

REVIEW

ENVIRONMENTAL TOXINS, A POTENTIAL RISK FACTOR FOR DIABETES AMONG CANADIAN ABORIGINALS

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ABSTRACT

Objectives. To review the current literature to determine if there is a case for examining the presence of toxins in traditional foods and the environment as a possible risk factor for type 2 diabetes in Canadian Aboriginal populations.

Study design. Literature review.

Methods. The scientific literature on possible causes of type 2 diabetes in Aboriginal populations in Canada was reviewed. Potential exposure through food and water to environmental toxins such as methylmercury, arsenic, persistent organic pollutants (POPs), including bisphenol A and phthalates, as well as Aboriginal lifestyle and composition of the traditional diet is discussed.

Results. There is growing evidence to suggest that environmental toxins may be associated with non-insulin-dependent diabetes mellitus (type 2 diabetes), which many consider to be endemic worldwide. In Canada, diabetes has reached epidemic proportions, especially among Aboriginal populations. Based on both molecular and pathological findings, some toxins found in the environment interfere with the functioning of the pancreas' islets of Langerhans cells, and *consequently* they affect insulin production. In addition, there is new evidence suggesting that obesity may be linked to endocrine disruptors, thus increasing the likelihood that obesity in itself may not be a chief risk factor for diabetes.

Conclusions. Diabetes prevalence rates among First Nations, Inuit and Métis populations are 3–5 times higher than the general population. Accepted risk factors such as diet, lifestyle and genetics do not fully explain this phenomenon. However, as many environmental toxins bioaccumulate in the food chain and are found in wild game and fish traditionally harvested and consumed by Aboriginal peoples, these chemicals could present health risks not yet fully explored. As there is not enough evidence to rule out this possibility, further studies are suggested. If correct, such environmental risk factors, especially if they are encountered early in life, would have implications on Aboriginal public health.

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Keywords: Aboriginal, diabetes mellitus type 2, risk factors, dietary proteins, environmental toxins, public health

INTRODUCTION

The occurrence of type 2 diabetes among Canadian Aboriginal peoples is far greater than the national average and is reaching what many now consider “epidemic proportions” (1–5). In some communities estimated prevalence rates are over 25% (6). The prevalence rate of diabetes among Canadian Aboriginal women is 5.3 times higher than other Canadians, and among Aboriginal men is 3.3 times higher (7). Among western Métis, the prevalence rate of diabetes is twice that of the rest of Western Canadians (2). In terms of public health, these rates are troubling, since diabetes, if left untreated, is a leading cause of complications and co-morbidity among Aboriginal peoples in Canada. In the province of Quebec a study of Mohawks with diabetes found over 60% had at least 1 major complication (8).

Aboriginals in Canada

The Aboriginal peoples of Canada consist of 3 distinct populations: the Inuit, who inhabit the circumpolar region of the far North; First Nations peoples, indigenous to North America and living mainly on reserves in remote rural communities; and the Métis, who are of mixed blood First Nations and European ancestry and are concentrated in the Prairie Provinces of Alberta, Saskatchewan and Manitoba. According to the 2001 Census, Aboriginal Canadians make up 4.4% of the total population and are rapidly increasing in number due to high birth rates (9). Of the non-urban Aboriginals, most live in poor conditions in remote areas, with limited access to comprehensive environmental services and quality health care. Many are employed in the forestry or mining sectors and may come in contact

with environmental toxins as an occupational hazard. Also, Canadian data show that the health risks associated with living in close proximity to industrial sources of pollution are more likely to affect low-income areas, minority and Aboriginal communities (including those living on reserves) (10–13). For Aboriginal populations, health problems of concern are: mental illness, alcoholism and foetal alcohol syndrome, suicide, family violence, injuries, diabetes, tuberculosis, HIV infection, obesity and hypertension (14). Moreover, as many Aboriginal communities rely on the environment for their livelihood, that is, for food, employment and spiritual well-being, it is important that they are aware that what used to be considered a healthy environment may harbor chemical toxins that can pose long-term health risks.

The Aboriginal traditional diet

The Aboriginal peoples of Canada have always relied on wild game, waterfowl, fish and various plants, including berries, as their main source of food. These traditions continue today. For many, the foods harvested make up a substantial portion of their diet. For example, in 2004–2005 in the Province of Manitoba, the Manitoba Métis Federation carried out a survey of Métis harvesting practices, of roughly 5,000 Métis harvesters. They observed that those who harvest for food share what they catch with the extended family, meaning that the consumption of traditional foods is more widespread than with just those families that include harvesters. Of approximately 980 respondents, 90% harvest fish, 78% berries and wild rice, 72% deer, 68% moose, 62% migratory birds (ducks and geese) and 56% small game like rabbit and beaver. In

addition to hunting, fishing and gathering for family needs, harvesting is used for ceremonial events and social gatherings, for clothing and for trading purposes (15). For most Aboriginal groups in Canada, hunting and fishing is part of their traditional lifestyle. However, Western (market) food is increasingly becoming a part of the Aboriginal diet. In a survey of two Sahtu Dene/Métis communities of the subarctic, it was observed that land mammals and fish provided a total of 68% of traditional food items consumed, but more market food than traditional food was consumed by children, teens and young adults (16).

Seafood consumption carries both benefits (fatty acids that are associated with several beneficial health effects) and risks (exposure to environmental contaminants). According to Éric Dewailly, a nutrition study of three ethnic groups of northern Quebec where fish intake and plasma phospholipid concentrations of n-3 fatty acid were compared, revealed that the Inuit, with the highest fish intake, had the highest concentration of beneficial fatty acids, which lowers cardiovascular disease risk factors such as obesity, high blood pressure and diabetes (17–19). This beneficial effect may account for lower diabetes rates among the Inuit, despite the consumption of fish with high body burdens of toxic metals and organochlorines (18,20).

Current explanations of high diabetes prevalence rates

Explanations of the increased level of diabetes in Aboriginal Canadians range from diet and sedentary behaviour resulting in obesity, to genetics (21). While these factors certainly play a role, there appears to be other factors involved in explaining the higher rates

observed among Aboriginals, particularly among the Métis, who are genetically more heterogeneous than other Aboriginal populations (22). Other explanations have been proposed, for example Benyshek et al. suggest that these high rates are due to foetal malnutrition (1). Although diabetes is considered a lifestyle disease with multifactorial causation, there are other possible risk factors not yet fully explored that contribute to the observed high prevalence rates.

The obesity epidemic

In several Arctic countries it has been observed that the percentage of overweight and obese persons is rapidly increasing. This seems to coincide with the Westernization of the diet. The current thinking is that it is this transition to the high carbohydrate and fat-rich Western-type food, and lifestyle changes, including a genetic predisposition and complex psychosocial factors that has resulted in increases in obesity, the accepted risk factor for diabetes. However, this may not be the only cause. A study conducted in Greenland concluded that, although obesity adversely affects nutritional and cardiovascular health, the observed increase in obesity cannot be correlated with either traditional or Western food intake (23). There is new evidence to suggest that the body's natural weight-control mechanisms are not functioning properly in obese people.

Baillie-Hamilton suggests that environmental factors in the last few decades, such as the production and wide-spread use of synthetic organic and inorganic chemicals (that eventually find their way into the Aboriginal diet), may have damaged many of the body's natural weight-control mechanisms. This, together with a wide range of additional,

possibly synergistic factors, may be playing a significant role in the obesity epidemic (24). It includes exposure to endocrine disrupting chemicals (EDCs) during critical stages of development, which has been reported as a possible cause of obesity (25–27). Synthetic chemicals are often used to deliberately cause weight gain in farm animals. Similarly, environmental toxins such as heavy metals, polychlorinated biphenyls (PCBs), organophosphates, phthalates and bisphenol A have been shown to cause weight gain in animals at lower doses than what is considered toxic (26). Although not conclusive, these findings indicate that, in some cases, obesity, a risk factor for diabetes, may be associated with environmental contaminants (27,28). While this is an intriguing possibility, it is evident that the lack of epidemiological evidence supports the need for further research.

Environmental toxins as potential risk factors

The diabetogenic effect of arsenic in humans has been reported in different ethnic groups with differing occupations and varied exposure routes (29–33). Tseng et al. carried out studies in Taiwan that showed an association between chronic high arsenic exposure in drinking water and diabetes mellitus (34). A 12-year study of contaminants in the Canada's Northwest Territories found that arsenic levels were higher in berries collected from areas around gold mines.

In addition, new laboratory evidence suggests that methylmercury (MeHg) impairs pancreatic function (35–37). In vivo investigations revealed that oral exposure to low-dose mercury increased plasma lipid peroxidation levels, decreased plasma insulin levels and

elevated blood glucose and glucose intolerance (35). These findings are further supported by pathological evidence (38). As methylmercury levels in human populations that consume fish are generally higher than what would be considered normal, this is a concern (39–43). Although not supported by epidemiological evidence, these studies suggest a possible link between mercury exposure (commonly found in wild game and fish) and diabetes.

Some studies suggest that diabetes is linked to persistent organic pollutants (POPs) that bioaccumulate in fatty tissue (28,44,45). Carpenter observed that obese persons who do not have elevated POPs are not at higher risk for diabetes, which suggests that POPs, rather than obesity, may play a greater role than currently assumed as a risk factor for diabetes (28).

Epidemiological studies suggest a possible link between dioxin-like compounds (DLCs), a wide-spread environmental contaminant, and diabetes; however, experimental evidence is lacking (46). DLCs are persistent, lipophilic and prone to bioaccumulation; as a result, chronic, low-dose exposure could hasten the onset of type 2 diabetes in susceptible individuals. Carpenter points out that a number of reports have recently emerged showing an increase in the number of diagnoses of diabetes in persons who have been occupationally exposed to dioxin, including a study of U.S. Air Force personnel in Vietnam involved in spraying Agent Orange, a defoliant which contained dioxin as a contaminate.

More recently, research indicates that organochlorine pesticides and non dioxin-like polychlorinated biphenyls (PCBs) may be associated with the risk of developing type 2 diabetes by increasing insulin resistance,

and that persistent organic pollutants may interact with obesity to also increase the risk (1,24,44,47).

Data from 1,455 American adults who took part in the U.S. National Health and Nutrition Examination Survey (NHANES) conducted in 2003–2004 showed that diabetes and heart disease were more common in subjects with high bisphenol A (BPA) concentrations (48). BPA, a monomer of plastic, is a chemical found in many consumer products, including baby bottles and food packaging. BPA is considered to be an endocrine disruptor. As experiments have shown a possible link between environmental estrogens and insulin resistance, exposure to BPA could enhance the risk of developing type 2 diabetes (49). Vom Saal and Myers suggest that, based on the results of new studies indicating adults with increased levels of BPA are at greater risk for metabolic disorders, this finding alone should stimulate further studies that relate exposure during critical periods in development to subsequent disease, to challenge the basic assumption in chemical risk assessments that BPA is safe (48).

In addition, there is increasing concern about a class of compounds called phthalate esters. Phthalates are found in a wide range of consumer products such as cosmetics, personal care products, pesticides, children's toys, food packaging and cleaning and building materials. Recent studies indicate widespread human exposure to multiple phthalates (50). Not only have phthalates been linked to reproductive developmental problems in laboratory animals and possibly humans as well, but also to 2 metabolic abnormalities in males, namely, abdominal obesity and insulin resistance (51).

There is no doubt that we are living in a chemical world, and environmental toxins appear to be increasing in concentration. Although the data are currently limited and inconsistent, there is mounting evidence suggesting that toxic substances in the environment are associated with diabetes (13,28,32,45,52).

The nature of chemical toxins in the environment

Arsenic is prevalent in the environment worldwide, and may be found in drinking water supplies, open water sources and soil, and it is often introduced by anthropogenic activities such as mining, forestry and farming. The use of pesticides, herbicides and wood preservatives, as well as certain mining activities, has increased arsenic levels far beyond their natural levels. As a result, common arsenic species present in soil can enter the food chain via plant accumulation and pose environmental risks to consumers (53). A study conducted by Koch et al. identified elevated arsenic levels in fungi collected from Yellowknife in the Northwest Territories, in areas that had been affected by past mining operations (54). Lichens are food for certain species of caribou, an animal which is commonly harvested by Canadian Aboriginals. Elevated arsenic concentrations have also been found in the vicinity of the mining and smelting areas of Flin Flon, Manitoba, and Atikokan, Ontario, which are communities with large Aboriginal populations (55). Also, Aboriginal communities in the vicinity of mining operations in northern Saskatchewan and Manitoba have reported high rates of non-insulin dependent diabetes mellitus (type 2 diabetes), which was virtually unknown in these communities as recently as 1937 (56).

As for other toxic trace metals, Yukon moose have high renal selenium concentrations, and moose and some woodland caribou from the same area have high renal cadmium levels (57). In ongoing monitoring programs of contaminants in Yukon wildlife that began in 1992, it was found that in samples submitted by Aboriginal hunters and trappers, cadmium in caribou livers and kidneys could pose a risk to people consuming them (if enough were consumed), and that variations in concentrations of renal cadmium, lead, mercury and zinc were significantly higher in spring than in fall (58). According to Treaty Rights, Aboriginals in Canada can hunt and fish at anytime of the year to procure game for food and traditional uses. These observations of temporal variations in contaminant levels have justified further studies of cadmium in moose and caribou, mercury in caribou, as well as emerging contaminants such as persistent fluorinated pollutants.

Like arsenic, elemental mercury is ubiquitous, natural and anthropogenic. It is easily converted by microorganisms into methylmercury (MeHg) and bioaccumulates in fish and game traditionally consumed by Aboriginals (59,60). The typical Aboriginal diet includes caribou, moose and freshwater predator fish such as whitefish, walleye and trout. It is well documented that Aboriginal Canadians who consume traditional foods have high exposure to mercury. It is also known that Métis from northern Canada have higher body burdens of mercury than other Canadians. Walker et al. reported that mercury was detected in 98% of Dene/Métis, but in only 88% of Caucasians living in the same area (60). Although research on arsenic in Canada is lacking, the same effect might also be true for this toxic metal-

loid, particularly among Aboriginals living in the vicinity of Canadian mining operations, where arsenic has been found in abundance. This reality suggests that a targeted biomonitoring program to look at arsenic concentrations in Aboriginals would be valuable.

Mercury levels in North America have increased steadily as a result of industrialization and peaked around 1980, with levels that have remained high since (61). Both As and MeHg occur naturally in the environment, but are also anthropogenic and are associated with metal ore mining operations, logging and forestry, emissions from coal-fired power plants, as an ingredient in pesticides, as a wood preservative and can be found in the effluent of the pulp and paper industry (62). MeHg is released into the atmosphere by industrial processes as Hg (II) and settles to earth where it is converted by bacteria into highly toxic and bioavailable MeHg (63). Mercury assimilation by plant foliage may be the source of a substantial amount of MeHg in ecosystems, which is concentrated by numerous insects and animals that feed on this material (64). MeHg then bioconcentrates as it moves up the food chain. In the Arctic, the spring thaw releases the mercury that has accumulated in snow packs, resulting in the high concentrations of MeHg observed in arctic wildlife (65,66). These high concentrations can be problematic for northern Aboriginal populations who regularly harvest fish and game as their primary food source. As a result, the Government of Canada periodically publishes advisories on mercury levels in fish (67).

Due to modern-day industrialization, we are being exposed to thousands of chemicals on a daily basis. The most common way the impact of these chemicals is measured is by

toxicity testing, which is done on a chemical-by-chemical basis. This, however, does not gauge the effects of complex mixtures of toxic chemicals in the human body. Although in low doses a chemical may not be deemed harmful, the effects of mixtures could be additive or synergistic, that is, greater than the sum of the individual components. Trivedi calls this the “toxic cocktail” effect (68). While very little research has been done to document this effect, toxic metals and organic pollutants that have entered the food chain may behave in this manner. Moreover, what is not well known is the cumulative risk posed by multiple chemical exposures of environmental toxins such as phthalates, which are used in a wide variety of consumer products (10). In the book *Phthalates and Cumulative Risk Assessment: The Tasks Ahead*, published by the National Academy of Sciences, the authors used 1999–2002 data from the CDC National Health and Nutrition Examination Survey, and found that 4 phthalate metabolites were significantly associated with greater waist circumference, and 3 with increased insulin resistance (50). Although some evidence is lacking, this suggests that cumulative risk assessment of combined exposures to low-dose contamination is a cause for concern, warranting further research.

The dietary dilemma

For Aboriginal Canadians, the traditional diet is considered superior to the Western diet. Although traditional food constitutes only a portion of the Aboriginal diet today, it is still a key source of many essential nutrients, and as a result is being promoted by health experts as beneficial (69–71). Traditional food is also a reason why, despite poor diets, Métis children

were not found to be undernourished (64,72). Some researchers argue that the potential benefits of traditional food may outweigh any detrimental side effects from toxins that these foods may contain (43,73,74). To imply that MeHg and/or arsenic or other environmental toxins that may be found in traditional food could be a risk factor for diabetes would result in disruption of lifestyle and eating patterns, and would have sociocultural and socio-economic implications among the affected populations (75). It is therefore essential to understand the impact that environmental toxins may have on diabetes prior to adopting any policies that either encourage or discourage traditional food use. However, this dilemma should not prevent research on risk factors for diabetes.

Current research initiatives

A 10-year study recently funded by Health Canada and in partnership with the University of Montreal, the University of Northern British Columbia and the Assembly of First Nations will attempt to address a gap in knowledge about the nutritional composition and temporal changes in First Nations people’s diets, and in the environmental safety of traditional foods that comprise that diet. Initiated in 2008, the First Nations Food, Nutrition and Environmental Study (FNFNES) will document the nutritional benefits and environmental contaminant challenges that are intrinsic to First Nations people living on reserves across Canada. In addition, drinking water will be examined for trace metal content and surface water for the presence of pharmaceuticals. A secondary objective of the project will be to describe the body burden of mercury in Aboriginals through hair analysis. Although diabetes is not a part of this 10-year

multidisciplinary research project (other than collecting information on perceived health status), the data collected will provide a baseline for subsequent studies on diabetes and environmental toxins.

A biomonitoring study is also under negotiation between the Assembly of First Nations and Health Canada. This study will seek to determine the body burden of environmental toxins of First Nations people living on reserves. Implementation is scheduled for 2009–2010.

Other similar studies are under negotiation with First Nations communities located in industrialized areas (11,12).

DISCUSSION

In summary, gaps in the current etiology of diabetes, namely, diet, lifestyle and genetics seem to point to other factors contributing to the current diabetes epidemic in Canadian Aboriginal peoples (13). Laboratory and pathological evidence suggest that arsenic, mercury, persistent organic pollutants, and possibly BPA, phthalates and dioxins, interfere with the functioning of the cells in the pancreas' islets of Langerhans (13). Some of these environmental toxins bioaccumulate in the food chain and are found in traditional diets as well as some drinking water supplies, resulting in exposure levels that are higher than the national average. Therefore, if more evidence shows that MeHg and/or arsenic, POPs and other environmental toxins (or any mixture of these) are contributing factors to diabetes, Aboriginal Canadians who regularly consume traditional foods or live in close proximity to industrial

areas are at greater risk for diabetes than the general population. In addition, there is a suggestion that substandard housing (common among Canadian Aboriginals) is associated with diabetes risk (76). Finding higher than normal levels of environmental toxins, either in traditional diets, by occupational exposure or through poor housing could explain some of the exceptionally high rates of diabetes in Aboriginal Canadians. If so, nutritional diabetes control programs, including Canada's Food Guide (77), which reflects the customary values, traditions and food choices of First Nations, Inuit and Métis, should be modified to take into account environmental contaminants as risk factors. By indicating which species of animal to hunt, the best times to harvest and which organs to avoid to minimize health risks, we may be better able to control diabetes complications and morbidity.

However, the difference between association and causation must be clear. The literature thus far only highlights associations, some of which are based on animal experimentation. Such results not only justify further study, they indicate exercising extreme caution when interpreting the data. As a result, studies are recommended to determine the level of contamination by environmental toxins in traditional foods, taking into account seasonality and the age and sex of the animal harvested, as well as case-control or epidemiological investigations of a possible link existing between these contaminants (individually, cumulatively and in mixtures) and diabetes in Canadian Aboriginal populations. In addition, care must be exercised not to provide contradictory information, which may confuse advi-

sories about consumption. Brustead et al. cautioned that dietary advice should be developed in the context of risk management, of which both epidemiologic evidence and risk assessment are essential components (74).

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