Malnutrition, defined by insufficient energy and protein intake, seriously affects cognitive functions. Nutritional deficiencies early in a child’s development have marked consequences for cognitive development and overall growth at later ages of development. Malnutrition is a preventable malady but is tightly linked to low socio-economic status, hampering implementation of corrective strategies. Along with insufficient energy and protein intake, generalized or specific micronutrient deficiencies can occur. Omega-3 deficiencies can also result from malnutrition, as a result of 

\(i\) the utilization of dietary linolenic acid to generate energy, 

\(ii\) deficient transformation of linolenic acid to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) due to deficiencies in other micronutrients that act as cofactors for long chain omega-3 PUFA biosynthesis, and 

\(iii\) reduced intake of EPA and DHA directly from foods of animal origin (particularly from rich sources such as fish). Severe malnutrition is known to lead to a decrease in DHA in plasma lipids. Little information is available with respect to the specific contribution that correction of long chain omega-3 PUFA intake can make to cognitive function in the context of malnutrition and underprivileged socioeconomic status.
A number of studies aiming to understand the role of long chain omega-3 PUFAs in cognitive development have focused on the perinatal period and the first few years of life. Fewer studies have investigated the role of omega-3 PUFAs in cognitive development in school age and preadolescent children. During preadolescence cognitive abilities continue to develop with increases in verbal working memory, goal-directed behavior, selective attention, strategic planning and organizational skills, but there is a need to better understand the role of specific micronutrients in this period. There is growing interest in obtaining a better picture particularly with regard to the extent of the plasticity and reversal of neurocognitive deficits that occur in preadolescent children and adolescence. Total blood levels of DHA, and EPA plus DHA, in 7-9 year olds are positively associated with reading skills (DHA) and working memory (DHA, EPA, EPA plus DHA, and total omega-3 levels). Supplementation with DHA can improve reading, working memory and externalizing behavior in apparently healthy children with below average reading performance.

In rodents a connection between a deficiency of DHA in brain and cognitive defects is well documented. It is clear that neuropsychological functions continue to develop after infancy, but there is a paucity of information on the relative contribution of essential fatty acids during this period. In the context of malnutrition where a range of macro- and micro-nutrients are affected by deficient intake, the relative role of omega-3 on cognitive functions in preadolescence is not well documented.
This study by Portillo-Reyes and colleagues, from the department of Psychology at the Autonomous University of Ciudad Juarez, Mexico, has focused on pre-adolescent schoolchildren of low socio-economic status, with a mild to moderate level of malnourishment. The researchers investigated whether supplementation with a modest daily dose of EPA/DHA would improve cognitive functions. Of significance, the researchers made an assessment of a large panel of nutrition-associated changes covering different aspects of cognition. Low socioeconomic status was defined according to population and housing census indices from the Mexican National Institute for Statistics and Geography (INEGI). Nutritional status was deduced from anthropometric measurements (age, weight, and height) from which height/age, and weight/height indices were used for determination of the level of malnourishment.

Fifty-five children of age 8 to 12 years (school grades 3 and 4 elementary) with a mild to moderate level of malnourishment were identified (corresponding to 85-95% in height/age and 70-90% weight/height indices). The children were randomly assigned to a treatment or placebo group after informed consent from primary caregivers. Excluded were children who had any neurological or hormonal diseases, or who had taken an omega-3 or vitamin supplement in the past 6 months. The study was a double-blind, placebo-controlled study. Children in the treatment group received a daily dose of three gelatin capsules of fish oil (containing together 270 mg EPA and 180 mg DHA), administered one in the morning, one at midday and one in the evening. The children in the placebo group received 3 capsules of soybean oil. The intervention lasted for 3 months. During the study 5 children dropped out from
the placebo group, leaving 20 children in the placebo group and 30 children in the treatment group to complete the study. Compliance was determined by counting of capsules. Baseline omega-3 status in blood was not determined, but the parents of the children were interviewed on the dietary habits of the children, with special attention to the intake of food with a high content of omega-3.

Changes in neuropsychological functions were evaluated through the application of a wide battery of different tests, 19 in total, which collectively measure processing speed, visuomotor coordination, attention, memory, language, and executive function. In addition, absenteeism and changes in school performance were recorded. An equal distribution of the children in the two groups with respect to demographic variables was verified. Analyses of variance measurements were made to determine the distribution of means of the various neuropsychological test variables among placebo and treatment groups before and after the intervention period. In addition to determining statistical significance of measured differences, effect sizes were determined in order to obtain measures of clinical significance. Individual responses of the test variables were classified as no improvement, medium-size improvement, and large-size improvement. The improvement frequency in each group was then compared for placebo and omega-3 supplemented children.

No statistically significant differences were found between the children of the two groups with respect to age, IQ, absenteeism, and school performance. Neither were statistically significant differences found in the mothers of the children regarding age, IQ, academic level, or economic status. Eight percent of children ate fish-containing meals at least twice a week, 39% once a week, 19% once every two weeks, and 34% once a month. Over 60% of the children
consumed canned tuna and sardines as the only source of fish. Consumption of omega-3 enriched foods was low (10% of children reportedly drank omega-3 enriched milk).

After three months children supplemented with EPA/DHA had a statistically significant (P<0.05) improvement in the following neurocognitive variables: Symbol Search, which is a measure of processing speed (matching symbols appearing in different groups), Embedded Figures (finding a figure as quickly and accurately as possible within a more complex figure) and Visual Closure (completing figures that are interrupted), which are tests to determine visuoperceptive integration, Block Design, which is a test for visuoconstructive integration (requires arranging red and white colored blocks into a specific design), Stroop Color and Stroop Color Word, which are tests that require the fast and accurate naming of colors and reading of colored words, and Matrix Reasoning, a test that requires choosing one of several given solutions to complete a picture matrix. The Stroop and Matrix Reasoning tests, respectively, measure reasoning and inhibitory aspects of the so-called executive functions of the brain, which are involved in the control and regulation of cognitive processes.

Analysis of group effect sizes showed that the children that had taken the EPA/DHA supplement for 3 months showed a moderate to big improvement in 12 of the 19 test variables (Cohen’s d value above 0.5). In the placebo group effect size improvements were observed in 4 variables, which were shared among the 12 variables that improved in the EPA/DHA group, suggesting that these improvements are unrelated to the daily supplementation with EPA/DHA. The 8 variables that improved in effect size were related to processing speed,
visuoperceptual integration, visuoconstructive integration, verbal memory, and executive functions. There was also an increase in the number of children with a moderate to large improved effect size for academic performance.

When looking only at the children in the study with a clinically relevant large effect size (a Cohen $d$ value greater than 0.8), for 8 neurocognitive variables, more than 80% of the children were found to have received EPA/DHA. In 14 tests more than 60% of the children with large improvements had received EPA/DHA. These improvements were related to processing speed, visuoperceptive integration, visuoconstructive integration, attention, verbal memory, visual memory, and several aspects of executive function (reasoning, working memory, and inhibition). In 4 tests with a clinically relevant large improvement, there was no difference in the percentage of children who had received EPA/DHA or placebo.

The study results point to a measurable improvement in several neuropsychological functions, suggesting that clinically relevant recovery in cognitive functions is achievable in preadolescent children in the context of malnutrition by supplementation with a modest daily omega-3 intake during 3 months. Even in the context of a deficit in multiple macro- and micro-nutrients, which can underlie malnutrition, it appears that restoration of long chain omega-3 intake can provide measurable improvements in cognitive functions. A previous study with 6-10 year old marginally nourished schoolchildren that looked at supplementation with DHA (100 mg) and linolenic acid, but no EPA, provided together with a mixture of micronutrients, did find a benefit in cognitive performance outcome but the effect could not be attributed to the supplementation with
omega-3s. There are a number of studies in children that have shown improvements in cognitive processes, such as learning and attention, with daily doses of EPA plus DHA that are higher (250-500 mg), in children that have low omega-3 intake and tissue levels, but not specifically studied on a background of malnutrition (see references worth noting below). The present study was relatively small in number, and omega-3 status was not measured although dietary intake of long chain omega-3 was determined to be relatively low. Future studies may be adding valuable supportive evidence for the potential benefits of EPA/DHA for children in poor and underprivileged communities with limitations in access to essential nutrients.

This study provides important indications that in the context of mild to moderate malnutrition, preadolescent school children from families of low socio-economic status can receive significant benefits from increased daily EPA/DHA intake, leading to measurable improvements in cognitive functions and performance at school.


Worth Noting

Catalan J, Moriguchi T, Slotnick B, Murthy M, Greiner RS, Salem NJ. Cognitive deficits in docosahexaenoic acid-


Muthayya S, Eilander A, Transler C, Thomas T, van der Knaap


