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Toxic risks and nutritional benefits of traditional diet on near visual contrast sensitivity and color vision in the Brazilian Amazon

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ABSTRACT

Background: Visual functions are known to be sensitive to toxins such as mercury (Hg) and lead (Pb), while omega-3 fatty acids (FA) and selenium (Se) may be protective. In the Tapajós region of the Brazilian Amazon, all of these elements are present in the local diet.
Objective: Examine how near visual contrast sensitivity and acquired color vision loss vary with biomarkers of toxic exposures (Hg and Pb) and the nutrients Se and omega-3 FA in riverside communities of the Tapajós.
Methods: Complete visuo-ocular examinations were performed. Near visual contrast sensitivity and color vision were assessed in 228 participants (≥15 years) without diagnosed age-related cataracts or ocular pathologies and with near visual acuity refracted to at least 20/40. Biomarkers of Hg (hair), Pb (blood), Se (plasma), and the omega-3 FAs eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in plasma phospholipids were measured. Multiple linear regressions were used to examine the relations between visual outcomes and biomarkers, taking into account age, sex, drinking and smoking.
Results: Reduced contrast sensitivity at all spatial frequencies was associated with hair Hg, while %EPA, and to a lesser extent %EPA + DHA, were associated with better visual function. The intermediate spatial frequency of contrast sensitivity (12 cycles/degree) was negatively related to blood Pb and positively associated with plasma Se. Acquired color vision loss increased with hair Hg and decreased with plasma Se and %EPA.
Conclusions: These findings suggest that the local diet of riverside communities of the Amazon contain toxic substances that can have deleterious effects on vision as well as nutrients that are beneficial for visual function. Since remediation at the source is a long process, a better knowledge of the nutrient content and health effects of traditional foods would be useful to minimize harmful effects of Hg and Pb exposure.

1. Introduction

Methylmercury (MeHg) neurotoxicity has been recognized for a long time and alterations of visual functions are well known signs of MeHg exposure. Minamata disease, a severe neurological disorder caused by MeHg intoxication, was largely documented following the contamination episodes in Japan and Iraq, where populations were exposed to high doses of MeHg (Watanabe and Satoh, 1996). In both incidents, visual deficits were reported and

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constriction of the visual field was a predominant sign among mercury-poisoned individuals (Iwata, 1980; WHO, 1990). Visual contrast sensitivity in Japanese patients with Minamata disease was significantly lower compared to controls in the upper spatial frequencies on the Arden grating tests (Mukuno et al., 1981). However the authors did not establish a direct association with biomarkers of mercury (Hg) exposure in this study.

In the Amazon Basin, fish is a dietary mainstay for many communities and biomarkers of Hg exposure are elevated (Barbieri and Gardon, 2009; Passos and Mergler, 2008). Studies in the Tapajós River Basin of the Brazilian Amazon have consistently shown strong correlations between fish consumption and elevated Hg in hair and blood (Passos and Mergler, 2008). On the other hand, beneficial nutrients, such as omega-3 fatty acids (FA) likewise increase with fish consumption (unpublished data), as does selenium (Se) (Lemire et al., 2006), although the major source for Se is Brazil nuts (Lemire et al., 2010b). In this region, blood Se concentrations are in the normal to elevated range (Lemire et al., 2006, 2009; Pinheiro et al., 2005). Recently, elevated blood lead levels (B-Pb) were reported in communities of the Tapajós, with median levels of more than 10 μg/dL in this population unexposed to any known occupational Pb source (Barbosa et al., 2009). The authors suggest that the artisanal metal plate used for the transformation of manioc into flour (known as *farinha*) could be transferring Pb to the flour during the roasting process (Barbosa et al., 2009).

While Hg (Bridges et al., 2007; Chang, 2007) and Pb (Kohler et al., 1997) have been shown to be ophthalmo-toxic, omega-3 FA and Se may be ophthalmo-protector. Omega-3 FAs are recognized as crucial for visual and ocular system development and maintenance (Forsyth and Carlson, 2001, Horrocks and Yeo, 1999). They play a role in the retina (Uauy et al., 2001), especially in ganglion cells (Nguyen et al., 2008) and at the ocular level in the prevention of cataract formation (Townend et al., 2007). Se is a well-known anti-oxidant and has been shown to be protective for glaucoma, age-related cataracts and macular degeneration (Bartlett and Eperjesi, 2004, Brown et al., 1998, Flohe, 2005, Lemire et al., 2010a). Several animal studies suggest that Se may protect against the toxic effects of Hg (Watanabe, 2002), although epidemiologic evidence on the effects of Se in human populations exposed to Hg is inconsistent. Some studies have observed beneficial effects of Se on neurologic and ocular outcomes negatively affected by Hg (Boucher et al., 2010; Lemire et al., 2010a, 2011), while others did not (Choi et al., 2008; Despres et al., 2005; Saint-Amour et al., 2006; Steuerwald et al., 2000).

Past studies have examined near visual contrast sensitivity loss and acquired dyschromatopsia in relation to hair Hg (H-Hg) in persons living in villages on the Tapajós River. Lebel et al. (1998) reported an inverse association between H-Hg levels and near visual contrast sensitivity at intermediate and high frequencies (6, 12 and 18 cycles/degree – cpd). In a pilot study with 29 participants, these authors likewise observed an association between H-Hg and color vision loss (Lebel et al., 1996), but they did not obtain the same results when they repeated the study in a larger group from the same region the following year (Lebel et al., 1998). Recently, a repeated measure follow-up of 31 participants from a village in this region showed that color vision deterioration observed between 1995 and 2006 was associated with 1995 H-Hg levels, despite a decrease in Hg exposure over this period, suggesting that Hg exposure could have long term non reversible effects on the visual system (Fillion et al., 2011).

The objective of this study was to examine how near visual contrast sensitivity and color vision loss vary with biomarkers of toxic exposures (Hg and Pb) and the protective nutrients Se and omega-3 FA in an adult riverside population of the Tapajós River in the Brazilian Amazon.

2. Materials and methods

2.1. Study population

Since the mid-nineties, our research group has been involved in an interdisciplinary project on Hg exposure and its potential effects on human health in the Lower Tapajós River Basin (State of Pará, Brazil) (CARUSO, 2011). In this region, there are approximately 50 communities of diverse size and origin, with varying access to health care, education and goods. The results presented here are part of a cross-sectional study whose objective was to examine factors that may influence Hg toxicity. For this study, we selected 12 communities to reflect the diversity of regional populations, social conditions and ecosystems (Fig. 1). Recruitment was based on a convenience sampling procedure since it is difficult to apply a random sampling strategy in this setting (Passos et al., 2007).

Several weeks before the present study, each village was visited and persons 15 years and older were invited to participate on a voluntary basis. The study was explained at a village meeting and at home visits. A total of 448 participants, representing 25% of the adult population, volunteered to participate in the present study. Individuals in the younger range (15–40 years) were underrepresented and those in the middle-age range (40–65 years) were overrepresented, while the distribution of the oldest participants (>65 years) was similar to the underlying population (Lemire et al., 2010a).

For each day of testing, a maximum of 12 participants were brought by boat to a technical school in the nearby city, Itaituba, where there was access to electricity and freezers for storing biological material. Each village was scheduled for a specific number of days. The boats arrived in the villages the previous day and made the trip during the night. The study was carried out from May to July 2006.

The study was approved by the Ethics Review Boards of the University of Quebec at Montreal, of the Federal University of Rio de Janeiro and of the Faculty of Pharmaceutical Sciences of the University of São Paulo-Ribeirão Preto. All participants signed an informed consent form, which was read to them in Portuguese. There was no remuneration for study participation.

2.2. Socio-demographics and medical history

An interview-administered questionnaire was used to collect information on socio-demographics, occupational and residential history. A food frequency questionnaire (Passos et al., 2007) was used to collect dietary information on fish species consumed over the 7 days preceding the interview. A trained nurse administered the questionnaire on medical history. When the boats arrived in the villages, research assistants visited each participant in their homes and noted the names of all currently used medications. None of the interviewers were aware of the participants' exposure levels.

2.3. Assessment of biomarkers of Hg, Pb and Se

2.3.1. Hair

Hair has often been used as a biomarker for current and retrospective exposure to Hg (Bastos et al., 1998), and a large number of studies have shown that this biomarker reflects Hg intake from fish consumption (for a review see (Mergler et al., 2007)). This non-invasive method provides samples that can be stored for a long time without deterioration before being analyzed. Hair strands from the occipital region were cut at the root and stored in plastic bags, with the end root stapled. The first 2 cm from the root were used to determine hair total Hg concentration (H-Hg) by cold vapour atomic absorption spectrometry (CVAAS), according