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Omega-3 supplements reduce self-reported physical aggression in healthy adults

Laurent Bègue[a,*], Ap Zaalberg[b], Rébecca Shankland[a], Aaron Duke[a], Julie Jacquet[a], Perla Kaliman[c], Lucie Pennel[d], Marc Chanove[e], Philippe Arvers[a], Brad J. Bushman[f]

[a] LIP/PC2S, University Grenoble Alpes, Grenoble, France.
[b] Ministry of Security and Justice, Crime, Law Enforcement and Sanctions Research Division (CRS), The Hague, The Netherlands.
[c] Center for Mind and Brain, University of California, Davis, United States.
[d] University Hospital, University Grenoble Alpes, Grenoble, France.
[e] MSH Alpes, CNRS/University Grenoble Alpes, Grenoble, France.
[f] School of Communication and Department of Psychology, The Ohio State University, Columbus, Ohio, United States.

ABSTRACT

There is emerging evidence that Omega-3 polyunsaturated fatty acids (PUFA) supplements can decrease aggression. However, experimental studies with adults from non-specific populations are scarce. We hypothesized that Omega-3 supplements would decrease self-reported aggression among non-clinical participants. In a double-blind randomized trial, two groups of participants ($N = 194$) aged 18–45 from the general population followed a 6-weeks treatment with 638 mg docosahexaenoic acid (DHA) and 772 mg eicosapentaenoic acid (EPA) per day or the equivalent quantity of copra oil (placebo). Self-reported aggressiveness was measured at baseline and after the 6-week treatment period. Findings showed that Omega-3 supplements significantly decreased self-reported aggressiveness at the end of the 6-week period ($d = 0.31$). In conclusion, this experiment indicates that Omega-3 administration has beneficial effects in reducing aggression among the general population.

1. Introduction

A number of epidemiological and econometric studies suggests a relation between dietary status and human behavior. Among the nutritional components that have been studied, omega-3 long-chain polyunsaturated fatty acids (n-3 LCPUFA's) appeared to be related to various positive health and behavioral outcomes. Omega-3 levels are selectively concentrated in the brain, and play an important role in its neuronal structure and function (Bourre et al., 1991). They compose 20% of the dry weight of the brain, and 33% of the fatty acids in the nervous system (Logan, 2003). Omega-3 is considered to play an important role in cell membrane elasticity and myelination, and may thus affect neural signaling (Bazinet and Layé, 2014).

Several different omega-3 fatty acids exist, but the majority of scientific research focuses on three: (1) alpha-linolenic acid (ALA), (2) eicosapentaenoic acid (EPA), and (3) docosahexaenoic acid (DHA). The primary source of EPA and DHA is fish, especially cold water oily fish such as mackerel, salmon, tuna, herring, and trout. For example, 100 g of some types of mackerel contain more than 2000 mg of EPA and DHA. Some seeds (e.g., chia seeds), nuts (e.g., black walnuts), and oils (e.g., soybean oil) contain high levels of ALA. In the liver, ALA is converted into EPA and DHA (Arterburn et al., 2006; Parker et al., 2006). Because this conversion is incomplete in humans, dietary ALA is thought to have a limited effect on DHA and EPA levels in humans (Kalminj et al., 2004).

Omega-3 fatty acids also might have several psychological health benefits (Parker et al., 2006). For example, omega-3 fatty acids have been shown to benefit children suffering from ADHD (Bloch and Qawasmi, 2011) and autism (Vancassel et al., 2001), and adults suffering from bipolar disorder (Sams et al., 2012), and depression (Sublette et al., 2011). The present research focuses on the potential benefits of omega-3 fatty acids on reducing aggressive behavior.

1.1. Link between omega-3 and aggression

Several correlational studies have found a negative relation between omega-3 blood levels and aggression and violence. For example, one study found that omega-3 blood levels were negatively related to self-reported and behavioral measures of aggression (Meyer et al., 2015). Another study involving 3581 participants found that more seafood

* Correspondence to: LIP/PC2S, University Grenoble Alpes, 1251, Avenue Centrale BP 47, 38040 Grenoble Cedex 9, France.
E-mail address: Laurent.Begue@univ-grenoble-alpes.fr (L. Bègue).

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consumption was related to less hostility (Iribarren et al., 2004). A 5-year study found that a special diet high in fish significantly decreased hostility (Weidner et al., 1992). Another study found low blood levels of omega-3 fatty acids in violent and impulsive offenders (Virkkunen et al., 1987). An ecological study carried out in 36 countries also found a negative correlation between seafood consumption and homicide rates ($r = -0.63$; Hibbeln, 2001). In fact, the aggression-reducing benefits of fish might transfer from mother to child. A large study of 11,875 pregnant women in England found that mothers who consumed large amounts of fish during pregnancy had children who exhibited less antisocial behavior at age seven (Hibbeln et al., 2007).

Experimental studies suggest a causal relationship between omega-3 fatty acids and antisocial behavior, including aggression (Gajos and Beaver, 2016). In one experiment, a 26.3% decrease in antisocial behavior was found in young male offenders incarcerated in England after receiving omega-3 supplements (among other nutrients) for an average length of 142 days (Gesch et al., 2002). A replication of this experiment found a 34% decrease in antisocial behavior in young male offenders in the Netherlands after receiving omega-3 supplements (Zaalberg et al., 2010). In another experiment, a decrease in verbal and physical aggression was found in a sample of women with borderline personality disorders after receiving EPA supplements (Zanarini and Frankenburg, 2003). More recently, researchers found a 41.6% reduction in externalizing behaviors such as aggression in a community sample of 8-to-16-year-old children in Mauritius after they had received daily 1000 mg supplements of omega-3 fatty acids for 6 months (Raine et al., 2015), although the effect dissipated over time. Although there was a significant short-term reduction in self-reported child reactive and proactive aggression (59.9% and 49.7% respectively), there was no long-term effect on these measures. There was also a significant reduction in parent–reported child aggression. Interestingly, this experiment also found a significant reduction in psychopathy and reactive aggression in the parents of treated children, possibly induced by the improved behavior of their children. Several other experiments also indicate a decrease of externalizing problems such as aggression (Benton, 2007; Fontani et al., 2005; Hamazaki et al., 1996; Stevens et al., 1996), with some notable exceptions (see Dean et al., 2014; Hirayama et al., 2004; Kirby et al., 2010).

1.2. Overview of the present experiment

The present experiment has four advantages over previous experiments on omega-3 related aggression. First, most omega-3 fatty acid studies have very small sample sizes, which can produce unreliable results. In a meta-analysis (Cooper et al., 2016), seven out of eight experiments had fewer than 50 participants. The present experiment has a relatively large sample size ($N = 198$), and dropout was limited (only 4 participants dropped out, leaving a sample of $N = 194$). Second, most omega-3 fatty acid studies sample participants from vulnerable populations, like children suffering from ADHD and adults suffering from a variety of mental disorders. The present experiment sampled participants from the general population. Third, several earlier experiments combined omega-3 fatty acids with other nutrients known to influence aggression (Schoenthaler et al., 1997). In one experiment, for example, participants received supplements containing 13 vitamins and 12 minerals along with supplements containing omega-3 fatty acids (Gesch et al., 2002), making it impossible to separate the effects of omega-3 fatty acids from the effects of the vitamins and minerals. The supplements used in the present experiment used only omega-3 supplements. Fourth, some previous studies used projective tests to measure aggression (e.g., Hamazaki et al., 1996; 2002; Long and Benton, 2013). For example, several studies used the Rosenzweig Picture Frustration Test (Rosenzweig et al., 1947), in which participants are shown cartoons of various frustrating situations (e.g., being accidentally splashed with water by a passing car) and are asked how they would respond verbally to each situation. Although this projective test may provide a proxy for aggression, it is an indirect rather than a direct test (Lilienfeld et al., 2000). In addition, participants tend to respond to projective tests in socially desirable ways (Krahé, 2001). In the present experiment, a reliable, validated instrument was used to measure aggressiveness. In sum, the present experiment tests the effect of omega-3 supplements on self-reported aggression in a relatively large sample of healthy adults, using a reliable measure of aggressiveness.

Table 1
Pre-experimental comparisons of placebo and omega-3 groups, Standard deviations are in parentheses.

Variable	Placebo	Omega-3	Statistical test
Age (*SD*)	32.52 (10.46)	33.61 (10.79)	$t(192) = 0.71$, $p > 0.47$, $d = 0.10$
Female (*n*)	42	49	$\chi^2(1) = 0.54$, $p > 0.46$, $\phi = 0.05$
Male (*n*)	53	50	
BMI (Kg/M^2)	23.0 (0.30)	23.0 (0.40)	$t(192) = 0.22$, $p > 0.82$, $d = 0.00$
Omega – 3 consumed T1 (grams)	5.07 (10.81)	4.57 (8.82)	$t(191) = 0.35$, $p > 0.72$, $d = 0.05$
Aggressiveness (baseline)	1.62 (0.66)	1.55 (0.60)	$t(174) = 0.66$, $p > 0.50$, $d = 0.11$

2. Methods

2.1. Participants

Participants were 198 French adults recruited by local press advertisements and fliers in public places for a study on omega-3 and emotion regulation. Four participants dropped out of the study (3 in the omega-3 group, and 1 in the placebo group), but the dropout rates did not significantly differ for the two groups (Fisher's exact test $p > 0.62$). Thus, the final sample was 194 participants. No significant pre-experimental group differences were found on any of the baseline measures (Table 1). Thus, random assignment to conditions was successful. The study was reviewed and approved by the ethics committee of the University Hospital of Grenoble, France, and was conducted in accordance to the ethical guidelines in the Helsinki declaration.

2.2. Procedure

2.2.1. Inclusion and exclusion criteria

To be included in the study, participants had to be native French speakers with a valid social security number, between 18 and 45 years old, and consume alcohol at least once a month (another study on alcohol and emotion regulation was carried out at the same time[1]). Participants were excluded if they were allergic to the pill capsules, had taken omega-3 capsules in the previous 8 weeks, were currently participating in other biomedical research studies or undergoing medical treatment, had certain medical disorders (i.e., cirrhosis, hepatitis, blood clotting disorder), or were taking certain medications (i.e., anti-clotting drugs, vitamin E, baclofen, opioid replacement drugs). Pregnant females were also excluded. Included participants watched an 8-min video about various aspects of the procedure, and received a medical screening from a doctor.

2.2.2. Randomization

After giving informed consent, pairs of participants were matched based on age and gender. Using a computer program, one member of the pair was randomly assigned to the omega-3 group, whereas the

[1] In addition to measures of alcohol consumption, this study also included measures of emotion regulation and anxio-depression. However, these measures are not relevant to the present study and are not discussed further.

other member of the pair was assigned to the placebo group. A double-blind procedure was used (i.e., both participants and the researcher were blind to the type of supplements participants received). As can be seen in Table 1, the two groups did not significantly differ on key study variables.

2.2.3. Intervention

In the experimental condition, participants received 2 capsules, each containing 319 mg of DHA and 386 mg of EPA (total dose = 638 mg DHA and 772 mg EPA). The quantity of omega-3 fatty acids administered was in the range used in previous aggression studies (i.e., 1–2 g per day). Participants in the placebo condition received 2 identical capsules, each containing 705 mg of copra oil. Copra oil mainly consists of saturated fatty acids, with no known behavioral effects. All capsules were identical in shape, size and color. To increase compliance, participants were given a jar containing all the capsules and a box containing 7 drawers. Participants were instructed to put two capsules in each drawer each week for six consecutive weeks, and to swallow one capsule in the morning and the other capsule in the evening, if possible during meal time (as in previous studies), to avoid unpleasant minor side effects like belching and nausea. No participants experienced any side effects from the supplements. Participants were given stickers with a picture of the capsules printed on them, and were told to put the stickers in various locations (e.g., phone, desk, fridge, bathroom mirror, car) to remind them to take the capsules. They also received a text message on their phone at 6:00 p.m. each day to remind them to take their pills.

2.2.4. Dependent variable

Reducing aggressiveness was the main objective of the study. Aggressiveness was measured using the physical aggression subscale of the Aggression Questionnaire (AQ; Buss and Perry, 1992), (e.g., “If I have to resort to violence to protect my rights, I will” and “Given enough provocation, I may hit another person”) that are rated on a 5-point scale (1 = *extremely uncharacteristic of me* to 5 = *extremely characteristic of me*; Cronbach $\alpha = 0.71$). We modified the scale by asking participants to answer the items for the past month, rather than in general. Responses were averaged to obtain an overall measure of physical aggressiveness. We chose this measure because it has been validated in many countries (Ramirez and Andreu, 2006), including in France (Bègue et al., 2009), and is one of the most reliable self-reported measure of aggressiveness. Unlike projective tests, this measure of aggressiveness is relatively uninfluenced by social desirability (Becker, 2007). We focused on physical aggressiveness because is of the form of aggressiveness with the highest social concern (e.g., it is more likely to lead to injury or even death). To test whether omega-3 fatty acids had changed aggression levels, the measure was administered at baseline and at the end of the 6-week study.

2.2.5. Dietary intake

At the beginning of the experiment, participants reported how much fish (e.g., mackerel, herring, sardine, salmon, trout, sturgeon, cod), nuts, and various oils they had consumed in the previous week. All of these foods have high levels of omega-3 fatty acids. An estimation of omega-3 fatty acid intake was calculated based on correspondence tables (e.g., 100 g of mackerel contains 1.8 g of DHA). Individual consumption of Omega-3 fatty acids the previous week was used as a covariate in the primary analysis, as in other studies (Long and Benton, 2013).

2.2.6. Adherence to protocol and manipulation check of treatment

Adherence to protocol was checked each week. Participants were asked if they had forgotten to take their pills during the week. If participants had forgotten to take one or more pills during the week, a research assistant (blind to condition) contacted them to discuss a practical solution to ensure their future compliance. The percent of participants who took both capsules every day was high in both groups, but was significantly higher in the omega-3 (93%) group than in the placebo (83%) group, $z = 2.15$, $p < 0.033$. Thus, this variable was used as a covariate in the primary analysis.

Participants were also asked what treatment they thought they had received: omega-3, placebo, or “I don’t know.” The percent of participants correctly guessing their treatment condition did not differ for the omega-3 (36.6%) and placebo (46.1%) groups, $z = 1.34$, $p > 0.18$. Thus, the double-blind procedure was effective.

2.2.7. Compensation and debriefing

Finally, participants were fully debriefed, thanked, and paid 120 euros for their participation. No participants expressed suspicion about the study during the debriefing.

3. Results

3.1. Gender and age analyses

Because the effects of Omega-3 fatty acid treatment on aggressiveness did not depend on participant gender ($p > 0.76$) or age ($p > 0.81$), the data from men and women of different ages were combined for the primary analyses.

3.2. Primary analyses

Data were analyzed using the General Linear Model function in SPSS (version 24), in an Analysis of Covariance (ANCOVA) model with covariates, and in an Analysis of Variance (ANOVA) model without covariates. The ANCOVA included post-test aggressiveness scores as the dependent variable, treatment condition (Omega-3 versus placebo) as the independent variable, and pre-test aggressiveness scores, how often participants took their pills, and grams of pre-experimental omega-3 consumed as the covariates. The ANOVA model included post-test aggressiveness scores as the dependent variable, and treatment condition (Omega-3 versus placebo) as the independent variable.

Because post-test aggressiveness scores were positively skewed (skewness = 2.38, kurtosis = 7.03), a natural logarithm transformation was applied to aggressiveness scores, which made the distribution more normal (skewness = 1.33, kurtosis = 1.63).

3.3. Analysis with covariates

In line with our hypothesis, the ANCOVA revealed that participants in the Omega-3 group had significantly lower (transformed) aggressiveness scores ($M_{Ln\ Physical\ Aggression} = 0.27$, $SE = 0.026$) than participants in the placebo group ($M_{Ln\ Physical\ Aggression} = 0.35$, $SE = 0.027$), $F(1168) = 4.14$, $p < 0.043$, $d = 0.31$. As expected, there also was a strong relation between pre-test and post-test aggressiveness scores ($r = 0.61$, $p < 0.0001$). How often participants took their pills and the number of grams of fish and nuts consumed did not significantly influence aggressiveness scores ($F(1168) = 0.058$, $p > 0.81$ and $F(1168) = 0.21$, $p > 0.73$, respectively). The results are depicted in Fig. 1.

3.4. Analysis without covariates

The same pattern of results was obtained when the covariates were excluded from the analysis and the data were analyzed using ANOVA. As in the ANCOVA, participants in the omega-3 group had significantly lower aggressiveness scores ($M = 0.26$, $SD = 0.27$) than participants in the placebo group ($M = 0.35$, $SD = 0.33$), $F(1191) = 4.67$, $p < 0.032$, $d = 0.31$.

4. Discussion

As predicted, this experiment showed that omega-3 supplements

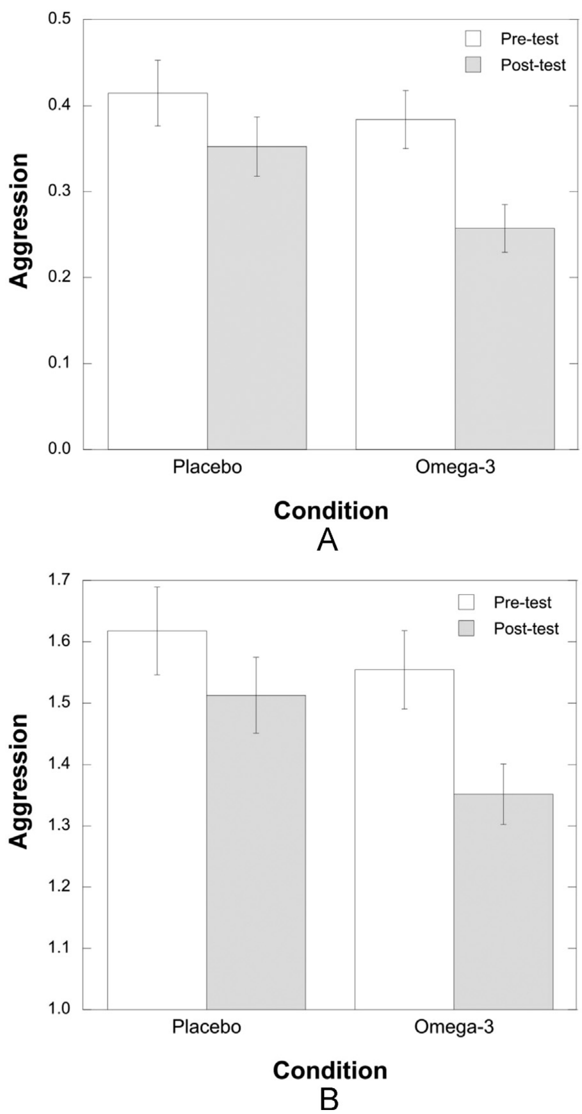

Fig. 1. *A*. Aggression levels at pre-test and post-test 6 weeks later for participants in the omega-3 and placebo groups. To reduce skewness, aggression scores were transformed using a natural logarithm transformation. Capped vertical bars denote 1 standard error. *B*. Aggression levels at pre-test and post-test 6 weeks later for participants in the omega-3 and placebo groups. Aggression scores were not transformed. Capped vertical bars denote 1 standard error.

decreased self-reported aggression levels among non-clinical, adult participants. The effect size $d = 0.31$ exceeded the benchmark value of $d = 0.25$, which is reserved for treatments labeled as *significant*, *important*, *notable*, and *consequential* (Promising Practices Network (PPN), 2014). Thus, the reduction in aggression levels caused by taking omega-3 supplements for 6 weeks was not trivial.

This experiment had five primary strengths. First, the sample size was larger than in similar studies. However sample size estimates (see Cohen, 1988) suggested that to detect an effect of $d = 0.31$, with the power set at 0.80, a much larger sample would be necessary (approximately 335). The power of the present study was estimated at 0.57. Second, it used a sample of participants from the general population rather than a clinical sample. Third, it isolated the effects of omega-3 fatty acids from other nutritional supplements that might influence aggressiveness. Fourth, the double-blind procedure was successful. An inherent problem in the study of fatty acid is keeping participants blind to conditions due to the fishy aftertaste of fish oil. For example, in one study 49% of participants guessed they were taking fish oil at the beginning of the study, which rose to 75% at the end of the study (Zaalberg, 2010; also see Giles et al., 2015). In order to keep participants blind to their condition, all participants were told that the pills could have a fishy aftertaste. Fifth, it used a valid and reliable objective measure of aggressiveness.

This experiment also had at least four weaknesses. First, we did not measure long-term patterns of dietary intake, so the intake estimates might be inaccurate. Second, we did not have access to biological samples from the participants that could be used to determine the cellular levels of omega-3 fatty acids. However, most omega-3 studies share this limitation. Third, we only studied short-term effects of omega-3 after taking supplements for only 6 weeks. It would be important for both clinical and social purposes to investigate the long-term effects of omega-3 supplements on aggressiveness. However, it is worth noting that a meta-analysis found no relationship between the length of omega-3 supplementation and ADHD problems (Cooper et al., 2016). Fourth, the outcome measure was a self-report measure of aggression, which represents a weaker measure than a behavioral measure of aggression (e.g., Gesch et al., 2002). It should also be noted that the levels of aggressiveness in the study population were very low at baseline.

We offer three suggestions for future research. First, we recommend taking blood levels of omega-3 fatty acids in future studies. Blood samples might be better predictors of study outcomes. Blood samples also provide the opportunity to test hypotheses about genetic determinants of responding to omega-3 fatty acids, as has for instance been suggested for the ApoE4 allele carriers (van de Rest et al., 2008; Plourde et al., 2009). Blood samples also provide the opportunity to test possible interactions with other nutrients. Second, some omega-3 fatty acid studies suggest that effects in non-aggressive study populations are more pronounced under stressful conditions (Hamazaki et al., 1996). Future experiments can directly test this hypothesis by also manipulating the level of stress. Third, because levels of physical aggressiveness turned out to be very low in our study population, it also might be useful to measure other aspects of aggressiveness, such as verbal aggressiveness.

In conclusion, this experiment suggests that omega-3 administration may reduce physical aggression in the general population. This is an important positive effect of omega-3 supplements, in addition to their many other positive benefits.

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