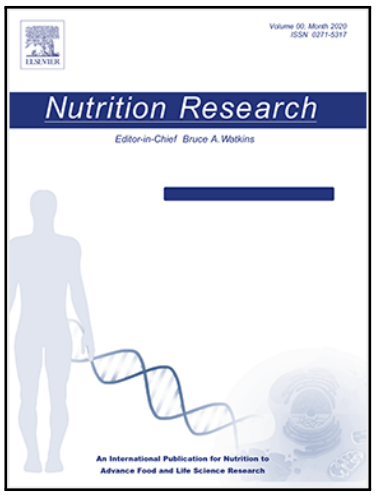

Omega-3 Index improves after increased intake of foods with omega-3 polyunsaturated fatty acids among United States service academy cadets

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Highlights

- Fish alternatives high in polyunsaturated fatty acids can improve Omega-3 Index.
- Smoothies with omega-3 fatty acids are good post-workout snacks for Service Members.
- It is feasible to reach the ideal Omega-3 index of 8%

Omega-3 Index improves after increased intake of foods with omega-3 polyunsaturated fatty acids among United States service academy cadets

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Abbreviations: omega-3 fatty acids (omega-3), Omega-3 Index (O3I)

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ABSTRACT

The inclusion of omega-3 fatty acids in our dietary intake is important for performance and recovery, and may reduce the risk of various health issues. Studies have shown the omega-3 fatty acid status of U.S. Service Members is low. The purpose of this study was to evaluate whether offering fish and omega-enhanced foods would increase the Omega-3 Index (O3I). We hypothesize cadets will increase O3I with enhanced omega-3 options more than fish alone. Food service venues at three U.S. Service Academies offered fish and other omega-3 foods to cadets for 12 weeks. Questionnaires were used to collect information on the dietary habits and omega-3 food intake of participants. The O3I of each participant was measured at baseline, mid- (6 weeks), and post-data collection (12 weeks) time points. Following the 12-weeks, we found a significant increase in O3I. More specifically, the intake of other omega-3 foods, smoothies (3 per week) and toppings (3 per week), increased O3I in cadets. This study identified a strategy encouraging omega-3 food intake and improving O3I among cadets. These results help us understand how we can more effectively impact military Service Member nutrition for optimal health and performance.

Keywords: cadets, docosahexaenoic acid (DHA), eicosapentaenoic acid (EPA), fish, Omega-3 Index

1. Introduction

Omega-3 fatty acids (omega-3) are essential fatty acids we must include in our diet for optimal health. Consuming inadequate amounts of omega-3 increases the risk of various health issues and chronic diseases [1-3]. Research has indicated most Americans including Service Members do not eat the recommended 2–3 servings/week of oily fish and have low omega-3 status. Therefore, alternative approaches are warranted. There are multiple types of omega-3, but the

majority of research studies focus on alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA)[1, 4-7]. EPA and DHA are found in oily fish and seafood, with salmon, herring, mackerel, and sardines having the highest amounts. Plant foods such as flaxseeds, chia seeds, and walnuts are good sources of ALA[6]. It has become clear that because the absorption and conversion of ALA to EPA is very low (typically reported as < 5%) and conversion to DHA is even lower[6], consuming ALA alone may not confer the requisite benefits of consuming omega-3. Here our focus will be on EPA and DHA, because of the low conversion from ALA, which is not thought to impact the Omega-3 Index (O3I).

O3I is a blood-based measure, representing the sum of eicosapentaenoic acid (EPA) C20:5n-3 and docosahexaenoic acid (DHA) C22:6n3 as the percent total of erythrocyte fatty acids. The O3I has been shown to correlate with cardiovascular risk factors [1, 2, 7, 8], with less than 4% O3I associated with high risk and 4–6% O3I with moderate risk of a cardiovascular disease (CVD) event [2]. An O3I of 8% or higher is believed to be optimal [2], and recommended as an approach to lower the risk of cardiovascular disease. Of particular interest to Service Members, an O3I above 8% might also correlate with less pain, and improve recovery and performance [5, 9-14]. Preliminary research indicates an O3I over 8% might also be associated with less inflammation, better recovery and less risk of injury [10, 12]. The average O3I for Americans is around 4.3% and studies have shown similar results for Service Members [4, 13, 15-17].

The mission of the U.S. service academies is to provide instruction and experience for cadets to graduate with the essential knowledge, character, leadership and motivation of career officers in the U.S. military [18]. To that end, nutritional fitness is a pivotal factor for cadet health and performance. The food service environment at the service academies differs from college or

other military dining facilities. Cadets are required to eat at least one to two meals per day in the dining facility where they are served all at the same time, using a family style dining approach. Because of the large volume of meals prepared and served at one time meals are brought out on hot carts and served to cadets at each of the tables. From a logistics standpoint, this approach takes preparation and planning to ensure proper food handling and desirable, appealing meals. Currently, there are a limited number of other dining locations at service academies, and none have fast food establishments. Although dining options might be available in the local community, they are not often an option for cadets due to their busy schedules. Given the unique food service environment at service academies for both diners and food service operators, the purpose of our study was to evaluate whether offering omega-3 (EPA/DHA) enhanced smoothies and toppings for 12 weeks could increase omega-3 consumption and O3I of cadets. We hypothesize cadets will increase O3I with alternative omega-3 options more than fish alone. Offering smoothies and topping with EPA and DHA allows for self-selection of omega-3 products other than fish, which is not widely accepted and not portable or convenient. This is unique because very few foods (oily fish and algae) contain EPA and DHA. Creative approaches to improve omega-3 offerings will be necessary to raise O3I.

2. Methods and Materials

2.1 Study population

Participants were cadets enrolled at the United States Military Academy (USMA), West Point, NY; United States Air Force Academy (USAFA), Colorado Springs, CO; or United States Naval Academy (USNA), Annapolis, MD, and were willing to complete three finger pricks (at week 1,

6, and 12) for the O3I measurements. Participants with fish allergies or intolerances were excluded from the study.

2.2 Study design

This is a cohort study with 12 weeks of data collection. From baseline to 12 weeks, fish was offered at least twice a week and from 6 to 12 weeks, three Enhanced Omega-3 (EO3)™ smoothies were permitted each week. USMA participants were also offered omega-3 toppings typically used in yogurt and beverages (i.e. milk) from 6 to 12 weeks. The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board at the Uniformed Services University (Protocol MEM-91-10314) on 18 October 2021. Recruitment occurred via email and word of mouth. Interested volunteers emailed the study address for eligibility screening. Informed consent was obtained from all participants in the study. Participants were informed which foods are high in omega-3 and potential benefits during the consenting process.

2.3 Data collection

Self-reported demographics included height, weight, sex, age, race, year at academy, and supplement intake. Body Mass Index (BMI) was calculated from height and weight. Participants were asked whether they take any omega-3 or fish oil supplements. If the response was “yes”, they were asked to notate which supplement and the amount taken. Fish intake was also collected at weeks one, six and twelve. Participants were asked “Over the last 30 days, how often did you consume nonfried fish?”. The response options were rarely or never, once a month, twice a month, once a week, two to three times a week and four or more times per week. Participants also recorded two consecutive days of dietary intake with an automated self-administered 24-

hour online dietary assessment tool (ASA24-2020) the first and last week (week 1 and 12) of data collection. The dietary recall was used to assess overall diet quality of participants and ensure the minimal changes in other dietary habits. Nutrition education was not emphasized throughout the study. Participants were informed which foods are high in omega-3 and potential benefits during the consenting process.

2.3.1 Diet Quality

Dietary intake from the ASA24-2020 was used to calculate the Healthy Eating Index (HEI). The HEI is one way to compare dietary changes from pre to post data collection. Each component of the HEI is weighted equally at 10 points and some contain subcomponents (fruit, vegetables, and protein). The total score is calculated from the sum of the individual component scores for a potential maximum score of 100 [19, 20]. The HEI uses a density approach, where each component is scored per 1,000 calories, to create a standardized method for comparing diet quality across the general population [19]. Our previous publication contains further explanation of HEI scoring [17].

2.3.2 Omega-3 Index collection

The O3I were determined from a finger prick of blood collected at baseline, week 6, and week 12. Participants were instructed to rub their hands together for 20 seconds to increase blood flow. The fingertip was then cleaned with an alcohol wipe, then a lancet was placed lightly on the clean fingertip and pressed downward firmly into the finger until a click sound from the release of a small spring-loaded needle was heard. A drop of blood was obtained by lightly touching it to the center of a dotted circle on the antioxidant treated collection card. This was repeated three to four times until the circle on the collection card was covered. Pressure was then applied to the

finger with a gauze pad, and an adhesive bandage was placed on the finger. The blood spots on the card were left to dry for 15–20 minutes and then placed in a plastic bag. The cards containing only a participant ID were sent to OmegaQuant (Sioux Falls, SD, USA) for analysis. The OmegaQuant laboratory is CLIA certified and measures EPA and DHA with a validated method per the Guidance for Industry: Bioanalytical Method Evaluation (FDA; 23 May 2001).

2.3.3 Dining menu

The menus at each service academy were developed or reviewed by the dietitians to ensure fish was offered at least twice a week. However, menu development and production were not part of the research. The only modification of the menu for this research was the inclusion of fish twice per week during the 12-week study. All facilities were already typically offering fish twice a week.

2.3.4 Enhanced Omega-3 Multi-Nutritional (EO3)™ smoothies

EO3™ smoothies were available for participants to pick up in or near the dining facility. The smoothie provided 1600 mg of omega-3 (820 mg DHA, 550 mg EPA, 230 mg ALA). This product is also high in protein, vitamin D, vitamin E, iodine **(Figure 1)**. Participants were permitted to pick up three smoothies each week. In an effort to track intake, participants were asked how many smoothies they consumed the week prior when they picked up a smoothie. This information was recorded on a smoothie intake log by the dietitian or research staff at each location.

2.3.5 Omega-3 toppings

In addition to smoothies, omega-3 toppings were offered at USMA. The toppings were purchased from Zack snacks and distributed in 15 ml (1 tbsp) individual servings. Each 15 ml

serving contained 1500 mg of omega-3 from EPA and DHA **(Figure 2)**. The toppings were citrus or lime flavored and intended to be added to milk, yogurt or food of choice. Participants reported their topping intake when they reported their smoothie consumption.

2.4 Statistical analysis

Data analyses were completed using IBM SPSS statistics for Windows, Version 28 (IBM Corp., Armonk, NY, USA). This study was powered to detect significant changes in effect size in the smaller range (d = 0.2-0.3). Two-tailed power analyses were conducted with alpha set at 0.05 and power at 0.8. In order to detect small but significant within-subject changes along each outcome, a sample of 90-199 participants were needed. We also anticipated some subjects being lost to follow-up. Frequencies and measures of central tendency were computed to summarize participant demographics. The results are presented as frequency/mean ± standard deviation (SD), unless noted otherwise. Paired sample t-tests were conducted to assess the average change in O3I from baseline to post data collection and to compare HEI means for pre- and post-data collection analyses. Finally, a multiple linear regression was conducted to assess the relationship between increased omega-3 consumption (variables of interest included baseline O3I, mid O3I, fish intake, smoothie intake, topping intake) and changes in post-data collection O3I, while controlling for covariates. Multiple comparisons were controlled using the Benjamini-Hochberg method. Standard alpha levels ($p \leq 0.05$) were used to determine significance.

3. Results

3.1 Demographics

A total of 198 participants signed the informed consent; of those 31 did not complete the baseline visits and were excluded from analysis where data was not available. Twenty-six participants

were lost to follow up and 40 antioxidant collection cards from the USAF were not mailed in time and thus were unable to be analyzed, however these 40 participants were not excluded from earlier analysis. Pairwise list deletion was used to handle missing data in inferential analysis (paired sample t-test and regressions). A summary of participant demographics including institution, year at academy, sex, race, height, weight, BMI and supplement intake is shown in **Table 1**. The majority of the sample is Caucasian, male (58%) with an average BMI, this is representative of the population at the service academies. Dietary supplement intake was not included in any further analysis because only two participants who reported taking dietary supplements completed both O3I measures.

3.2 Omega-3 Index

A multiple linear regression indicates baseline O3I, mid O3I, high smoothie consumption (3/week), and topping consumption (3/week) are predictors of post O3I ($F = 13.0$, $p < 0.05$, $Radj^2 = 0.54$) (**Table 2**). The largest increase in O3I was from baseline to post data collection (12 weeks), with minimal change occurring the first 6 weeks (**Table 3**). Of note, the number of participants in the high risk O3I category (< 4.0%) decreased from 32 at baseline to four at post data collection. In addition, five participants had an O3I greater than 8% and five more with greater than 7% at post data collection compared to only two participants at 7% or above at baseline (one in 4.0–7.9% and one in the ≥ 8% category) and no participants at 7% or higher at mid data collection (6 weeks). All 10 participants with a post-data collection O3I of 7% or higher consumed three or more smoothies per week. When taking a look at how the individual fatty acids within the O3I changed we found that DHA C22:6n3 and EPA C20:5n3 both significantly increased and Arachidonic Acid (AA) C20:4n6 decreased **(Table 4).**

3.3 Dietary intake

Participant dietary intake patterns from total HEI scores (**Table 5**) were not significantly different between baseline ($\bar{x}$ 65.1 ± 9.5) and post data collection ($\bar{x}$ 64.5 ± 9.0; p = 0.74). In addition, no individual HEI components were significantly different. Participants did not significantly increase their fish intake from baseline to 6 or 12 weeks; therefore, fish consumption was not a significant predictor of post-data collection O3I (p = 0.22). The most common response for the amount of fish consumed was 2-3 times per week at all three time points. For the other omega-3 foods provided, 31 participants consumed 18 or more smoothies (average of 3/week), 15 participants consumed 10–17 smoothies (average of 2/week), and 10 participants consumed 2–9 smoothies over the 6-week study duration. Toppings were only offered at USMA and 12 participants were reported to consume toppings. All but two participants who consumed the toppings also consumed the smoothies (**Table 6**).

3.4 Participant feedback

Participants reported that some of the fish (especially non-oily fish) was dry and therefore did not choose it when it looked dry. On the other hand, some USNA participants reported being very satisfied with the appearance and taste of salmon. The EO3™ smoothies also had mixed reviews. Most participants tolerated the smoothies and no adverse reactions were reported. However, two participants reported they preferred to eat fish, and a few participants did not like the taste or consistency of the smoothies. One female participant reported not consuming the smoothies because they had too many calories.

4. Discussion

Our results support the hypothesis that offering alternative omega-3 foods will improve omega-3 consumption and therefore O3I among cadets. This is one of the first studies in the military attempting to improve the O3I through *ad libitum* intake of select foods high in omega-3. Our results suggest that a recovery snack (smoothie) with enhanced omega-3 improves O3I. Providing omega-3 enhanced recovery snacks, such as smoothies or possibly enhancing the recovery bars or chocolate protein drinks already part of the military system, might be a feasible approach to increase O3I.

Several studies in the military have attempted to increase the O3I through dietary supplements [13, 15], but compliance is typically low. Given the low compliance outcomes are largely null are not what one would expect. One Army study [21] provided military members common foods enhanced with omega-3 (chicken meat, chicken sausage, eggs, salad dressings, pasta sauces, cooking oil, mayonnaise, and peanut butter). This followed a similar study conducted in civilians that also provided smoothies enhanced with omega-3, with the greatest improvement seen in those ingesting both omega-3 enhanced foods and smoothies [22]. Our approach was to increase access to fish in a dining facility and provide omega-3 enhanced smoothies as a recovery snack or omega-3 enhanced toppings for adding to milk, yogurt or a food of choice.

One purpose of this study was to evaluate changes in the O3I of cadets offered fish twice a week for 12 weeks. Unfortunately, our participants did not significantly increase their fish intake from baseline to 6 or 12 weeks; therefore, fish consumption was not a significant predictor of post-data collection O3I. The main reasons why fish intake did not increase are likely due to the lack of educational material encouraging fish intake, the type of fish offered and how the fish was prepared. Due to supply chain issues during a national health crisis (Coronavirus disease) and

rising food costs, some service academies only offered salmon and high omega-3 fish once a week and provided other types of fish (cod, tilapia, rockfish, flounder, and tuna) for additional fish offerings. This uncontrollable logistical challenge might have affected the study results since the non-oily fish options are not as high in omega-3 as salmon. Another reported reason for low fish intake was the appearance, some participants reported they did not like the texture. This might be explained by the use of hot carts and the ability of salmon to better withstand the heat from the carts than non-oily fish.

No significant differences were noted in total HEI scores from baseline to post data collection. The only planned menu change was the increased offering of fish and omega-3 smoothies and toppings. Therefore, we did not expect an improvement in total HEI scores, although we did expect to see an improvement in the fatty acids HEI component if participants had consumed more oily fish. It is important to note the total HEI scores for the service academies (65) is higher than a recent Army cohort on military bases (60) [17].

Overall, the EO3™ smoothies were well accepted by cadets, but consumption was lower than expected. However, consuming three or more smoothies per week was a significant predictor of improved O3I. This result was expected because each smoothie contained 1600 mg of omega-3, which is more than double or triple the amount in a serving of fish.

One limitation of the study was the participants had to pick up the ready to drink smoothies in or near the dining facility, and although we made it as convenient as possible, that extra step may have decreased consumption of smoothies. Another limitation of this study was not being able to control for the quality or quantity of fish offered. However, due to the low consumption of fish nationwide, it is possible the number of participants choosing to eat fish would not have been

much higher, regardless of this limitation. In addition, relying on self-reported intake of smoothies is a limitation and may not accurately reflect the true amount participants consumed. Alternatively, requiring participants to drink the smoothies when provided would have helped minimize our reliance on self-reported intake. Education at point of selection may have increased fish consumption at least temporarily. This could be done using table tents, menu boards or educational campaigns. However, it is unknown if participants would continue to choose fish. Our goal is to improve regular self-selection of omega-3 foods.

Multiple linear regression indicates the baseline O3I, mid O3I, high smoothie consumption (3/week), and high topping consumption (3/week) are predictors of post O3I. We anticipated baseline and mid O3I would be predictors of post O3I based on our previous research [23]. Although our participants did not consume enough omega-3 from fish to statistically increase O3I, high consumption of other omega-3 foods, including smoothies and toppings, were sufficient to raise O3I. These results are consistent with previous studies indicating it is possible to improve O3I if participants consume more omega-3 through foods [22]. The challenge of increasing O3I to the desired 8% is in finding a way that encourages regular consumption of EPA/DHA rich omega-3 foods. Since the majority of our participants did not reach an O3I of 8%, offering omega-3 enhanced foods regularly or ensuring ingestion of a recovery snack enhanced with omega-3 might be viable solutions. Ways this can be increased are by modifying the food environment to offer fish in an appealing manner and including omega-3 options at fueling stations, snack bars and other available venues. Additionally, providing education and marketing the potential benefits at point of purchase are all strategies to increase demand and desire to consume omega-3 foods. Given the limited number of omega-3 enhanced foods

available in the military food supply chain, ready to drink smoothies seem to be an ideal approach.

This study moves research one step forward by indicating other food options to increase omega-3 consumption. Smoothies are convenient and portable, which make them a good option as a recovery snack after exercise or when desired as compared to a meal that is only offered at a set time. The omega-3 toppings were also a predictor of post-O3I, but it is important to note that many of those who consumed the toppings also consumed the smoothies. The toppings were not a popular choice, most likely because they had to be added to a beverage, yogurt or food of their choice.

Although this study was not focused on HEI, it was used as a measure to ensure no other dietary changes were affecting the O3I results. However, participants in both studies had low average scores for the fatty acid ratio HEI component, which suggests an intervention is necessary to increase the intake of monounsaturated and omega-3 fatty acids and reduce the intake of saturated and omega-6 fatty acids DoD wide. Regardless, our study clearly showed that those who consumed higher amounts of omega-3 had the greatest improvement in post O3I. In addition, when looking at the individual fatty acids EPA and DHA increased, while AA decreased. We expected to see EPA and DHA increase given the increase omega-3 from baseline. Several plausible explanations may be responsible for the decrease in AA, including greater consumption of EPA/DHA, reduced consumption of foods higher in AA, or replacing high AA foods with high omega-3 foods (i.e., smoothies). Nevertheless, improving the ratio of omega-3 to omega-6 fatty acids is desirable. The average American diet is typically high in AA

and low in EPA and DHA. However, the change was minimal and likely not clinically significant for this study. It is worth evaluating in future research.

Interest in omega-3 research to understand the effect of O3I on the performance, health, and readiness of Service Members has increased, however more studies are needed for a complete picture of their potential benefits. To date, no comparisons of performance measures in cohorts with low and high O3I have been made. Importantly, one military study showed that supplementing military personnel with protein, arginine, glutamine, omega-3, vitamin D, zinc, and vitamin C helped facilitate wound healing after sleep restriction [24]. Future studies can optimize the nutrition environment to make it easy and convenient to choose foods high in omega-3. Additional research can address if and how consumption of omega-3 might affect military performance and readiness.

5. Conclusion

We found the O3I can be improved by offering cadets more omega-3 food options. This positive impact on O3I provides a way forward for increasing the O3I in military populations, which has been consistently low. Future studies seeking to understand the effect of O3I on the performance, health, and readiness of Service Members can use this method to improve omega-3 consumption in their sample populations. Making omega-3 options convenient and portable, by increasing access at different food service venues (e.g., dining halls, commissary, and vending), can improve the inclusion of omega-3 in snacks or a recovery meal.

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Author Contributions

Melissa Rittenhouse: Conceptualization, methodology, analysis, writing-original draft. **Nick Barringer**: Methodology and recruitment. **Daniel Jaffe**: Recruitment and data collection. **Jenna Morogiello:** Data collection. **Jessica Kegel:** Statistical analysis. **Beth McNally**: Editing. **Patricia Deuster:** Conceptualization, funding, writing-review, and editing.

Author Declarations

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Legends to Figures

Figure 1: Enhanced Omega-3 Multi-Nutritional (EO3)™ smoothie nutrition facts label for smoothies consumed by cadets.

FL OZ = fluid ounce; mL = milliliters; mg = milligram; g = grams; µg = microgram; % = percent; * = Percent Daily Values are based on a 2,000 calorie diet

Nutrition Facts

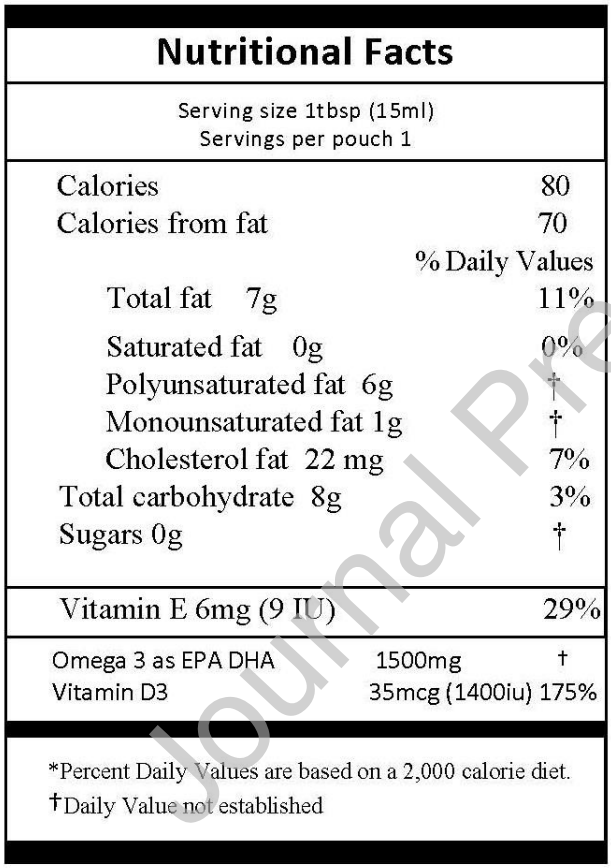
Serving Size 1 (8.45 FL OZ) (250mL)

Amount Per Serving	
Calories	252
	% Daily Value*
Total Fat 8g	**10%**
Saturated Fat 1.5g	**12%**
Trans Fat 0g	
Monounsaturated Fat 3.7g	
Polyunsaturated Fat 2.5g	
Cholestrol 65mg	**22%**
Sodium 149mg	**6%**
Total Carbohydrate 25g	**9%**
Dietary Fiber 1.5g	**5.3%**
Total Sugars 23g	
Includes 0g Added Sugars	**0%**
Protein 20g	**40%**
Vitamin D 5µg	**25%**
Vitamin E 3mg	**20%**
Calcium 65mg	**5%**
Iron 0.45mg	**2.5%**
Potassium 392mg	**8.3%**
Phosphorus 75mg	**6%**
Iodine 87.4µg	**58%**

*Percent Daily Values are based on a 2,000 calorie diet. Your Daily Values may be higer or lower depending on your calorie needs.

Figure 2: Toppings nutrition facts label for addition of Omega-3 fatty acids (Omega-3) to foods consumed by cadets

Tbsp = Tablespoon; ml = milliliters; g = grams; mg = milligram; mcg = microgram; % = percent; IU = International Unit; * = Percent Daily Values are based on a 2,000 calorie diet; † = Percent Daily Value not established.



Nutritional Facts

Serving size 1tbsp (15ml)
Servings per pouch 1

Calories		80
Calories from fat		70
		% Daily Values
Total fat	7g	11%
Saturated fat	0g	0%
Polyunsaturated fat	6g	†
Monounsaturated fat	1g	†
Cholesterol fat	22 mg	7%
Total carbohydrate	8g	3%
Sugars	0g	†
Vitamin E	6mg (9 IU)	29%
Omega 3 as EPA DHA	1500mg	†
Vitamin D3	35mcg (1400iu)	175%

*Percent Daily Values are based on a 2,000 calorie diet.
†Daily Value not established

Tables

Table 1: Cadet demographics indicated by frequency and percent sample

Demographic	**n (%)/ ($\bar{x}$ SD)**
Service Academy	
United States Naval Academy (USNA)	78 (40%)
United States Military Academy (USMA)	79 (41%)
United States Air Force Academy (USAFA)	40 (20%)
Race	
African American/Black	12 (6%)
Asian	17 (9%)
Caucasian/White	114 (58%)
Hispanic or Latino	4 (2%)
Mixed	31 (15%)
No answer	19 (10%)
Sex	
Male	103 (58%)
Female	76 (42%)
Height (in)	67.9 ± 3.4
Weight (lbs)	160 ± 27.2

BMI	24.2 ± 2.7
Age (years)	20.4 ± 1.5
Year at academy	2.1 ± 1.3
Supplement Intake	
NO	Pre: 180 (91%) / Post: 39 (20%)
YES	Pre: 17 (9%) / Post: 6 (3%)

Values are n = frequency (% = percent sample), BMI = Body Mass Index; SD = Standard Deviation; $\bar{x}$ = mean; in = inches; lbs = pounds

Table 2: Multiple linear regression identified baseline O3I, mid O3I, high smoothie, and high toppings consumption as predictors of post O3I among cadets.

Predictors	Adjusted Model (n = 62)
	β (95% CI)
Baseline O3I	0.34 (0.16 – 0.99)*
Mid O3I	0.31 (0.11 – 0.93)*
High fish consumption	-0.10 (-0.92 – 0.29)
High smoothie (≥ 18)	0.33 (0.24 – 1.7)*
Low smoothie (< 18)	0.18 (-0.19 – 1.33)
Omega-3 toppings (yes/no)	0.27 (0.32 – 1.66)*

* Significant at $p < 0.05$; O3I = Omega-3 Index; β = standardized coefficients beta; 95% CI = 95% confidence interval

Table 3: The O3I average, category frequency, and percentage at baseline, mid, and post data collection for cadets.

Category	Baseline	6 weeks	12 weeks
Omega-3 Index (O3I)	4.8 ± 0.9	4.8 ± 0.8	5.8 ± 1.3
O3I category			
< 4.0%	32 (19%)	23 (16%)	4 (5%)
4.0–7.9%	134 (80%)	118 (84%)	77 (81%)
≥ 8%	1 (1%)	0 (0%)	5 (6%)

Values are means +/- SD or frequency with percent sample; O3I = Omega-3 Index; % = percent of sample

Table 4: Select Omega-3 and omega-6 fatty acids at baseline and post data collection.

Fatty Acid	Week 1	Week 12	t	p
EPA C20:5n3	0.6 ± 0.2	0.8 ± 0.5	- 4.7*	< 0.00
DHA C22:6n3	2.8 ± 0.6	3.0 ± 0.7	- 4.8*	< 0.00
ALA C18:3n3	0.5 ± 0.2	0.5 ± 0.2	0.7	0.51
AA C20:4n6	10.8 ± 1.4	9.7 ± 1.1	7.7*	< 0.00
LA C18:2n6	23.7 ± 2.6	23.7 ± 2.3	0.4	0.66

EPA = eicosapentaenoic acid; DHA = docosahexaenoic acid; ALA= alpha-linolenic acid; AA= Arachidonic acid; LA= Linoleic acid, t = t-statistic, p = significance value. * Significant at $p < 0.05$.

Table 5: Healthy Eating Index (HEI) average scores and paired sample t-test analysis at baseline and post data collection.

HEI Component	Baseline (mean ± SD)	Post Data collection (mean ± SD)	t
Adequate components			
Total fruit	2.1 ± 1.9	2.1 ± 1.8	0.19
Whole fruit	2.6 ± 2.2	2.5 ± 2.2	0.16
Total vegetables	2.9 ± 1.4	2.9 ± 1.7	-0.02
Greens and beans	2.2 ± 2.1	2.6 ± 2.2	-0.90
Whole grains	2.6 ± 2.6	3.6 ± 3.1	-1.64
Dairy	5.7 ± 3.0	6.0 ± 3.0	-0.57
Total protein foods	4.9 ± 0.4	4.8 ± 0.9	0.27
Seafood and plant Proteins	3.4 ± 2.0	3.3 ± 2.1	0.09
Fatty acids	2.0 ± 0.4	2.1 ± 0.9	-0.62
Moderation components			
Refined grains	9.4 ± 2.0	8.6 ± 2.8	1.74
Sodium	8.4 ± 3.4	7.7 ± 4.2	0.67
Added sugar	9.1 ± 1.1	9.4 ± 1.0	-1.44

Saturated fats	9.8 ± 0.5	8.8 ± 2.8	2.07
Total HEI	65.1 ± 9.5	64.5 ± 9.0	0.34

Values are means +/- SD; SD = standard deviation; t = t statistic

Table 6: Smoothie, and topping intake reported at baseline and post data collection are listed as frequencies (% sample).

Metric	Baseline	Post Data collection
Smoothie category		
None	NA	142 (72%)
Low (2–9 smoothies)	NA	10 (5%)
Medium (10–17 smoothies)	NA	15 (8%)
High (18+ smoothies)	NA	31 (16%)
Toppings (only offered at USMA)		
No	NA	50 (81%)
Yes	NA	12 (19%)

Values are number of participants (% = percentage of sample).

Legend:

A 12-week cohort study was conducted with fish being offered twice a week for six weeks, followed by another six weeks of fish with omega-3 smoothies. The Omega-3 Index (O3I) was compared before and after data collection. The O3I only reached the desired O3I of 8% when omega-3 enhanced smoothies were offered in addition to fish. This indicates a benefit of this type of fish alternative to increased O3I over a short timeframe.