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Childhood and adolescent fish consumption and adult neuropsychological performance: An analysis from the Cape Cod Health Study

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ABSTRACT

Objective: This exploratory analysis examines the relationship between childhood and adolescent fish consumption and adult neuropsychological performance.
Design: Data from a retrospective cohort study that assessed fish consumption from age 7 to 18 years via questionnaire were analyzed. A subset of the population underwent domain-specific neuropsychological assessment. Functions evaluated included omnibus intelligence, academic achievement, language, visuospatial skills, learning and memory, attention and executive function, fine motor coordination, mood, and motivation to perform.
Setting: Eight towns in the Cape Cod region of Massachusetts, USA, an area characterized by high fish consumption and an active seafood industry.
Subjects: A cohort of 1245 subjects was recruited based on Massachusetts birth records from 1969 to 1983. Sixty-five participants from the original cohort underwent neuropsychological testing in adulthood (average age = 30 years).
Results: Participant report of consuming fish at least twice per month was associated with better performance on tests of visual learning, memory, and attentional abilities. However, self-report of consuming fish at rates higher than twice per month was not associated with improved abilities. No statistically significant associations were observed between type of fish consumed (e.g., species known to be high in methylmercury content) and test outcomes.
Conclusions: The results suggest that moderate fish consumption during childhood and adolescence may be associated with some cognitive benefits and that consumption of fish during this exposure window may potentially influence adult neuropsychological performance. Future prospective studies should take into account this time period of exposure.

1. Introduction

1.1. Mercury

Dietary consumption of fish and seafood is the main non-occupational source of exposure to the toxicant methylmercury (MeHg) (Birch et al., 2014). Mercury is a ubiquitous heavy metal that enters the environment from several anthropogenic and natural sources. It is emitted into the atmosphere from coal burning power plants, mining and smelting operations, incineration of solid waste, volcanic activity, forest fires and other sources (UNEP, 2013). When elemental mercury from these sources is emitted into the atmosphere it undergoes photochemical oxidation resulting in inorganic mercury and enters the aquatic environment through rainwater. Inorganic mercury is then methylated in the aquatic environment by natural bacterial processes. MeHg, in turn, bioaccumulates in marine animals and moves up the food chain, thereby contaminating fish and seafood (Morel et al., 1998; Wang et al., 2004). The highest levels of contamination appear in long living, large, predatory marine species such as swordfish and shark (World Health Organization, 1990).

MeHg exposure can affect multiple organ systems in humans but it is well established that the central nervous system is most sensitive. Because the prenatal period is a critical window of neurodevelopment

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numerous studies have focused on exposure to MeHg from the mother's fish consumption during pregnancy. Studies of three geographically distinct cohorts of children have been paramount to understanding the developmental effects of this toxicant. These population cohorts are located in the Faroe Islands, New Zealand, and the Seychelles (Rice et al., 2003; Grandjean et al., 1997; Debes et al., 2006; Crump et al., 1998; Myers et al., 1997; Myers et al., 1995a; Myers et al., 1995b; Davidson et al., 1995; Davidson et al., 1998).

In the Nordic fishing population of the Faroe Islands, the main source of exposure to MeHg occurs through the consumption of pilot whale meat. A prospective cohort study of this high exposure population enrolled 1022 singleton births between Osterrieth, 1986 and 1987 and analyzed mercury levels in cord blood and mother's hair at parturition. At age 7 years, 917 of these children underwent an extensive battery of neuropsychological tests. Poorer performance on neuropsychological tasks that assess the domains of language, attention, memory, visuospatial skills, and motor function was related to prenatal MeHg exposure as measured in cord blood (Grandjean et al., 1997). At age 14 years, 878 of these children underwent a second set of neuropsychological tests and poorer performance on tests assessing motor, attention, and verbal skills was again associated with higher prenatal MeHg exposure (Debes et al., 2006). These results suggested that prenatal exposure to MeHg has long-lasting impacts on multiple neuropsychological domains (Grandjean et al., 1997; Debes et al., 2006).

The New Zealand cohort of 237 children whose mother's hair mercury had been measured at birth underwent 26 psychologic and academic achievement tests between the ages of 6 and 7 years. This study reported associations for high prenatal MeHg exposure with decreased performance on tests of language, visuospatial ability, attentional ability, and fine motor skills (Kjellstrom et al., 1986; Kjellstrom et al., 1989; Crump et al., 1998).

The Seychelles Child Development Study (SCDS) followed 779 mother-infant pairs from a high-fish eating population from birth to 19 years and administered tests to evaluate multiple neurological domains. In contrast to the Faroes and New Zealand studies the SCDS found null associations for peripartum maternal hair mercury with neurodevelopment. Using an alternative postnatal exposure metric (taking samples of the children's hair at the time of neurological evaluation), the SCDS found a beneficial association between higher hair mercury and improved IQ in 9-year-old males. The primary explanation for this association has been confounding by the presence of nutrients highly beneficial for brain development also contained in fish (Myers et al., 2009).

1.2. Polyunsaturated fatty acids

Fish and seafood are the primary dietary source of long-chain n-3 polyunsaturated fatty acids (PUFAs), specifically, docosahexaenoic acid (DHA), and eicosapentaenoic acid (EPA) (Kris-Etherton et al., 2000, 2002; Molendi-Coste et al., 2011). PUFAs, the most abundant fatty acid in the mammalian central nervous system, are concentrated in the membrane lipids of brain grey matter and the visual elements of the retina (Innis, 2008). These fatty acids are critical nutrients for brain development and are often low in the Western diet (Ryan et al., 2010).

Several studies have shown positive associations between levels of docosahexaenoic acid (DHA) in blood and improvements in tests of cognitive and visual function during early life (reviewed by Ryan et al., 2010). A prospective study of 341 mother-child pairs in Massachusetts using a food frequency questionnaire to assess the mother's fish consumption during pregnancy observed that higher fish intake (>2 servings/week) compared to no fish intake was associated with higher scores on the Peabody Picture Vocabulary Test and Wide Range Assessment of Visual Motor Abilities in children at 3 years of age (Oken et al., 2008).

In another prospective cohort study of 25,446 children born to mothers in the Danish National Birth Cohort between 1997 and 2002 higher maternal fish intake during pregnancy was associated with higher developmental scores at 18 months of age. In this study mothers reported child development in a standardized interview, which was then used to generate developmental scores. (Oken et al., 2008).

A population-based prospective birth cohort in New Bedford, Massachusetts (1993–1998) measured inattentive and impulsive/hyperactive behaviors in 8-year-old children using the Conners Rating Scale for Teachers. This study revealed an increased risk for teacher-reported inattentive/impulsive/hyperactive behaviors with increased peripartum maternal hair mercury and a reduced risk for these behaviors with consumption of >2 servings per week of fish during pregnancy. This study highlights the importance of disentangling nutritional benefits of fish consumption from the risk of low-level mercury exposure from fish (Sagiv et al., 2012).

1.3. Childhood and adolescence

To our knowledge, few studies examining fish consumption during childhood and adolescence and neuropsychological performance have been conducted. Fish consumption during childhood and adolescence may have a different effect on brain development than prenatal exposure through maternal fish consumption. Although the majority of brain development occurs during the prenatal period, the human brain continues to develop and mature after birth well into the second decade of life. This continued growth occurs in both grey and white matter (Brain Development Cooperative Group, 2012). Thus, beneficial effects of PUFAs on cognitive function during this window as well as any adverse effect of MeHg could potentially occur. Because the existing literature focuses heavily on the impacts of fish consumption of the mother during the prenatal window the rationale for the current study was to examine the impacts of fish consumption during this later childhood and adolescent window another period of robust neurodevelopment.

While numerous intervention studies have examined PUFA supplementation during childhood and neurocognitive endpoints, the results have been inconsistent (Ryan et al., 2010; Dalton et al., 2009; McNamara and Carlson, 2006; Kennedy et al., 2008). A prospective cohort study of 3972 Swedish males reporting fish consumption levels at age 15 years found that fish consumption of more than once per week was associated with higher scores in combined intelligence, verbal performance, and visuospatial performance at age 18 years across all educational levels (Aberg et al., 2009). Notably, some studies have shown that fish oil supplementation does not confer the same benefits of fish consumption (Visioli et al., 2003; Elvevoll et al., 2006).

2. Methods

2.1. Study population

The Cape Cod Health Study is a population-based retrospective cohort study of individuals born in eight towns in the Cape Cod region of Massachusetts between 1969 and 1983. The cohort was originally designed to examine possible associations between exposure to the solvent tetrachloroethylene (PCE) in drinking water and multiple neurological endpoints. The population was exposed to PCE when it leached from the vinyl-lining of asbestos cement drinking water pipes installed across the Northeastern United States from 1969 to 1980. Information about this exposure scenario and the associated health effects have been described in detail elsewhere (Aschengrau et al., 2008; Aschengrau et al., 2009; Aschengrau et al., 2011; Aschengrau et al., 2012; Janulewicz et al., 2008; Janulewicz et al., 2012). Study participants completed a self-administered questionnaire which included demographic information and developmental, educational, occupational, medical and residential histories (Janulewicz et al., 2012). In addition,