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Case Study

The Impact of DHA on Attentional Performance: A Series of Case Studies

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Abstract

Docosahexaenoic acid (DHA) is an omega-3 fatty acid vital for neurological development and function. Children with attention-deficit/hyperactivity disorder (ADHD) have been found to have low levels of blood plasma levels of DHA. The present series of case studies examined the potential of improving the attentional abilities of individuals with ADHD with the supplementation of DHA. The Test of Variables of Attention (TOVA), a psychometrically valid tool used to evaluate attentional abilities, was employed as an objective measure of attention. to evaluate the effects of supplementation. The results indicated that DHA supplementation of 267mg b.i.d., 12 hours apart, was effective in improving the attentional abilities of individuals with ADHD.

INTRODUCTION

Attention-deficit/hyperactivity disorder (ADHD) is a clinical neurodevelopmental disorder involving difficulty with inattention, hyperactivity, and impulsivity, or a combination of these. It affects approximately 6% to 8% of youth around the world [1], and more than 10% of youth in the United States [2], including approximately 30% to 50% of individuals with specific learning disabilities such as dyslexia [3,4]. ADHD involves deficits in executive functioning, such as difficulty sustaining attention, planning, organizing, initiating tasks, completing tasks, managing time and/or materials, inhibiting responses, controlling emotions, being flexible, and metacognition. Over one-third of youth with ADHD have co-occurring oppositional defiant disorder [5], and ADHD can also co-occur with other psychiatric and medical issues, such as behavior disorders [6], enuresis [7], and conduct disorder [8]. Relative to their peers, children with ADHD are more likely to experience emotional difficulties, such as anxiety [9], depression [10], and poor self-esteem [11].

ADHD has a significant impact on one's life and the lives of those around them. Individuals with ADHD are more likely to engage in risky behaviors [12], which can result in vehicle accidents [13], use of illicit substances [14], and/or substance abuse, risk for pregnancy, and sexually-transmitted infections [15,16]. Individuals with ADHD also often experience difficulties with interpersonal skills and relationships [17]. They are less likely to apply to college [18], are more likely to experience difficulties in college when enrolled [19], and are less likely to graduate [20]. Adults with ADHD are more likely to be terminated from employment [18], divorce [21], and/or live with their parents [22]. ADHD is evident across academic, occupational, and interpersonal settings and can affect people throughout their youth and into adulthood [23].

Evaluation should include objective [24], and subjective assessments, as well as thorough clinical interviewing. Traditional strategies for ADHD management frequently include behavioral (e.g., environmental changes, accommodations, intensive skill instruction) and pharmaceutical intervention [25]. Medication has been used as a treatment for ADHD with relative success for some time [26]. Stimulant medications, such as methylphenidate and amphetamine formulations, as well as nonstimulant medications, such as norepinephrine reuptake inhibitors and alpha-agonists (clonidine and guanfacine), significantly improve ADHD symptoms [27] and, in combination with behavioral intervention, FDA-approved medications are recommended as first-line treatment considerations for youth ages 6 to 18 years. Unfortunately, many medications have side effects [28,29], such as suppressed appetite and adverse events [27]. As a result, many families are wary of using medications [30,31]. While families tend to initiate pharmaceutical intervention to support their child's academic functioning, fewer parents demonstrate a preference for medication only (11%) than behavioral intervention only (28%), both

interventions (25%), or neither (36%), and these goals and preferences are an important component in determining initiation of treatment [32]. In addition, pharmacological intervention is not recommended as a first-line treatment for children preschool-aged [33], or younger. Further, medication is not recommended for youth with subclinical levels of inattention and/or impulsivity.

Recently, research of non-pharmacological interventions has increased [34]. Supplements have been considered for the treatment of ADHD, such as omega-3 fatty acids [35,36], particularly docosahexaenoic acid (DHA; [37]). DHA is an essential omega-3 fatty acid found in fatty fish such as salmon, which is crucial for brain development and function, especially in children [38]. Studies have found that children with ADHD have low plasma levels of DHA [39-41]. This suggests that a viable mechanism for treatment might include supplementation with DHA. Although this may be the case, the evidence has been equivocal (see [42] and [27], and [36]s meta-analyses). If effective, DHA supplementation has multiple benefits: essentially no side effects for children or adults [43], and is safe with little possibility of overdose [44].

Although DHA can be endogenously metabolized from its precursor alpha-linolenic acid (ALA), the conversion of ALA to DHA is not efficient. Therefore, the acquisition of DHA comes from consumption. Dietary supplementation may be suggested, particularly during fetal neurological development [45]. DHA is essential for maintaining cell wall functioning which assists inter-neuronal communication [46,47], and repair [48]. DHA is required for fetal brain development [49], hence the reason that there are high concentrations of DHA in breastmilk (32% by weight; [50]).

The neuronal mechanisms that are specifically affected by DHA involve receptor sites by helping to regulate ion channels, releasing neurotransmitters, and influencing synaptic plasticity (e.g., [51,52]). DHA modulates the sodium/potassium pump as a function of its role in regulating membrane function and structure [53]. Metabolites of DHA (e.g. docosanoids) have been implicated in the protection of neurons from oxidation stress (e.g., [54,55]).

The reduction of DHA in a person's diet potentially negatively affects neuronal functioning including those described above [56], and generally leads to cognitive and behavioral deficits that can last throughout the affected person's life [57]. The suggested mechanism for describing the relationship between deficient DHA levels and suboptimal neurological functioning include deficient cell membrane efficiency which leads to a host of difficulties related associated with poor functional neurotransmission, and lower levels of glucose absorption in the brain, among other issues [58,59]. Insufficient DHA is related to an increased probability of cognitive decline associated with psychiatric disorders [60-63].

The present series of case studies investigated the effectiveness of DHA supplementation as a strategy to assist with reducing symptomology of ADHD. To evaluate the potential effectiveness of DHA supplementation, pre- and post-treatment performance in the participants' attentional performance was examined with the Test of Variables of Attention, Ninth Edition (TOVA-9). The TOVA has been used in a variety of studies to evaluate the potential effectiveness of treatment (e.g., [64-68]). The TOVA is a continuous performance test (CPT), an objective method of measuring attention and impulse control. It is primarily used to aid in the evaluation and diagnosis of ADHD and to evaluate the effectiveness of treatment applications. During administration of the TOVA, the individual holds a microswitch in their preferred hand and responds by depressing the microswitch with their thumb as quickly as possible every time the identified target is presented without sacrificing accuracy. When the non-target is presented, the individual is asked to refrain from responding. The target or non-target occurs every two seconds for the duration of the 22.6-minute administration. The target during the first half of the administration occurs infrequently (1:3.5 target-to-nontarget ratio), while in the second half, the target density is high (3.5:1 target-to-nontarget ratio). The TOVA-9 provides five scores: omission and commission errors, response time and response time variability, and an overall Attention Comparison Score (ACS). Response time variability, a hallmark of ADHD [69-71], accounts for 80% of the variability between individuals with and without ADHD.

METHOD

Participants

Children. Three White male children were involved in the case studies. The initial participant was 8 years 4 months old. After the initial case study, two additional male children were included, aged 10 years 2 months and 11 years 8 months.

Adult. The adult participant was 28 years 7 months old and also a White male.

Measures

Test of Variables of Attention (TOVA). Version 9.0 of

the Test of Variables of Attention (TOVA-9) was used to assess changes in attentional abilities prior to and after supplementation with DHA. It has acceptable psychometric properties [72]. Specific instructions regarding the nature of the task and the need to balance speed and accuracy is followed by a three-minute practice session, then test administration occurs. Corrective feedback is provided to participants if needed during the three-minute practice session, but not thereafter. The participant fixates on a small dot in the middle of the screen, and responds when the target appears (Figure 1). Both the target and non-target are presented for 100 ms. The inter-target interval is 2 s. The ACS is a standard score in which the test-taker's performance is compared to a group of individuals who participated in the standardization sample who were independently diagnosed with ADHD. Performance below 0 indicates that that test-taker likely has ADHD. The ACS was the TOVA variable assessed in this study.

Procedure

TOVA-9. The participants were assessed on the TOVA-9 in a quiet, dimly lit evaluation lab. The second time of administration was completed after the participant had received daily doses of DHA supplementation for six to eight weeks.

DHA. Participant 1 initially received 267mg q.d. in the morning. Subsequent to the second time of testing (Time 2), Participant 1 began taking 267mg b.i.d. twelve hours apart. All other participants received 267mg of DHA b.i.d. for their entire regimen. The source of the DHA was GNC's Triple Strength Fish Oil (267mg DHA, 734mg EPA, 65mg other omega-3s), which has an enteric coating and can be purchased without a prescription.

RESULTS AND DISCUSSION

The present case studies were conducted to determine if daily supplementation of DHA would affect attentional performance. The first participant to receive the DHA supplementation improved his ACS from a −3.58 to a −2.2 (see Time 1 and 2 of Figure 2). The participant indicated that he felt that he could concentrate better, and others remarked that his attentional behavior had improved. A second administration of the DHA b.i.d. 12 hours after the first administration was added. As can be seen in Figure 2, Time 3, the participant's performance on the TOVA further improved. Dosage was then stabilized at 267mg b.i.d. with no further changes. The participant's Time 4 performance was in the "not ADHD" range (Figure 2). At this point, the participant continued his current regimen of DHA supplementation.

Due to the success of the DHA supplementation of the first participant, three additional participants were examined to determine if the results could be replicated. All participants received the same dosage of 267mg b.i.d. The first participant's pre- and post-scores were included in Figure 3. Two of the participants who initially had

Figure 1 Stimuli used in the TOVA.
Note. The white square on the left with the small black square at the top is the target. The square to the right is the nontarget. One or the other appears every 2 seconds during the administration of the TOVA.

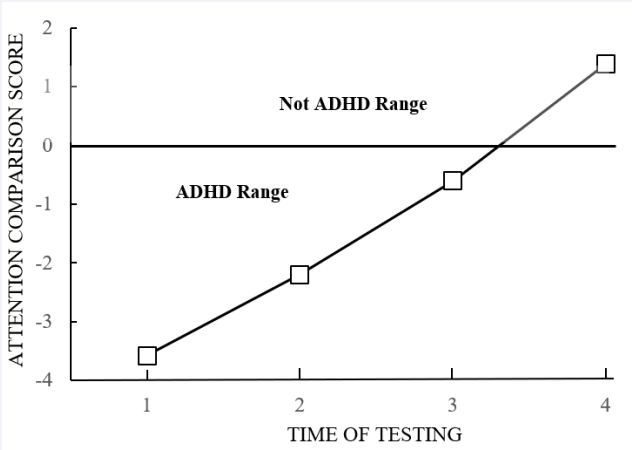

Figure 2 Participant 1's ACS by Time of Testing.
Note. ACS = Attention Comparison Score from the TOVA. ACS are provided in z-score units. Scores below 0 are considered to be in the ADHD range.

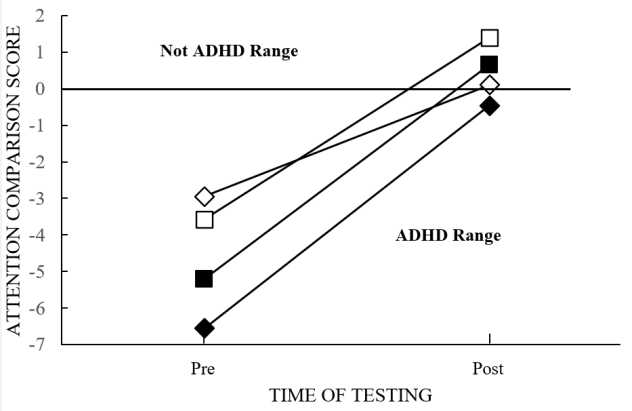

Figure 3 Participants ACS by Time of Testing.
Note. ACS = the black diamond shape indicates the performance of the adult white male.

significant challenges with attentional ability moved their performance into the "not ADHD" range, while the third was near the cutoff for the "not ADHD" range (Figure 3). A related t-test confirmed that the ACS were significantly better post-supplementation, $t(3) = 6.8$, $p = .007$, indicating ipsative and normative improvement, supporting the efficaciousness of DHA supplementation on an objective measure of attention.

CONCLUSIONS

The present study examined the potential remedial effects of daily DHA supplementation. All participants (all White males) performed significantly better after taking 267mg of DHA b.i.d. via supplementation. A more thorough examination of DHA is required that includes a more diverse population and randomized controlled trials. In addition to objective assessment via psychometrically adequate CPT, future studies should include a comparison of multiple interventions, blinded raters of functional-behavioral improvement [36], and a placebo control. However, the current case studies suggest that DHA might have potential use in the treatment of ADHD that warrants further investigation.

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