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Association between fish consumption, dietary omega-3 fatty acids and persistent organic pollutants intake, and type 2 diabetes in 18 First Nations in Ontario, Canada

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ABSTRACT

Background: First Nations (FNs) populations in Canada experience a disproportionally higher rate of obesity and type 2 diabetes (T2D) compared to the general population. Recent data suggest that a high consumption of fish may help prevent T2D. On the other hand, fish might also be a potential source of environmental contaminants which could potentially be a risk factor for T2D.
Objective: To investigate the potential associations between self-reported T2D and consumption of locally-harvested fish, dietary long-chain omega-3 fatty acids (n-3FAs) and persistent organic pollutants intake among adult FNs living on reserve in Ontario.
Design: Data from the First Nations Food Nutrition and Environment Study, which included a cross-sectional study of 1429 Ontario FNs adults living in 18 communities across 4 ecozones in 2012 were analyzed. Social and lifestyle data were collected using household interviews. The consumption of locally-harvested fish was estimated using a traditional food frequency questionnaire along with portion size information obtained from 24hr recalls. Fish samples were analyzed for the presence of contaminants including dichlorodiphenyldichloroethylene (DDE) and polychlorinated biphenyls (PCBs). Dietary intakes of DDE and PCBs were estimated using community-specific levels of DDE/PCBs in fish species. Multiple logistic regression models adjusted for potential covariates including age, gender, body mass index, physical activity, total energy intake, smoking, and education were developed.
Results: The prevalence of T2D in Ontario FNs was 24.4%. A significant positive association between fish consumption of one portion per week and more and T2D compared to no fish consumption was found (OR = 2.5 (95% CI: 1.38–4.58). Dietary DDE and PCBs intake was positively associated with T2D (OR = 1.09 (95%CI: 1.05–1.75) for DDE and OR = 1.07 (95%CI: 1.004–1.27) for PCBs) per unit increase in DDE/PCBs while n-3-FAs intake, adjusted for DDE/PCBs intake, showed an inverse effect against T2D among older individuals (OR = 0.86 (95% CI: 0.46–0.99).
Conclusion: Our results support previous findings that exposure to DDE and PCBs may increase the risk of T2D. Elevated levels of contaminants in fish may counteract with potentially beneficial effects of n-3FAs from fish consumption. However, the overall health benefits of high consumption of fish with a high n-3 FAs content may outweigh the adverse effect of contaminants.

1. Introduction

The prevalence of type 2 diabetes (T2D) has dramatically increased worldwide over the last two decades, and it is recognized as one of the most important public health concerns. According to the World Health Organization, the global diabetes prevalence for adults aged 20 years and older was estimated to be 6.6% in 2000 and is predicted to reach 7.7% by 2030 (Wild et al., 2004). In Canada, the First Nations population experiences a disproportionally higher rate of T2D compared to the general Canadian population (Dyck et al., 2010; Young

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et al., 2000). Age-standardized prevalence of T2D in First Nations was 17.2% compared to 6.8% in general Canadians (Pelletier et al., 2012), ranging from about 7–36% in individual First Nation communities (Dannenbaum et al., 2008; Imbeault et al., 2010; Horn et al., 2007). T2D is a multifactorial disease caused by a complex interaction between lifestyle, genetic and environmental factors. Recognized risk factors for T2D are obesity, high-calorie diets, low physical activity and smoking (Byrne et al., 2012; Day and Bailey, 2011; Chang, 2012).

Recent data from the population-based prospective cohort studies have suggested that a high consumption of fish may help prevent T2D (Patel et al., 2009; Rylander et al., 2014). Potential benefits of fish and seafood were attributed to the presence of long chain omega-3 fatty acids (n-3 FAs), specifically eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) which have shown a beneficial effects on multiple risk factors associated with diabetes, such as lipid profile, blood pressure, and inflammation, as well as on coronary heart disease and stroke (He, 2009; Panagiotakos et al., 2007). Epidemiological studies on the association between fish consumption, n-3 FAs and T2D have reported controversial results: some studies found a protective effect (Nanri et al., 2011a; Nkondjock and Receveur, 2003; Rylander et al., 2014), while others showed a negative effect (Djoussé et al., 2011; Kaushik and Mozaffarian, 2009a). Meta-analyses on the associations between fish consumption, n-3 FAs and the development of T2D found heterogeneity of the overall summary estimates based on geographical differences of the studies: an inverse association in population of Asian countries, no association in population of Western countries and a positive relation in US population (Muley et al., 2014; Wallin et al., 2012; Xun and He, 2012; Zheng et al., 2012). Differences in fish consumption patters may partially explain the inconsistency between the findings. Environmental contaminants present in fish may also influence the association between fish intake and T2D (Lee et al., 2014; Wallin et al., 2015).

Fish is a potential source of environmental contaminants, such as persistent organic pollutants (POPs) (Seabert et al., 2014). POPs are toxic substances which persist in the environment, have long half-lives, and therefore bioaccumulate and biomagnify in living organisms such as fish, mammals, predatory birds, and humans (Hardell et al., 2010; Sobek et al., 2010; Vorkamp and Rigét, 2014). This is a concern especially among First Nation populations whose diets rely on locally harvested fish and other wild foods. A study conducted on Mohawk men and women showed that local fish consumption was a major pathway of POPs exposure (Fitzgerald et al., 1999, 2004). Recently, a number of studies found positive associations between diabetes and POPs such as dioxin-like chemicals, non-dioxin-like polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDE), and other organochlorine pesticides (Codru et al., 2007; Lee et al., 2010; Philibert et al., 2009; Silverstone et al., 2012). Pal et al. (2013) found higher POP concentrations in plasma in diabetic compared to non-diabetic Canadian First Nation individuals. Thus, First Nation people might be exposed to elevated concentrations of POPs from fish consumption which can be risk factors for T2D (Sharp, 2009).

It is clear that there is a need to evaluate the risk-benefit associated with fish consumption with respect to POPs and n-3 FAs intake, and whether it is associated with T2D. The objectives of this study are: to describe fish consumption patterns among First Nation adults in four Ontario ecozones; to estimate n-3 FAs and PCBs, and DDE intake; and to explore the associations between self-reported T2D and fish consumption, dietary n-3 FAs and POP intake among First Nations living on reserve in Ontario.

2. Methodology

2.1. Study population

Data from the First Nations Food Nutrition and Environment Study (FNFNES), a 10-year cross-sectional study (2008–2017) were used (Chan et al., 2013). The FNFNES survey was designed to assess diets, the exposure to contaminants, and food security status of First Nations people living on reserves, south of the 60th parallel across Canada. First Nations communities were sampled using a combined ecozone/cultural area framework to ensure that the diversity in ecozones and cultural areas were represented in the sampling strategy. Three stages sampling proceeded: primary sampling was carried out with random sampling of communities within each of eight Assembly of First Nation (AFN) regions of Canada; secondary sampling was conducted with the random sampling of 125 households within each selected community; and tertiary sampling when one randomly selected adult in each household who was self-identified as being a First Nations person living on reserve aged 19 and older was asked to participate in the study. Estimation weights were calculated in order to obtain representative estimates of the total population. Weighting was required to minimize nonresponse bias. The design weight was adjusted based on the assumption that the responding communities represent both responding and non-responding communities. The Bootstrap method was adopted for the estimation of the sampling error of the estimates produced for this study (Chan et al., 2013). The detailed information on the study design and methodology are publicly available online (www.fnfnes.ca). The current study analyzed data from eighteen First Nations communities across four Ontario ecozones: 1- Boreal Shield/ Subarctic, 2- Boreal Shield/Northeast, 3- Hudson Plains/Subarctic, 4- Mixed-wood Plains/ Northeast collected in the fall of 2011 and 2012 (Fig. 1). In total, 1429 participants aged 19 years and over were recruited in this study (Chan et al., 2013). The overall participation rate was 79%. To avoid potential misclassification of gestational diabetes, pregnant and breastfeeding women who reported having diabetes were excluded from the analyses. The final sample included 1426 participants (893 women and 533 men).

2.2. Ethics

Individual participation in the project was voluntary and based on informed written consent after an oral and written explanation of each project component. This survey was conducted following the "Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans" and in particular Chapter 9 research involving the First Nations, Inuit and Métis Peoples of Canada. The study was approved by the Ethical Review Boards at the University of Northern British Columbia, the University of Ottawa, the Université de Montréal, and Health Canada.

2.3. Data collection

During the household interviews, the study participants were asked to complete a series of questionnaires that collect information on dietary patterns (a 24-h recall and a Traditional Food Frequency Questionnaire (FFQ)), and social-demographic, health, and lifestyle data ((SHL) Questionnaire).

To collect the 24 h recall, the multi-pass technique with 3 stages was used as follows: the first step was to make a quick list of all foods consumed during prior 24 h; the second one was to do a detailed description of the consumed foods and beverages (brands, amounts, and amount eaten, etc..); and the third step was to review the recall with the participant to see if anything was missed (Raper et al., 2004). Three-dimensional food and beverage models were used in order to estimate corresponding quantities of the intakes. The FFQ collected data regarding consumption of locally-harvested traditional foods during the four seasons in the past year. The questionnaire was developed based on a comprehensive list of traditional foods that was representative for each participating community. In Ontario, the FFQ combined 150 traditional food items, including 30 fish species, 21 land mammals, 26 wild bird species, 22 wild berries, and 48 wild nuts, plants, tree foods, and mushrooms. In this study, only data on the frequency of