RM × 10 rep	
	8 Week Intensity 60% 15 rep Lat-pull down, Crunch, Leg raise, Leg curl, Chest press, Squirt. Lunge, Arm curl, Deadlift, Plank, Chest press, Arm curl.		
	12 week Intensity 80% 10 rep Back extension, Calf raise, lunge, Leg raise, Dumbbell Curl, Leg press, Plank. Wide squirt, Ab Crunch, Leg curl, Push-up, Chest press.		
Cool-down	recovery Body stretching program	5 min	

comprehensive details of the study protocol were explained orally and in writing, all participants provided their written informed consent.

2. Participants

Twenty-one obese females (46.14±5.01yr,BMI= 28.54±2.26 kg/m2) recruited through advertisements on the Internet. The exclusion criteria included cigarette smoking, or use of prescribed medications or dietary supplements. Participants were randomly assigned to one of three groups (7 subjects in each group): placebo, omega-3 and omega-3 in combination with exercise training (COMBI). Daily 2000mg omega-3 supplement was consumed by omega-3 and COMBI.

3. Intervention

Present study interventions consist of placebo (not participating in aerobic training program, not taking omega-3 supplements), omega-3 supplementation (taking omega-3 supplement, not participating in aerobic training program) or omega-3 in combination with exercise training (take omega-3 supplement along with participation in aerobic training and resistance exercise training), which both of them conducted for 12 weeks according to considered procedure.

4. Combined training program

The exercise program of this study was conducted in moderate aerobic training (MAT) combined with resistance training (RT) for 70 minutes a day 3 times a week for 12weeks. The RT consisted of 8 exercises in total, covering the main muscle groups (pectoralis, latissimus dorsi, biceps, triceps, quadriceps, and hamstrings), and 3 sets for each exercise, with a 60-s interval between sets and exercises.

5. Omega-3 Supplementation

It is a product that is important in omega-3 quality evaluation such as content, heavy metals, and acidity, and does not use genetically modified agricultural products. It is a safe product that has passed the test. Contains 2000mg of Wild Fish Oil Concentrate, 700mg of EPA, 500mg of DHA, 300mg of Polyphen-oil, and 10mg of seame seed lignan extract. As for the intake method, in order to prevent gastrointestinal disorders and increase absorption, a total of 4 capsules were taken twice a day after lunch and dinner. To prevent rancidity, store in a cool and dry place, and check daily intake. In addition, if you are taking anticoagulant or antiplatelet drugs or have a bleeding disorder, you should immediately stop taking it, and educate and control not to exceed the recommended dosage. A healthy diet and lifestyle were maintained during intake, and the non-consumption group controlled intake of other drugs and dietary supplements for 12 weeks during the study period.

6. Materials and Methods

1) Body composition

Body composition was measured using In body 720 (Bio-space., Korea), a body composition analyzer using bioelectrical resistance method, weight (kg), body mass index (BMI), waist-hip ratio (WHR), body fat mass (kg), muscle mass (kg) , the visceral fat area (cm^2) was measured.

2) Blood analysis test

For blood test, after fasting from 8 pm the night before to 9 am the next day, arrive at the laboratory on an empty stomach and rest for 10 minutes. A clinical pathologist collects 10mL of blood from the subjects' antecubital vein using an anticoagulated syringe, incubates it at room temperature for 30 minutes, and puts it in an anticoagulated and untreated tube according to each analysis item and centrifuges. Serum was separated for 10 minutes at 3000 rpm using a vacuum cleaner, and placed in each tube and stored frozen at -70 ° C until analysis.

3) Inflammatory cytokines

The concentration of TNF-a IL-6 was analyzed using plasma by Enzyme-Linked Immunosorbent Assay: ELISA and CRP were analyzed by automated immunoturbidity using an automatic analyzer (Olympus AU 2700, Olympus).

4) Bone density test

The bone density test measured the bone density of the subjects' lumbar spine and femur using dual energy absorptiometry (DEXA), which measures the bone density of a specific part of the body.

5) Isokinetic muscle function test

Cybex 770 (CSMI, USA) was used to measure the isokinetic muscle function of the subjects. For isokinetic muscle function, flexion and extension of the knee were measured, and the chair rotation angle, backrest angle, and chair fixation position were adjusted in consideration of the subject's physical characteristics

6) Cognitive function test.

Venous blood was collected in a vascular tube and serum was separated using a centrifuge at room temperature. The concentration of serum BDNF was analyzed using a standard ELISA (Sandwich enzyme-linked immunosorbent assay) Human BDNF Kit (R&D, Minneapolis USA).

7. Statistical analysis

After determining data normality and variance homogeneity using the Shapiro-Wilk test and Levene's Test for Equality of Variances, Two-way ANOVA (time and groups) by repeated measure was used to determine if interactions between time and groups existed for the physical and metabolic measures. When a significant F-ratio was obtained, Tukey's post hoc tests were used to determine where the significance occurred. Data are presented as means ± SD. Statistical significance was accepted as $p<0.05$ for all tests. Statistics were computed using SPSS/PC 25.0 for Windows (Chicago, IL, US).

III. Result

1. Body composition

weight, body fat, muscle mass, visceral fat area, waist hip ratio, body mass index). There was no statistically significant difference between three groups in thebodyweight(p=.725), muscle mass (p=.083), visceral fat area (p=.264), waist hip ratio(p=.090) and body mass index (p=.144) of but the interaction effect between the groups and repeated measurements in the body weight, muscle mass, visceral fat area, waist hip ratioand body mass index was a statistically significant difference at $p<.001$. The mean difference between three groups in the body fat (p=.029) was which was statistically significant, and the interaction effect between the group and repeated measurement was a statistically significant difference at $p<.001$.

2. Blood lipids, HbA1c and glucose

The mean difference between the three groups in total cholesterol (p=.000) and triglyceride (p=.017) was statistically significant, and the interaction effect between the group and repeated measurement in total cholesterol and triglyceride was a statistically significant difference at $p<.001$. The mean difference between three groups in high-density lipoprotein (HDL, p=.872) and low-density lipoprotein (LDL, p=.000) was statistically significant, and the interaction effect between the group and repeated measurement in HDL and LDL was a statistically significant difference at $p<.001$. The mean difference between the three groups in HbA1c (p=.018) was statistically significant, and the interaction effect between the group and repeated measures in HbA1c was a statistically significant difference at $p<.001$ level. The mean difference between the three groups in glucose (p=.052) was not statistically significant, but the interaction effect between the group and repeated measures in glucose was a statistically significant difference at $p<.001$.

3. Inflammatory biomarkers

The mean difference between the three groups in TNF-α (p=.000) and IL-6 (p=.000) was a statistically significant, and the interaction effect between the group and repeated measurement in TNF-α and IL-6 was a statistically significant difference at $p<.001$. The mean difference between the three groups in CRP (p=.038) was statistically significant, and the interaction effect between the group and repeated measures in CRP (p=.018) was a statistically significant difference at $p<.05$.

4. Bone density

The mean difference between the three groups in lumbar bone density (p=.841) and femoral bone density (p=.233) was not statistically significant difference, and the interaction effect between the group and repeated measures in lumbar bone density (p=.537) and femoral bone density (p=.000) was no statistically significant difference at $p>.05$ and was statistically significant difference $p<.001$, respectively.

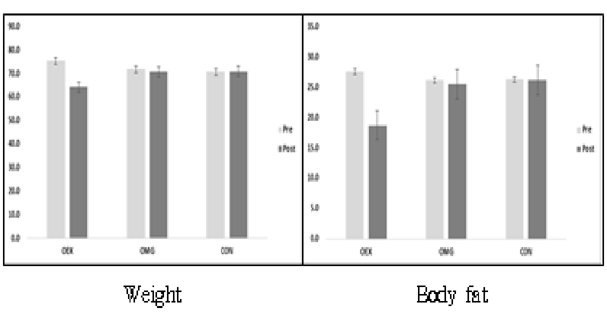
5. Isokinetic muscle function

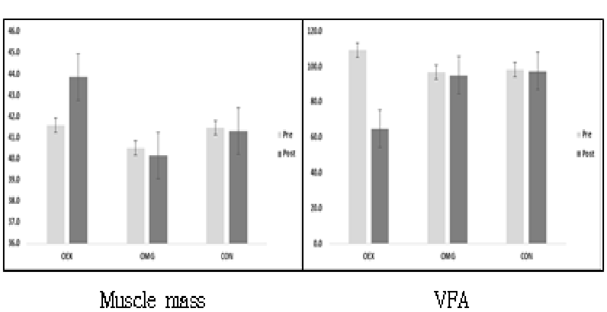
The mean difference between the three groups in the maximum right femoral extensor force (p=.000) and left flexor peak torque (60°/sec) (p=.000) was statistically significant, and the interaction effect between the group and repeated measurement in and the maximum right femoral extensor force (p=.000) and left flexor peak torque (60°/sec) (p=.000) was a statistically significant difference at $p<.001$. The mean difference between the three groups in the maximum right femoral extensor force (60°/sec) (p=.000) and the maximum right femoral flexion peak force (60°/sec) (p=.000) was statistically significant, and the interaction effect between the group and repeated measurement in the maximum right femoral extensor force (60°/sec) (p=.000) and the maximum right femoral flexion peak force (60°/sec) (p=.000) was a statistically significant difference at $p<.001$.

The mean difference between the three groups in the right femoral flexor (180° /sec) (p=.000) and the right femoral extensor (180° /sec) (p=.000) was statistically significant, and the interaction effect between the group and repeated measurement in the right femoral flexor (180° /sec) (p=.000) and the right femoral extensor (180° /sec) (p=.000) was statistically significant difference at p<.001.The mean difference between the three groups in right extensor total work (180° /sec) (p=.000) and left flexor total work (180° /sec) (p=.000) was statistically significant, and the interaction effect between the group and repeated measurement in right extensor total work (180° /sec) (p=.000) and left flexor total work (180° /sec) (p=.000) was a statistically significant difference at p<.001.

6. Cognitive Function

The mean difference between the three groups in Mini Mental State Examination (MMSE) (p=.260) was not statistically significant, and the interaction effect between the group and repeated measures in Mini Mental State Examination (MMSE) (p=.862) was no statistically significant difference at the level of p>.05. The mean difference between the three groups in Brain-Derived Neurotrophic Factor (BDNF) (p=.000) was statistically significant, and the interaction effect between the group and repeated measurement in Brain-Derived Neurotrophic Factor (BDNF) (p=.000) was statistically significant difference at p<.001.





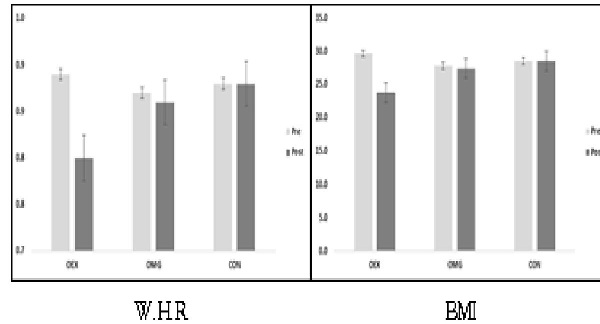


Fig 1. Effects of omega-3 and combined exercise on by body composition on afte childbith. Date represent the mean±SD (n=7 per group).*p<0.05. (two-way ANOVA Tukey post hoc tests).

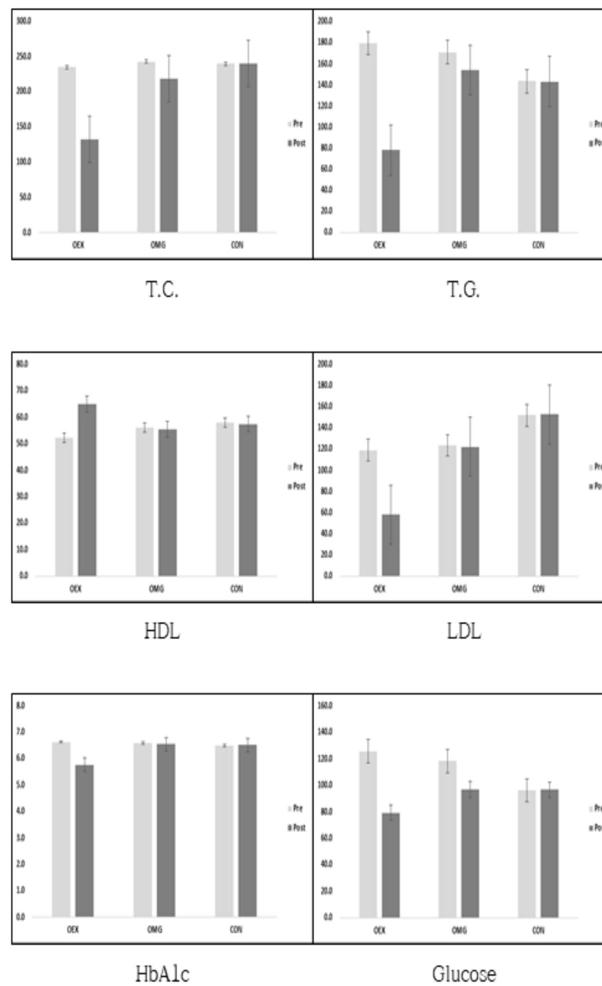


Fig 2. Effects of omega-3 and combined exercise on serum lipid by afte childbith. Date represent the mean±SD (n=7 per group).*p<0.05. (two-way ANOVA Tukey post hoc tests).

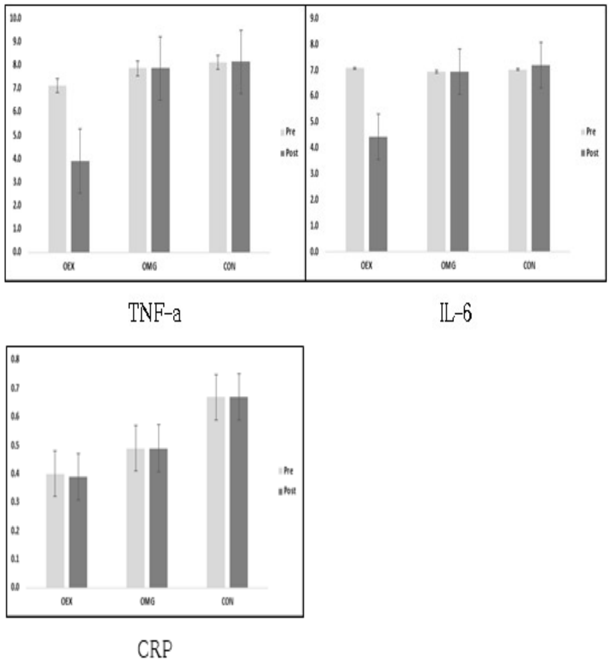


Fig 3. Effects of omega-3 and combined exercise on by inflammatory mediators afte childbith. Date represent the mean±SD (n=7 per group).*$p<0.05$. (two-way ANOVA Tukey post hoc tests).

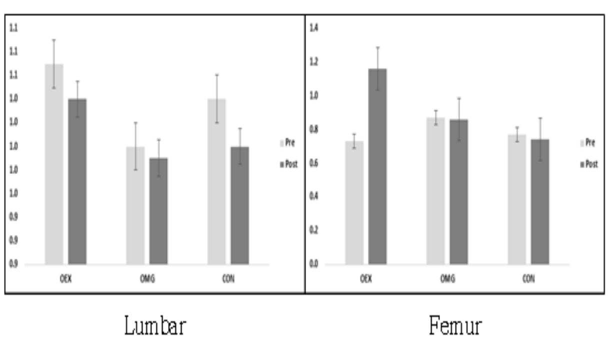
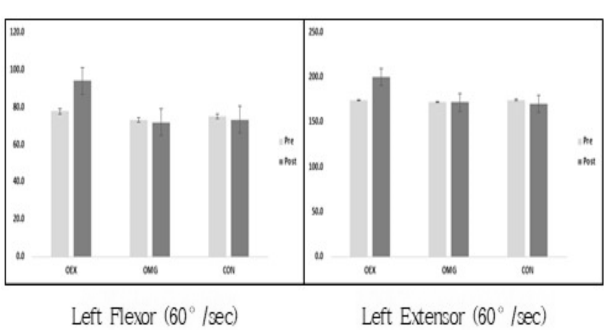


Fig 4. Effects of omega-3 and combined exercise on by bone mineral density on afte childbith. Date represent the mean±SD (n=7 per group).*$p<0.05$. (two-way ANOVA Tukey post hoc tests).



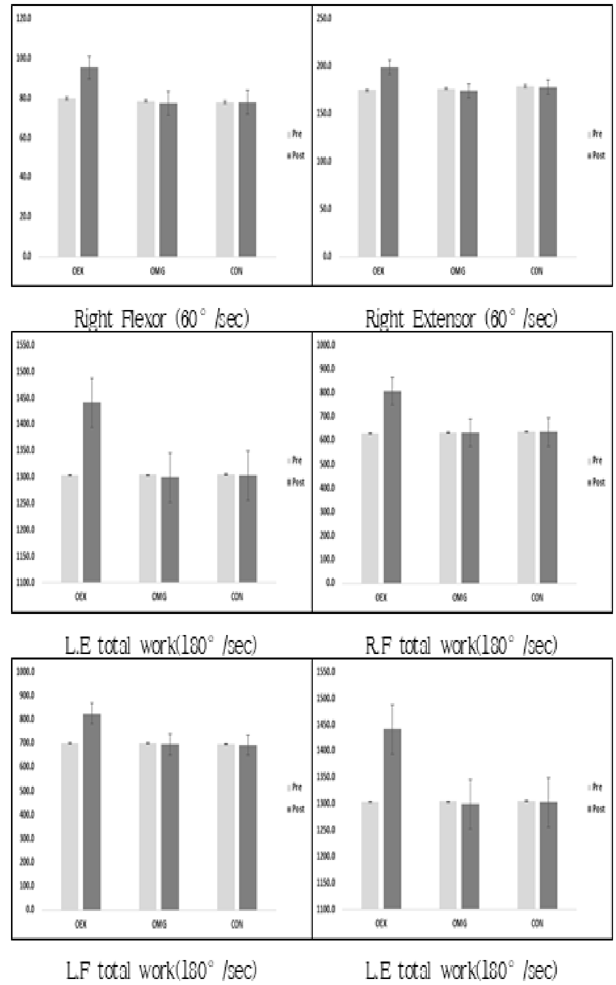


Fig 5. Effects of omega-3 and combined exercise on by m uscular performance on afte childbith. Date represent the mean±SD (n=7 per group).*$p<0.05$. (two-way ANOVA Tukey post hoc tests).

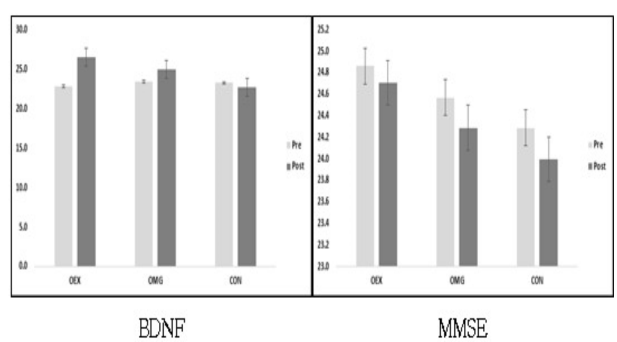


Fig 6. Effects of omega-3 and combined exercise on by cognition capacity on afte childbith. Date represent the mean±SD (n=7 per group).*$p<0.05$. (two-way ANOVA Tukey post hoc tests).

Ⅳ. Discussion

This study examined the effects of ω-3 supplementation in combination with exercise training on body composition, blood lipids, inflammatory biomarkers, muscle function, and cognitive function in obese women. The study found that no effects on body composition were observed when ω-3 supplementation was given to obese women, suggesting that ω-3 supplementation alone is not effective in obese women.

However, the most important finding of this study was that ω-3 supplementation in combination with exercise training affected body fat mass, body weight, visceral fat area, WHR, BMI, and muscle mass, suggesting that ω-3 supplementation in combination with exercise training is effective in positively changing body composition. This study is consistent with previous research (Cheng et al., 2018; Brellenthin et al., 2021; Sardeli et al., 2022; Félix et al., 2021).

This is partially consistent with studies showing that low ω-3 supplementation negatively affects dyslipidemia and cardiovascular disease risk, while ω-3 fatty acids containing EPA and DHA reduce insulin resistance and dyslipidemia in middle-aged women (Martínez., 2015; Gellert et al., 2017). However, in this study, ω-3 supplementation alone for 12 weeks in obese women did not appear to have an effect on serum lipid profiles and blood glucose levels. These results are consistent with previous findings that ω-3 supplementation alone did not result in significant increases in HDL and decreases in LDL (Hartweg et al., 2008; Wooten et al., 2009).

In other word, the present study shows that ω-3 supplementation combined with exercise training reduced TC, TG, LDL and increased HDL in obese women. It could be hypothesized that fish oil enriched with ω-3 supplementation combined with exercise training may enhance fat metabolism by activating peroxisome proliferator-activated receptor alpha, (PPAR-α), which serves as a regulator of lipid homeostasis. Thus, EPA and DHA, major components of n-3 FAs, activate PPAR-α agonists and subsequently activates specific mediators for fat metabolism.

Furthermore, in obese women who received ω-3 supplementation in combined with exercise training, HbA1C levels were significantly reduced, whereas ω-3 supplementation did not have a positive effect on lowering HbA1C levels. These results are consistent with previous studies designed to determine the effects of exercise training or ω-3 supplementation on HbA1C and glucose levels, which reported inconsistent results (Wang et al., 2018; Natto et al., 2019; Kirwan et al., 2017).

Obesity, which is a feature of metabolic syndrome, was associated with chronic inflammation in obese subjects. However, there is a limited information about simultaneous effect of exercise training and ω-3 supplementation on inflammatory mediators. Therefore, the present study investigates the association of TNF-α, IL-6 and CRP as biomarkers of systemic inflammation with obesity. The data of present study indicate that 12 weeks of ω-3 supplementation does not appear to be effective when taken alone in obese women. This result indicates that ω-3 supplementation alone has a limitation in reducing inflammation. Therefore, the contradiction with previous studies is related to the characteristics of the subjects in the present study.

Conversely, ω-3 supplementation combined with regular moderate exercise is effective in reducing cardiovascular risk and suppressing inflammation (Hill et al., 2007). In this study, obese women who took ω-3 supplements with exercise for 12 weeks had lower levels of TNF-α, IL-6, and CRP compared to women who took a placebo and ω-3 supplements alone.

The present study's findings are consistent with previous studies showing a reduction in TNF-α and IL-6, which reduce and modulate inflammatory cytokine levels in obese postmenopausal women, and indicate that 12 weeks of ω-3 supplementation in combination with exercise training promotes anti-inflammatory effects in obese women (Abd & Osama, 2019). However, as there is little information on the simultaneous effects of exercise training and ω-3 supplementation, the mechanisms of effect, including lipid profile and inflammation reduction, should be further investigated in future studies.

Furthermore, lowering inflammation is crucial for obese women to improve muscle mass and strength and maintain physical function and independence to improve their quality of life. In fact, the combination of ω-3 supplementation and exercise training for 12 weeks resulted in significantly greater improvements in leg strength than CON alone or ω-3 supplementation alone. The results of this study show consistent findings that ω-3 supplementation in combination with exercise training is effective in increasing muscle mass and strength by inducing muscle protein synthesis in obese women (Smith et al., 2011; Rodacki et al., 2012; Gray & ittendorfer, 2018; Rossato et al., 2020; Philpott et al., 2019; Murphy et al., 2021). Therefore, ω-3 supplementation for 12 weeks in combination with exercise training has a synergistic effect.

The decreased BDNF levels may be due to mutation of the BDNF gene or TrkB receptors in the obese (Mandelman & Grigorenko, 2012). Thus, Low circulating BDNF levels has been found related to increased TG and LDL levels, decreased HDL levels, presence of diabetes mellitus, obese and occurrences of cardiovascular events (Nurjono, Tay, & Lee, 2014; Jiang et al., 2011).

It was reported that ω-3 intake regulates brain energy and brain glucose metabolism, thereby preventing cognitive decline middle-aged women and is closely related to BDNF gene expression in the central nervous system brain (Cook et al., 2019; Singh et al., 2020; Kiecolt et al., 2013). In addition, previously available data confirms a positive relationship between physical exercise and circulating BDNF levels in both the short and long term, and appears to support the beneficial impact of training programs that amplify acute BDNF responses.

Obese women were given ω-3 supplements alone or in combination with exercise training and then administered the Mini-Mental State Examination-K (MMSE-K) to study the association between circulating BDNF and cognition. The study found that BDNF levels were significantly increased in obese women who received ω-3 supplements alone and in the group that received exercise training, which is consistent with previous findings that omega-3s enhance BDNF by significantly increasing DHA in the brain (Sugasini & Subbaiah, 2020: (Gaitán et al, 2021; Walsh & Tschakovsky, 2018; Choi et al, 2018).

More importantly, the combination of ω-3 intake and exercise increases BDNF, which supports research showing that it is effective in improving brain synaptic plasticity and cognitive function (Gomez et al., 2011). Therefore, exercise training and ω-3 intake in obese women appears to be associated with increased BDNF levels. However, there were no significant differences between the three groups on the Mini-Mental State Examination (MMSE-K), and no interaction effect between groups was observed. This is due to the lack of research on cognitive function in middle-aged women, as most MMSE-K studies are based on findings from older adults.

Ⅴ. Conclusion & Recommendation

In conclusion, ω-3 intake in combination with exercise training may help prevent obesity in obese women by modulating serum lipid profiles to lower body fat, mitigate inflammatory biomarkers, promote serum BDNF levels, and positively influence muscle performance. Future studies may be needed to clarify the proposed speculation. While this study provided meaningful results, it has several limitations, including not controlling for participants' diet and daily activity levels.

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