Research Article

The Effect of Wild and Farmed Trout Consumption on Sport Performance, Lipid Profiles and 25-hydroxyvitamin D Levels in Trained Female Bodybuilders

Ayda Attary Shaghaji (iD) [1], Zohreh Eskandari (iD) [2, *], Mostafa Soltani (iD) [2]

[1] Department of Physical Education and Sports Sciences, Faculty of Social Sciences, Raja University, Qazvin, Iran
[2] Department of Sports Nutrition, Faculty of Social Sciences, Raja University, Qazvin, Iran

*Corresponding Author: Department of Sports Nutrition, Faculty of Social Sciences, Raja University, Qazvin, Iran. Email: z.eskandari@raja.ac.ir

Abstract

Background: Fish is a valuable source of food for athletes. The present study aimed to investigate the effects of consuming farmed and wild trout on sport performance, lipid profile levels, and 25-hydroxyvitamin D in trained female bodybuilders.

Methods: In this quasi-experimental study, 30 active female bodybuilders aged 20 to 30 years were randomly assigned to three equal groups: Farmed trout consumers, wild trout consumers, and a control group. During the intervention, 50 grams of fish were included in the lunch meal at least four to five times a week for four weeks. Sport performance, including maximum upper and lower body muscle strength measured by the chest press and leg press tests, average anaerobic power assessed through the RAST test, lipid profile, and vitamin D levels, was evaluated through blood tests conducted 48 hours before and after the study. Data were analyzed using analysis of covariance at a significance level of P < 0.05.

Results: No significant differences were observed in sport performance, triglyceride levels, cholesterol levels, or HDL levels among the three groups (P > 0.05). Vitamin D increased significantly in both fish consumption groups compared to the control group (P = 0.000). LDL decreased significantly in the wild trout group compared to the other two groups (P = 0.000).

Conclusions: The consumption of both farmed and wild trout increased vitamin D levels. LDL was reduced only in the wild trout group, and the effect of wild trout was superior to that of farmed trout.

Keywords: Wild and Farmed Trout, Sport Performance, Lipid Profile, 25-hydroxyvitamin D, Trained Female Bodybuilders

1. Background

Exercise training induces varying degrees of mechanical and metabolic stress on the human body, resulting in inflammation and oxidative stress (1). Excessive inflammation can hinder recovery and performance (2). For this reason, there is increasing interest in finding nutritional supplements and foods with functional benefits to enhance metabolic capacity, reduce the effects of oxidative stress, delay the onset of fatigue, improve muscle hypertrophy, shorten the recovery period, and, in other words, boost athletic performance in athletes (3, 4). The International Society of Sports Nutrition lists fish as one of the best sources of high-quality protein for athletes because it provides ample fuel and helps build and repair muscle (5). Fish provides a variety of nutrients, including protein, essential fats, and vitamins and minerals such as calcium, magnesium, selenium, zinc, iron, and vitamins A and D (6). The health benefits of fish are primarily attributed to their content of long-chain polyunsaturated fatty acids (n-3 LCPUFA) or omega-3 (7). Important features of fish oil and omega-3 include antioxidant and anti-inflammatory properties (modulating pro-inflammatory cytokines and eicosanoids), immune-modulatory effects (8-11), enhancement of lipid metabolism (12-14), and glucose metabolism (15), as well as changes in cell membrane

permeability (16). Fish compounds can improve endothelial function and increase blood flow, delivering more nutrients and oxygen to the muscles, enhancing endurance, and reducing fatigue (17). These properties have led athletes to use fish oil supplements as ergogenic aids in recent years. In studies by Jouris et al. and Philpott et al. and, it was found that fish oil reduces muscle damage and soreness caused by exercise (2, 18). In a study by Jeromson et al., ω-3 PUFA supplementation reduced protein breakdown in cancerous rodents (11). On the other hand, some studies have found that fish oil does not impact athletic performance (19). D'Angelo et al. stated that only limited scientific evidence proves that fish oil supplementation positively affects sport performance. Therefore, at present, it cannot be concluded that fish oil is consistently effective or energizing (3). Further studies are necessary.

Another feature of fish consumption is its potential effect on improving lipid profiles and enhancing fat metabolism. According to study results, compounds found in fish may influence the expression of genes involved in lipid metabolism. Omega-3 fatty acids can activate peroxisome proliferator-activated receptors (PPARs), which play an important role in regulating lipid metabolism and energy homeostasis (20). This activation can lead to increased fatty acid oxidation and improved athletic performance. However, the effect of fish consumption on lipid profiles is inconsistent. Several studies have shown that fish consumption or supplements lower triglycerides (3, 21), reduce LDL (21), and increase HDL (22). In some studies, LDL (22) and HDL (23) levels did not change; therefore, further investigation is necessary.

Vitamin D is an essential micronutrient for enhancing health and athletic performance. The main sources of vitamin D are dietary sources and exposure to sunlight. Among vitamin D-rich foods, oily fish are considered to be one of the best sources (24). A systematic study reported that consuming at least two servings of fish, or 300 grams of fish per week, over a period of at least four weeks, was associated with a significant increase in serum 25-hydroxy D concentrations (25). According to estimates, one billion people worldwide, with more than half of them in Iran, are deficient in vitamin D (26). A high prevalence of vitamin D deficiency has been documented among athletes in both outdoor and indoor sports (27). One characteristic of vitamin D is its impact on musculoskeletal health, cardiovascular health, and immune system function (28). Also, in observational and interventional studies, insufficient vitamin D levels were associated with adverse serum lipid profiles (29-31), which reduced exercise performance. Research has shown that high serum levels of vitamin D are associated with reduced injury rates and improved athletic performance. It is recommended that individuals with vitamin D deficiency be identified and take supplements to optimize their performance and prevent future complications (32). Consuming fresh rainbow trout is an excellent way to boost your vitamin D levels. That's because a 3-ounce (85-gram) serving of rainbow trout contains 645 international units of vitamin D. In fact, rainbow trout is one of the fish that are high in vitamin D (6).

Given the valuable properties of fish, it is essential to consider potential barriers to fish consumption among athletes. Factors such as taste preferences and concerns about sustainability and mercury exposure may limit fish consumption among some individuals. Wild fish tend to have higher mercury levels due to contaminants, while farmed fish are generally in a better position. On the other hand, due to increased fish consumption, aquaculture has risen, reducing the burden on wild fish stocks (33). Although most studies suggest that wild fish have higher levels of omega-3 and vitamin D than farmed fish (34, 35), the high mercury content of wild fish reduces their consumption. There is also controversy regarding the effects of fish on exercise performance, lipid profiles, and vitamin D3.

2. Objectives

The present study aimed to investigate the effect of increasing fish consumption (4 to 5 servings per week) on the aforementioned variables and, if it affects the variables, to determine whether farmed trout is as effective as wild trout.

3. Methods

3.1. Subjects and Study Procedure

This study employed a quasi-experimental design with pre-test and post-test assessments, comprising three parallel groups: Two intervention groups (wild trout and farmed trout consumers) and one control

group. Participants were non-randomly selected via convenience sampling from female bodybuilders training at Apadana Club in Rasht, Iran, but random allocation to groups was performed after recruitment to minimize bias. The statistical population consisted of female bodybuilders aged 20 to 30 years with ≥ 6 months of regular training history at Apadana Club. From 63 initial volunteers, 30 eligible participants were selected after screening based on inclusion/exclusion criteria. Sample size was determined using G*Power 3.1 software (α = 0.05, power = 80%, medium effect size).

3.2. Inclusion Criteria

Female gender, age 20 to 30 years, minimum 6 months of regular bodybuilding training, Body Mass Index (BMI) 18.5 - 25 kg/m^2, absence of chronic diseases (cardiovascular, diabetes, hypertension, etc.), no use of dietary supplements (especially vitamin D and omega-3/6 fatty acids), non-smoker and non-alcohol consumer, similar physical fitness [assessed through the International Physical Activity Questionnaire (IPAQ) and researcher-developed demographic/training history questionnaire], and informed consent.

3.3. Exclusion Criteria

Missing > 3 training sessions during the study, sustaining exercise-related injuries, consuming < 2 fish meals/week (for intervention groups).

To calculate BMI, height and weight were first measured. The subjects' height was measured without shoes using a wall-mounted stadiometer (0.1 cm precision). Their weight was measured with a digital scale while wearing minimal clothing (Seka, 0.1 kg precision). The BMI was calculated by dividing weight in kilograms by the square of height in meters. Exercise performance, lipid profile, and vitamin D (using blood sampling) were also measured.

After initial measurements, participants were randomly divided into three groups via a random number table: (1) Farmed trout group (n = 10, 4 - 5 farmed trout meals/week), (2) wild trout group (n = 10, 4 - 5 wild trout meals/week), (3) control group (n = 10, maintained habitual diet without fish). All three groups followed the same bodybuilding regimens. Given the nature of the dietary interventions in this study, blinding of participants and trainers was not feasible.

However, several strategies were implemented to minimize potential bias: Outcome assessors (including laboratory technicians conducting biochemical analyses) remained blinded to group allocation throughout the study period, all measurements were performed using standardized protocols, and random assignment to study groups was conducted only after participant recruitment and baseline assessments. After grouping, the intervention variable was applied for four weeks. Figure 1 shows the participant flow chart.

In the present study, all ethical considerations were observed. Written informed consent was obtained from all participants. Voluntary participation and the right to withdraw were emphasized. Confidentiality of participant information was guaranteed, and approval was obtained from the institutional ethics committee.

3.4. Measuring Research Variables

3.4.1. Measuring Athletic Performance

To measure maximum upper and lower body strength (1 repetition maximum), the chest press movement (36) and the leg press movement (37) were utilized, respectively. One repetition maximum is the maximum weight that a muscle or muscle group can lift at one time, calculated and estimated using the following formula. To prevent injury, several repetitions between four and eight were utilized to estimate one-repetition maximum (1RM). The test was stopped when the number of repetitions of the weight lifted was between 4 and 8. The number of repetitions and the weight lifted were then input into the formula below to calculate the maximum repetitions.

$$\text{One} - \text{repetition maximum}\left(1\text{RM}\right)$$
$$= \frac{\text{Weight (kg)}}{1.0278 - (\text{reps} \times 0.0278)}$$

In this study, the average anaerobic power was calculated using the RAST test. After warming up, the subject ran a distance of 35 meters at maximum speed on the handlebars. At the end of the distance, the athlete rested for 10 seconds. Immediately after the 10-second rest, the athlete ran the distance again at maximum speed. The athlete ran the distance at maximum speed six times. Records were taken at each stage. The six-step
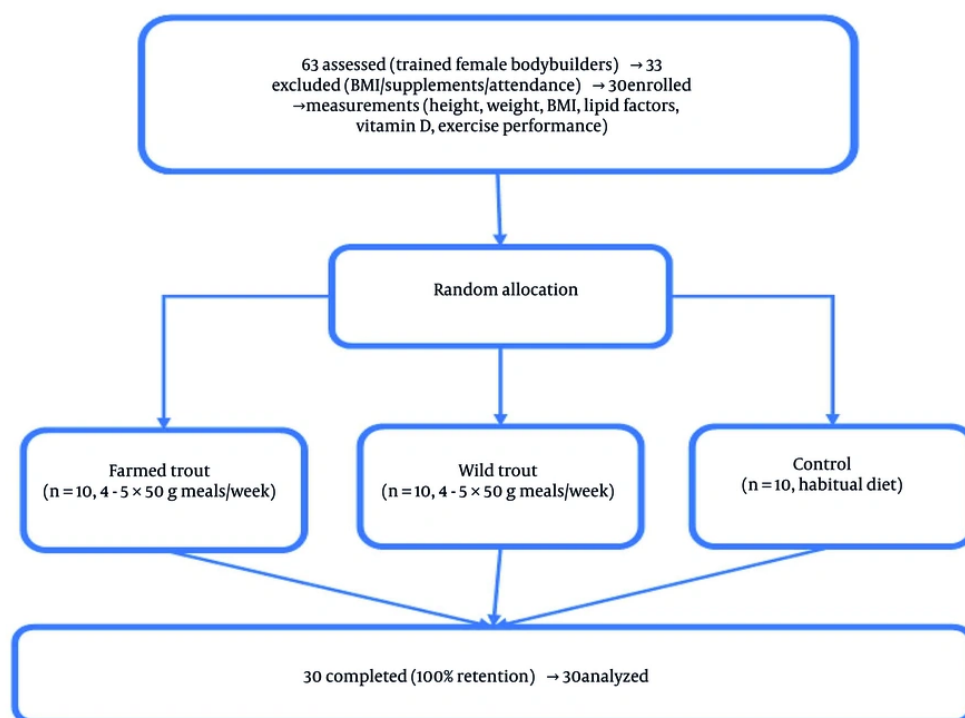
Figure 1. Research process

record was converted to anaerobic power using the formula "anaerobic power = weight × 1225 ÷ time³". To calculate the average anaerobic power, the average of the six power records was taken (the sum of the six anaerobic power values divided by six) (38).

3.4.2. Lipid Profile and 25-Hydroxyvitamin D3 Measurement

Blood sampling was performed 48 hours before the start of training and 48 hours after the last training session in a fasting state of 10 to 12 hours. Before each blood sampling session, the subjects rested for a few minutes in a sitting position. Then, in the shortest possible time, 10 cc of blood was drawn from the cubital vein of their left elbow between 8 and 9 a.m. by a laboratory technician. After blood collection, the blood samples were placed at room temperature for 20 minutes to allow for clotting. The tubes containing the samples were then centrifuged for 10 minutes at a speed of 3000 - 3500 rpm (Rontgen Company device, made in Germany). The separated serum was transferred into

special microtubes and stored at -20°C. Vitamin D analysis and determination were conducted using a commercial kit from Pars Peyvand Company, with intra-group and inter-group coefficients of less than 11% and 12%, respectively. The lipid profile, including total cholesterol, triglycerides, HDL, and LDL, was measured using an enzymatic method with a biochemical autoanalyzer and a Pars Azmoun kit at Alzahra Laboratory in Rasht. The error rate for all intergroup and intragroup assessments was under 1%.

3.5. Intervention

3.5.1. Exercise Protocol

Subjects in all three groups continued their activities, which included bodybuilding exercises three times a week, with each session lasting 60 minutes. After a 10-minute warm-up, the subjects performed the main exercise. After the main exercise, a 5-minute cool-down was performed. All training sessions were conducted

Table 1. Resistance Training Protocol for Trained Female Bodybuilders

Movements and Exercise Intensity	Week 1	Week 2	Week 3	Week 4
Leg press				
Set × rep	3 × 8 - 12	3 × 8 - 12	3 × 8 - 12	3 × 8 - 12
%1RM	40 - 50	50 - 60	60 - 70	70
Lying leg curl				
Set × rep	3 × 8 - 12	3 × 8 - 12	3 × 8 - 12	3 × 8 - 12
%1RM	40 - 50	50 - 60	60 - 70	70
Standing biceps cable curl				
Set × rep	3 × 8 - 12	3 × 8 - 12	4 × 8 - 12	3 × 8 - 12
%1RM	40 - 50	50 - 60	60 - 70	70
Triceps rope pushdown				
Set × rep	3 × 8 - 12	4 × 8 - 12	3 × 8 - 12	3 × 8 - 12
%1RM	40 - 50	50 - 60	60 - 70	70
Chest press				
Set × rep	3 × 8 - 12	3 × 8 - 12	3 × 8 - 12	3 × 8 - 12
%1RM	40 - 50	50 - 60	60 - 70	70
Machine seated crunch				
Set × rep	3 × 8 - 12	3 × 8 - 12	3 × 8 - 12	3 × 8 - 12
%1RM	40 - 50	50 - 60	60 - 70	70
Squats				
Set × rep	4 × 8 - 12	3 × 8 - 12	3 × 8 - 12	3 × 8 - 12
%1RM	40 - 50	50 - 60	60 - 70	70
Toe raises				
Set × rep	3 × 8 - 12	3 × 8 - 12	3 × 8 - 12	3 × 8 - 12
%1RM	40 - 50	50 - 60	60 - 70	70

Table 2. Individual Characteristics of Subjects in Three Groups of Trained Female Bodybuilders [a]

Variables	Control (n = 10)	Wild Trout (n = 10)	Farmed Trout (n = 10)	P-Value
Age (y)	24.90 ± 2.18	24.8 ± 1.68	24.2 ± 2.04	0.782
Height (cm)	166.7 ± 3.46	168.2 ± 3.96	167.7 ± 4.27	0.687
Weight (kg)	67.4 ± 3.83	69.3 ± 3.86	67.6 ± 4.55	0.530
BMI (Kg/m^2)	24.25 ± 0.77	24.5 ± 1.13	24.05 ± 1.60	0.713

Abbreviation: BMI, Body Mass Index.

[a] Values are expressed as mean ± SD.

under the supervision of a specialized trainer at Apadana Club (39).

3.5.2. Fish Consumption and Monitoring Protocol

This study provided farmed and wild trout (800 - 1000 g) to participants in the intervention groups. To ensure precise dietary control, participants were instructed to consume 50 g of fish per serving, totaling 4 - 5 servings per week for 4 weeks, exclusively during lunchtime meals. This portion size was selected based on practical feasibility and compliance considerations,

while still delivering a biologically relevant dose of n-3 fatty acids and vitamin D3 (25). The use of fish oil supplements was prohibited across all groups to isolate the effects of whole-fish consumption. The fatty acid and vitamin D3 content of trout were derived from published literature, as direct laboratory analysis was not feasible. Wild trout contained 6.82% EPA, 8.97% DHA (DHA/EPA ratio: 1.31), with total n-3 (∑n3) and n-6 (∑n6) fatty acids at 25.75% and 8.37%, respectively (40). Farmed trout exhibited distinct profiles: 1.86% EPA, 9.91% DHA (DHA/EPA ratio: 5.32), lower n-3 (15.79%), but higher n-6

Table 3. Sports Performance Variables in Pre-test and Post-test and Analysis of Covariance Results [a]

Variables and Steps	Control	Wild Trout	Farmed Trout	F	P-Value	η^2
Upper body strength (kg)				1.023	0.374	0.073
Pre-test	24.5 ± 2.90	24.1 ± 2.87	25.2 ± 2.99			
Post-test	28.6 ± 2.21	28.6 ± 2.17	29.5 ± 2.22			
Lower body strength (kg)				0.648	0.531	0.048
Pre-test	65.6 ± 5.25	66.2 ± 5.43	67.4 ± 5.42			
Post-test	74 ± 4.94	75.3 ± 5.18	76 ± 4.54			
Average anaerobic power (W/kg)				0.569	0.573	0.042
Pre-test	253.6 ± 33.72	258.2 ± 31.73	245.1 ± 38.56			
Post-test	258.3 ± 33.81	270.3 ± 29.23	256.5 ± 36.09			

[a] Values are expressed as mean ± SD.

(34.01%) (40). For vitamin D3, wild and farmed trout values were estimated at 1.10 µg/g and 1.12 µg/g, respectively (41). A qualified nutritionist supervised dietary adherence, with participants maintaining daily food diaries to record fish intake. No allergic reactions, gastrointestinal disturbances, or adverse events were reported, and all participants completed the study without withdrawals. The control group adhered to a fish-free diet under identical monitoring.

3.6. Statistical Analysis

In this study, all descriptive data were presented as means and standard deviations. After examining the normality of the data distribution with the Shapiro-Wilk test and confirming it, the ANCOVA test was employed to analyze the differences between groups. All statistical calculations were performed using SPSS statistical software version 26 at a significance level of P < 0.05.

4. Results

Table 1 shows the individual characteristics of the subjects before the interventions. The average age, height, weight, and BMI of all subjects were 24.63 ± 1.93 years, 167.53 ± 3.83 cm, 68.10 ± 4.04 kg, and 24.26 ± 1.19 kg/m^2, respectively. By performing a one-way ANOVA test, no significant differences were observed between the study groups in all baseline measurements, including age, weight, height, and BMI (P > 0.05) (Table 2).

The results of the covariance test showed no significant difference between the three groups in the indices of upper body muscle strength (P = 0.37, F = 1.02,

η^2 = 0.07), lower body muscle strength (P = 0.53, F = 0.64, η^2 = 0.04), and mean anaerobic power (P = 0.57, F = 0.56, η^2 = 0.04) (Table 3). The sports performance graph is shown in Figure 2.

According to the results of the analysis of covariance, significant differences were observed in the variables of vitamin D and LDL among the three groups (P = 0.000). However, no significant differences were observed in the variables of triglycerides (P = 0.15), total cholesterol (P = 0.48), and HDL (P = 0.05) among the three groups (Table 4).

The Bonferroni-adjusted pairwise comparisons demonstrated that both wild and farmed trout consumption significantly increased vitamin D levels compared to the control group [wild trout: +3.76 ng/mL, P < 0.000, 95% CI (2.66, 4.86); farmed trout: +3.15 ng/mL, P < 0.000, 95% CI (2.02, 4.30)], with no significant difference observed between the two trout groups [mean difference = 0.60 ng/mL, P = 0.554, 95% CI (-0.53, 1.73)]. For LDL cholesterol levels, wild trout showed significantly greater reductions compared to both farmed trout [-5.41 mg/dL, P < 0.000, 95% CI (-7.89, -2.92)] and control [-4.67 mg/dL, P < 0.000, 95% CI (-7.15, -2.18)], while farmed trout did not significantly differ from control [mean difference = 0.74 mg/dL, P = 1.000, 95% CI (-1.74, 3.22)] (Figure 2). These results indicate that while both trout types were equally effective at increasing vitamin D levels, only wild trout consumption led to significant LDL cholesterol reduction, suggesting potential differences in their bioactive compound profiles that warrant further investigation (Figure 3).
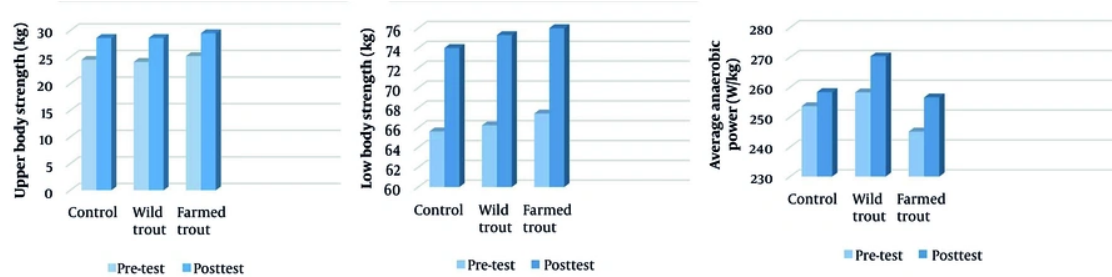
Figure 2. Sports performance in pre-test and post-test

Table 4. Vitamin D and Lipid Profile Variables in Pre-test and Post-test, and Analysis of Covariance for Intergroup Comparison [a]

Variables and Steps	Control	Wild Trout	Farmed Trout	F	P-Value	η^2
25-hydroxyvitamin D (ng/mL)				43.431	0.000 [b]	0.770
Pre-test	14.2 ± 1.53	14.3 ± 1.18	15.1 ± 1.13			
Post-test	14.25 ± 1.96	18.10 ± 1.10	18.20 ± 1.39			
TG (mg/dL)				2.026	0.152	0.135
Pre-test	159.5 ± 15.06	162.8 ± 15.21	159.4 ± 14.86			
Post-test	158.20 ± 15.48	158.21 ± 14.98	157.40 ± 15.28			
TC (mg/dL)				0.743	0.485	0.054
Pre-test	134 ± 10.94	134.8 ± 13.07	131.3 ± 11.64			
Post-test	133.5 ± 11.8	132.2 ± 11.56	130.8 ± 11.92			
HDL (mg/dL)				3.169	0.059	0.196
Pre-test	31.3 ± 4.05	30.9 ± 6.25	30.8 ± 4.85			
Post-test	32.10 ± 4.06	33.10 ± 5.97	32.5 ± 4.30			
LDL (mg/dL)				18.174	0.000 [b]	0.583
Pre-test	90.4 ± 10.6	92.6 ± 11.56	90.8 ± 8.86			
Post-test	91.97 ± 0.68	87.30 ± 0.69	92.71 ± 0.65			

[a] Values are expressed as mean ± SD.

[b] Statistical significance between groups.

5. Discussion

This study aimed to investigate the effects of consuming 50 grams of farmed and wild trout four to five times per week on exercise performance, lipid profiles, and vitamin D levels. Consuming four servings of farmed and wild trout did not affect upper and lower body muscle strength or anaerobic capacity in female bodybuilders. Studies examining the effects of fish consumption and its main components on athletic performance have been conducted in various populations, and the results of these studies have been somewhat inconsistent. A similar study reported in a review that fish oil consumption had no effect on endurance performance, muscle strength, or exercise adaptation (42). Lee et al. reported that omega-3 supplementation at 1.2 g of eicosapentaenoic acid and 0.72 g of docosahexaenoic acid per day for 12 weeks did not improve muscle strength and physical performance induced by resistance training, which is consistent with the findings of the current study (43). One study demonstrated that 18 weeks of omega-3 supplementation (3 × 1 g capsules daily, providing 2.1 g EPA/d + 0.6 g DHA/d) significantly improved muscle performance and quality (strength per unit muscle area) in older women undergoing resistance training.

However, this effect was not observed in male participants (44). Smith et al. also noted that six months of omega-3 supplementation, without an exercise intervention, resulted in significant increases in grip strength (45). Mamerow et al. acknowledged that the anti-inflammatory properties of omega-3 supplements can affect muscle repair and growth, as well as increase muscle protein synthesis (46). In another study, Krzyminska-Siemaszko et al. reported improvements in body mass and muscle strength in elderly individuals after 12 weeks of omega-3 supplementation (47), which were inconsistent with the findings of the current study.
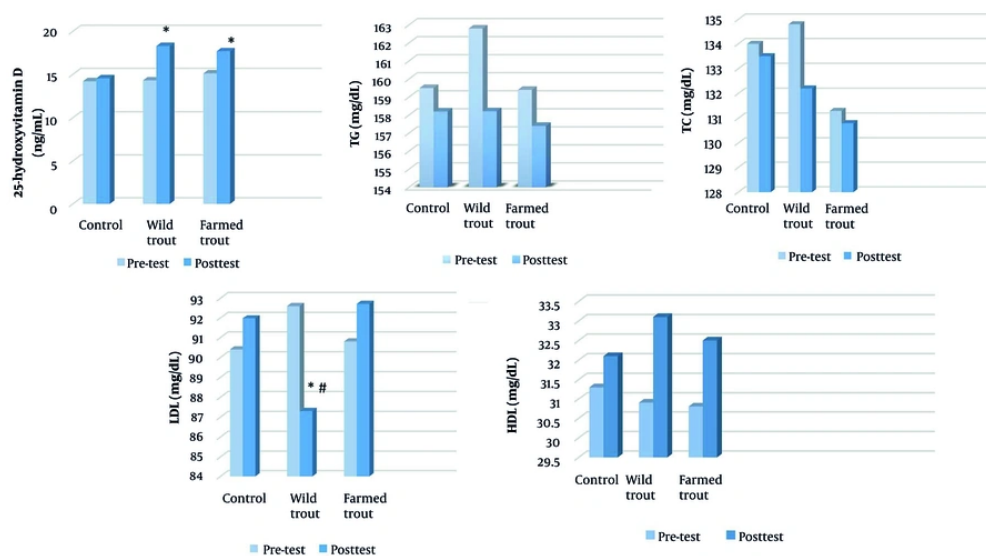
The lack of observed effect of fish consumption on exercise performance in the present study may be attributed to multiple factors. The relatively short study duration (4 weeks) likely played a significant role, as most comparable studies demonstrating positive effects employed intervention periods of 12 weeks or longer (44, 45, 47). Physiological adaptations to nutritional interventions — particularly for strength and anaerobic capacity — typically require ≥ 8 to 12 weeks to manifest (48). Furthermore, the anti-inflammatory properties of omega-3 fatty acids and their potential to enhance muscle protein synthesis may require extended exposure periods to yield measurable performance improvements (46). The dosage of fish consumption (200 - 250 g/week) in our study was notably lower than the 300 g/week used in similar research (25). It should also be considered that most existing studies examining exercise performance effects have focused on concentrated fish components (e.g., fish oil or isolated omega-3 supplements) rather than whole fish consumption, typically over longer intervention periods (2, 3, 11, 18, 20). Demographic variables including age, sex, baseline nutritional status, and fish species/source may further influence study results. An important consideration is that our participants' regular exercise habits and presumably adequate baseline nutrition may have minimized any additional benefits from fish consumption, as their nutritional status was likely already optimized for performance.

In this study, LDL levels remained unchanged in the farmed trout group but significantly decreased in the wild trout group compared to the control and farmed trout groups. No significant differences were found in other lipid parameters among the groups. Previous research on fish consumption's effects on lipid profiles has shown inconsistent results across different populations. Erkkila et al. found that low-fat fish consumption (≥ 4 times per week) for 8 weeks had no significant effect on triglyceride, cholesterol, or HDL levels, which is consistent with our findings (13). Wang et al. demonstrated that omega-3 intake led to a linear reduction in triglycerides and LDL (49). In contrast, Dadash Nejad et al. reported metabolic improvements after eight weeks of combined training and omega-3 supplementation, contradicting our result (50). Similarly, Fakhrzadeh et al. observed that fish oil supplementation (1 g/day for 6 months) effectively lowered triglycerides in elderly subjects, a finding inconsistent with our study (51). These inconsistencies may be attributed to variations in intervention duration, dosage, exercise regimens, demographic characteristics, or participants' health status. The beneficial effects of physical activity on lipid profiles are mediated through multiple mechanisms including reduced fat mass, enhanced lipolysis, increased oxygen consumption, improved glucose uptake (via GLUT-4 activation), and various muscular adaptations (52, 53). Similarly, fish consumption may positively influence lipid metabolism by modulating gene expression related to fat metabolism (20). However, the lack of change in lipid profile in the present study could be related to the short duration of the study. In some studies, fish consumption for 8 weeks or more has improved lipid profiles (50, 51). Changes in lipid metabolism often require sustained dietary changes (13, 49). On the other hand, the participants' baseline normal lipid levels may also have limited the extent of improvement.

This study found that both wild and farmed trout consumption significantly increased 25-hydroxyvitamin D3 levels compared to the control group, though no significant difference was observed between the two fish groups. Limited studies have examined the effects of consuming different types of fish on vitamin D levels. Lehmann et al. observed a significant increase in vitamin D concentrations in the group consuming farmed rainbow trout in a review study, which is consistent with the present study (25). Eslick et al. reported that consuming fatty and lean fish at least four times a week had no effect on vitamin D levels, which is inconsistent with the present study (54). In a study conducted in autumn in southwestern Norway at

Figure 3. Results of the Bonferroni test for comparing means in the post-test

latitude 60°N, it was reported that five 75-gram servings of salmon per week for dinner were inadequate to prevent a decrease in serum vitamin D in overweight adults (49). When analyzing vitamin D3 levels, it is important to consider that these levels can vary according to the season, geographic location, ethnicity, training environment, type of sport, and diverse populations (55). The Australian Nutrition Society recommends consuming fatty fish to optimize vitamin D levels (56). The increase in vitamin D in both fish consumption groups in the present study may be related to the high number of servings consumed. Unfortunately, at the start of the study, all subjects had lower than normal levels of vitamin D. Although fish consumption increased their vitamin D levels, they still remained below normal levels. The lack of difference in fish consumption between the two groups could be related to the duration of the study. In the wild trout group, vitamin D increased more, which was not significant compared to the farmed fish group, although it might have been significant if the study duration had been extended. As stated in previous studies, wild fish have higher levels of vitamin D (34). Despite the effect of vitamin D on improving athletic performance and lipid profile, this study found that its

increase, along with the anti-inflammatory properties of fish, failed to cause any change in athletic performance and lipid profile, which can be attributed to the short duration of the study.

5.1. Conclusions

The results of the study indicate that the consumption of farmed and wild trout had no effect on sport performance (upper body strength, lower body strength, and average anaerobic power), total cholesterol, triglycerides, and HDL levels in trained female bodybuilders. However, consuming both types of fish increased vitamin D levels in the subjects. On the other hand, LDL levels were significantly reduced in the group consuming wild trout compared to both the control group and the group consuming farmed trout. It is recommended that individuals with vitamin D deficiency consume fish. Additionally, further research should be conducted on the impact of fish consumption on athletic performance.

5.2. Limitations

This study had several limitations. The small sample size may reduce the generalizability of the findings, and the short 4-week intervention period might have been

insufficient to detect significant changes in performance and lipid profiles, as longer durations (≥ 8 - 12 weeks) are typically needed for measurable effects. The dosage of fish consumed (200 - 250 g/week) was relatively low compared to other studies, and participants' pre-existing athletic lifestyles and optimized diets may have limited additional benefits. Dietary intake outside the intervention was not strictly controlled, and the study focused solely on female bodybuilders, limiting applicability to other populations. Seasonal variations in vitamin D levels and natural differences in fish nutrient composition were not accounted for. Additionally, the lack of muscle biopsies or molecular analyses prevented deeper mechanistic insights. Future studies should explore longer interventions, larger and more diverse cohorts, and direct comparisons between whole fish and isolated omega-3 supplements.

Acknowledgements

Footnotes

References

1. Kawamura T, Muraoka I. Exercise-Induced Oxidative Stress and the Effects of Antioxidant Intake from a Physiological Viewpoint. *Antioxidants*. 2018;**7**(9):119. [PubMed ID: 30189660]. [PubMed Central ID: PMC6162669]. https://doi.org/10.3390/antiox7090119.

2. Jouris KB, McDaniel JL, Weiss EP. The effect of omega-3 fatty acid supplementation on the inflammatory response to eccentric strength exercise. *J Sports Sci Med*. 2011;**10**(3):432.

3. D'Angelo STEFANIA, Madonna G, Di Palma D. Effects of fish oil supplementation in the sport performance. *J Phys Educ Sport*. 2020;**20**(4):2322-9.

4. Reid K. Performance Food: Promoting foods with a functional benefit in sports performance. *Nutr Bull*. 2013;**38**(4):429-37. https://doi.org/10.1111/nbu.12065.

5. Hooks MP, Madigan SM, Woodside JV, Nugent AP. Dietary Intake, Biological Status, and Barriers towards Omega-3 Intake in Elite Level (Tier 4), Female Athletes: Pilot Study. *Nutrients*. 2023;**15**(13):2821. [PubMed ID: 37447148]. [PubMed Central ID: PMC10343224]. https://doi.org/10.3390/nu15132821.

6. Pierens SL, Fraser DR. The origin and metabolism of vitamin D in rainbow trout. *J Steroid Biochem Mol Biol*. 2015;**145**:58-64. [PubMed ID: 25305412]. https://doi.org/10.1016/j.jsbmb.2014.10.005.

7. de Roos B, Wood S, Bremner D, Bashir S, Betancor MB, Fraser WD, et al. The nutritional and cardiovascular health benefits of rapeseed oil-fed farmed salmon in humans are not decreased compared with those of traditionally farmed salmon: a randomized controlled trial. *Eur J Nutr*. 2021;**60**(4):2063-75. [PubMed ID: 33015732]. [PubMed Central ID: PMC8137615]. https://doi.org/10.1007/s00394-020-02396-w.

8. Calder PC. Omega-3 polyunsaturated fatty acids and inflammatory processes: nutrition or pharmacology? *Br J Clin Pharmacol*. 2013;**75**(3):645-62. [PubMed ID: 22765297]. [PubMed Central ID: PMC3575932]. https://doi.org/10.1111/j.1365-2125.2012.04374.x.

9. Dewailly EE, Blanchet C, Gingras S, Lemieux S, Sauve L, Bergeron J, et al. Relations between n-3 fatty acid status and cardiovascular disease risk factors among Quebecers. *Am J Clin Nutr*. 2001;**74**(5):603-11. [PubMed ID: 11684528]. https://doi.org/10.1093/ajcn/74.5.603.

10. Hill AM, Worthley C, Murphy KJ, Buckley JD, Ferrante A, Howe PR. n-3 Fatty acid supplementation and regular moderate exercise: differential effects of a combined intervention on neutrophil function. *Br J Nutr*. 2007;**98**(2):300-9. [PubMed ID: 17391558]. https://doi.org/10.1017/S0007114507707286.

11. Jeromson S, Gallagher IJ, Galloway SD, Hamilton DL. Omega-3 Fatty Acids and Skeletal Muscle Health. *Mar Drugs*. 2015;**13**(11):6977-7004. [PubMed ID: 26610527]. [PubMed Central ID: PMC4663562]. https://doi.org/10.3390/md13116977.

12. Calder PC. Marine omega-3 fatty acids and inflammatory processes: Effects, mechanisms and clinical relevance. *Biochim Biophys Acta*. 2015;**1851**(4):469-84. [PubMed ID: 25149823]. https://doi.org/10.1016/j.bbalip.2014.08.010.

13. Eslick GD, Howe PR, Smith C, Priest R, Bensoussan A. Benefits of fish oil supplementation in hyperlipidemia: a systematic review and meta-analysis. *Int J Cardiol*. 2009;**136**(1):4-16. [PubMed ID: 18774613]. https://doi.org/10.1016/j.ijcard.2008.03.092.

14. Mohamadpour H, Rahnama N, Faramarzi M. [Effect of consuming omega-3 fatty acid supplement along with resistance training on

some physical fitness factors in healthy elderly women]. *Sport Physiol*. 2014;**6**(22):41-54. FA.

15. Gammone MA, Riccioni G, Parrinello G, D'Orazio N. Omega-3 Polyunsaturated Fatty Acids: Benefits and Endpoints in Sport. *Nutrients*. 2018;**11**(1):46. [PubMed ID: 30591639]. [PubMed Central ID: PMC6357022]. https://doi.org/10.3390/nu11010046.

16. Duda MK, O'Shea KM, Lei B, Barrows BR, Azimzadeh AM, McElfresh TE, et al. Dietary supplementation with omega-3 PUFA increases adiponectin and attenuates ventricular remodeling and dysfunction with pressure overload. *Cardiovasc Res*. 2007;**76**(2):303-10. [PubMed ID: 17643403]. [PubMed Central ID: PMC2747038]. https://doi.org/10.1016/j.cardiores.2007.07.002.

17. Zebrowska A, Mizia-Stec K, Mizia M, Gasior Z, Poprzecki S. Omega-3 fatty acids supplementation improves endothelial function and maximal oxygen uptake in endurance-trained athletes. *Eur J Sport Sci*. 2015;**15**(4):305-14. [PubMed ID: 25176010]. https://doi.org/10.1080/17461391.2014.949310.

18. Philpott JD, Witard OC, Galloway SDR. Applications of omega-3 polyunsaturated fatty acid supplementation for sport performance. *Res Sports Med*. 2019;**27**(2):219-37. [PubMed ID: 30484702]. https://doi.org/10.1080/15438627.2018.1550401.

19. Shei RJ, Lindley MR, Mickleborough TD. Omega-3 polyunsaturated fatty acids in the optimization of physical performance. *Mil Med*. 2014;**179**(11 Suppl):144-56. [PubMed ID: 25373099]. https://doi.org/10.7205/MILMED-D-14-00160.

20. Shysh AM, Nagibin VS, Kaplinskii SP, Dosenko VE. N-3 long chain polyunsaturated fatty acids increase the expression of PPARgamma-target genes and resistance of isolated heart and cultured cardiomyocytes to ischemic injury. *Pharmacol Rep*. 2016;**68**(6):1133-9. [PubMed ID: 27588389]. https://doi.org/10.1016/j.pharep.2016.06.013.

21. Lara JJ, Economou M, Wallace AM, Rumley A, Lowe G, Slater C, et al. Benefits of salmon eating on traditional and novel vascular risk factors in young, non-obese healthy subjects. *Atherosclerosis*. 2007;**193**(1):213-21. [PubMed ID: 17069820]. https://doi.org/10.1016/j.atherosclerosis.2006.06.018.

22. McMullan JE, Yeates AJ, Allsopp PJ, Mulhern MS, Strain JJ, van Wijngaarden E, et al. Fish consumption and its lipid modifying effects - A review of intervention studies. *Neurotoxicol*. 2023;**99**:82-96. [PubMed ID: 37820771]. [PubMed Central ID: PMC11749167]. https://doi.org/10.1016/j.neuro.2023.10.003.

23. Kooshki A, Taleban FA, Tabibi H, Hedayati M. Effects of marine omega-3 fatty acids on serum systemic and vascular inflammation markers and oxidative stress in hemodialysis patients. *Ann Nutr Metab*. 2011;**58**(3):197-202. [PubMed ID: 21757893]. https://doi.org/10.1159/000329727.

24. Plum LA, DeLuca HF. The Functional Metabolism and Molecular Biology of Vitamin D Action. *Clin Rev Bone Miner Metab*. 2009;**7**(1):20-41. https://doi.org/10.1007/s12018-009-9040-z.

25. Lehmann U, Gjessing HR, Hirche F, Mueller-Belecke A, Gudbrandsen OA, Ueland PM, et al. Efficacy of fish intake on vitamin D status: a meta-analysis of randomized controlled trials. *Am J Clin Nutr*. 2015;**102**(4):837-47. [PubMed ID: 26354531]. https://doi.org/10.3945/ajcn.114.105395.

26. Basravi P, Taheri M, Irandoust K. [The effect of vitamin D3 intake and aerobic exercise on lipid profile, TSH and depression in obese women]. *Sport Physiol Manag Invest*. 2023;**15**(1):29-43. FA.

27. Larson-Meyer DE. The importance of vitamin D for athletes. *Sports Sci Exch*. 2015;**28**:1-6.

28. Owens DJ, Allison R, Close GL. Vitamin D and the Athlete: Current Perspectives and New Challenges. *Sports Med*. 2018;**48**(Suppl 1):3-16. [PubMed ID: 29368183]. [PubMed Central ID: PMC5790847]. https://doi.org/10.1007/s40279-017-0841-9.

29. Challoumas D. Vitamin D supplementation and lipid profile: what does the best available evidence show? *Atherosclerosis*. 2014;**235**(1):130-9. [PubMed ID: 24835432]. https://doi.org/10.1016/j.atherosclerosis.2014.04.024.

30. Dziedzic EA, Przychodzen S, Dabrowski M. The effects of vitamin D on severity of coronary artery atherosclerosis and lipid profile of cardiac patients. *Arch Med Sci*. 2016;**12**(6):1199-206. [PubMed ID: 27904508]. [PubMed Central ID: PMC5108383]. https://doi.org/10.5114/aoms.2016.60640.

31. Lupton JR, Faridi KF, Martin SS, Sharma S, Kulkarni K, Jones SR, et al. Deficient serum 25-hydroxyvitamin D is associated with an atherogenic lipid profile: The Very Large Database of Lipids (VLDL-3) study. *J Clin Lipidol*. 2016;**10**(1):72-81 e1. [PubMed ID: 26892123]. [PubMed Central ID: PMC4762185]. https://doi.org/10.1016/j.jacl.2015.09.006.

32. Koundourakis NE, Androulakis NE, Malliaraki N, Tsatsanis C, Venihaki M, Margioris AN. Discrepancy between exercise performance, body composition, and sex steroid response after a six-week detraining period in professional soccer players. *PLoS One*. 2014;**9**(2). e87803. [PubMed ID: 24586293]. [PubMed Central ID: PMC3929557]. https://doi.org/10.1371/journal.pone.0087803.

33. Raatz S, Picklo M, Wolters W, Bliss RM. Getting Hooked on Farmed Salmon: A Good Source of Omega-3s. *Agricult Res Mag*. 2013;**61**.

34. Chen TC, Chimeh F, Lu Z, Mathieu J, Person KS, Zhang A, et al. Factors that influence the cutaneous synthesis and dietary sources of vitamin D. *Arch Biochem Biophys*. 2007;**460**(2):213-7. [PubMed ID: 17254541]. [PubMed Central ID: PMC2698590]. https://doi.org/10.1016/j.abb.2006.12.017.

35. Özçiçek E, Can E, Yılmaz Ö. Comparison of nutrient contents of wild and farmed rainbow trout (Oncorhynchus mykiss, Walbaum 1792) from Keban Dam Lake in Eastern Anatolia region of Turkey. *Aquac Res*. 2022;**53**(6):2457-63. https://doi.org/10.1111/are.15763.

36. Nieman DC. *Exercise testing and prescription: a health related approach*. New York, USA: McGraw-Hill; 2003.

37. Mackenzie B. Performance evaluation tests. *London: Electric World plc*. 2005;**24**(25):57-158.

38. Burgess K, Holt T, Munro S, Swinton P. Reliability and validity of the running anaerobic sprint test (RAST) in soccer players. *J Trainol*. 2016;**5**(2):24-9. https://doi.org/10.17338/trainology.5.2_24.

39. Karami S, Ramezani AR. [Adaptation in Response of Excitation and Inhibition Factors of Angiogenesis after 4 Weeks of Progressive Resistant Training in Sedentary Men]. *Horiz Med Sci*. 2016;**22**(4):267-74. FA. https://doi.org/10.18869/acadpub.hms.22.4.267.

40. Oz M, Dikel S. Comparison of Body Compositions and Fatty Acid Profiles of Farmed and Wild Rainbow Trout (Oncorhynchus mykiss). *Food Sci Technol*. 2015;**3**(4):56-60. https://doi.org/10.13189/fst.2015.030402.

41. Ural MS, Çalta M, Parlak AE. The comparison of fatty acids, fat-soluble vitamins and cholesterol in the muscle of wild caught, cage and pond reared rainbow trout (Oncorhynchus mykiss W., 1792). *Iran J Fish Sci*. 2017;**17**(1):431-40.

42. Lewis NA, Daniels D, Calder PC, Castell LM, Pedlar CR. Are There Benefits from the Use of Fish Oil Supplements in Athletes? A Systematic Review. *Adv Nutr*. 2020;**11**(5):1300-14. [PubMed ID: 32383739]. [PubMed Central ID: PMC7490155]. https://doi.org/10.1093/advances/nmaa050.

43. Lee SR, Jo E, Khamoui AV. Chronic Fish Oil Consumption with Resistance Training Improves Grip Strength, Physical Function, and Blood Pressure in Community-Dwelling Older Adults. *Sports*. 2019;**7**(7):167. [PubMed ID: 31323951]. [PubMed Central ID: PMC6680896]. https://doi.org/10.3390/sports7070167.

44. Da Boit M, Sibson R, Sivasubramaniam S, Meakin JR, Greig CA, Aspden RM, et al. Sex differences in the effect of fish-oil supplementation on the adaptive response to resistance exercise training in older people: a randomized controlled trial. *Am J Clin Nutr*. 2017;**105**(1):151-8. [PubMed ID: 27852617]. [PubMed Central ID: PMC5183731]. https://doi.org/10.3945/ajcn.116.140780.

45. Smith GI, Julliand S, Reeds DN, Sinacore DR, Klein S, Mittendorfer B. Fish oil-derived n-3 PUFA therapy increases muscle mass and function in healthy older adults. *Am J Clin Nutr*. 2015;**102**(1):115-22. [PubMed ID: 25994567]. [PubMed Central ID: PMC4480667]. https://doi.org/10.3945/ajcn.114.105833.

46. Mamerow MM, Mettler JA, English KL, Casperson SL, Arentson-Lantz E, Sheffield-Moore M, et al. Dietary protein distribution positively influences 24-h muscle protein synthesis in healthy adults. *J Nutr*. 2014;**144**(6):876-80. [PubMed ID: 24477298]. [PubMed Central ID: PMC4018950]. https://doi.org/10.3945/jn.113.185280.

47. Krzyminska-Siemaszko R, Czepulis N, Lewandowicz M, Zasadzka E, Suwalska A, Witowski J, et al. The Effect of a 12-Week Omega-3 Supplementation on Body Composition, Muscle Strength and Physical Performance in Elderly Individuals with Decreased Muscle Mass. *Int J Environ Res Public Health*. 2015;**12**(9):10558-74. [PubMed ID: 26343698]. [PubMed Central ID: PMC4586628]. https://doi.org/10.3390/ijerph120910558.

48. Thomas DT, Erdman KA, Burke LM. American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. *Med Sci Sports Exerc*. 2016;**48**(3):543-68. [PubMed ID: 26891166]. https://doi.org/10.1249/MSS.0000000000000852.

49. Wang T, Zhang X, Zhou N, Shen Y, Li B, Chen BE, et al. Association Between Omega-3 Fatty Acid Intake and Dyslipidemia: A Continuous Dose-Response Meta-Analysis of Randomized Controlled Trials. *J Am Heart Assoc*. 2023;**12**(11). e029512. [PubMed ID: 37264945]. [PubMed Central ID: PMC10381976]. https://doi.org/10.1161/JAHA.123.029512.

50. Dadash Nejad F, Gholami M, Soheili S. [The effect of eight-week combined exercise training (resistance-endurance) and Omega-3 ingestion on the levels of fetuin-A and metabolic profile in obese elderly women]. *Daneshvar Med*. 2020;**27**(4):35-44. FA.

51. Fakhrzadeh H, Ghaderpanahi M, Sharifi F, AkbariKamrani AA, Badamchizade Z, Larijani B. [Effect of Fish Oil on Serum Levels of Lipid Profile, Lipoprotein (a), Apolipoprotein A-1 and B, Fasting Sugar and Insulin, and InsulinResistance in the Elderly Residents of Kahrizak Charity Foundation]. *Iran J Ageing*. 2010;**4**(2):0 EP. FA.

52. Cox JH, Cortright RN, Dohm GL, Houmard JA. Effect of aging on response to exercise training in humans: skeletal muscle GLUT-4 and insulin sensitivity. *J Appl Physiol*. 1999;**86**(6):2019-25. [PubMed ID: 10368369]. https://doi.org/10.1152/jappl.1999.86.6.2019.

53. DeFronzo RA, Jacot E, Jequier E, Maeder E, Wahren J, Felber JP. The effect of insulin on the disposal of intravenous glucose. Results from indirect calorimetry and hepatic and femoral venous catheterization. *Diabetes*. 1981;**30**(12):1000-7. [PubMed ID: 7030826]. https://doi.org/10.2337/diab.30.12.1000.

54. Erkkila AT, Schwab US, de Mello VD, Lappalainen T, Mussalo H, Lehto S, et al. Effects of fatty and lean fish intake on blood pressure in subjects with coronary heart disease using multiple medications. *Eur J Nutr*. 2008;**47**(6):319-28. [PubMed ID: 18665413]. https://doi.org/10.1007/s00394-008-0728-5.

55. Maroon JC, Mathyssek CM, Bost JW, Amos A, Winkelman R, Yates AP, et al. Vitamin D profile in National Football League players. *Am J Sports Med*. 2015;**43**(5):1241-5. [PubMed ID: 25649084]. https://doi.org/10.1177/0363546514567297.

56. Jakobsen J, Smith C, Bysted A, Cashman KD. Vitamin D in Wild and Farmed Atlantic Salmon (Salmo Salar)-What Do We Know? *Nutrients*. 2019;**11**(5). [PubMed ID: 31036792]. [PubMed Central ID: PMC6566758]. https://doi.org/10.3390/nu11050982.