Can Increasing Pulse Consumption in Canada Reduce Healthcare Expenditures?

FINAL REPORT

By

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SUMMARY

Canada's Food Guide encourages the consumption of dietary pulses, such as beans, peas, and lentils, as part of a generally healthy diet and lifestyle. In addition to their nutritional significance, pulses intakes has been shown to protect against a number of major public health concerns worldwide, including type 2 diabetes (T2D) and coronary heart disease (CHD), which are both leading contributors to considerable economic burdens on healthcare and related resources around the world. Still, limited knowledge is available on the economic benefits associated with T2D and CHD of habitual or recommended consumption of pulses. The objective of this research was to systematically determine the socioeconomic value of the recommended intake of pulse crops in the context of reductions in T2D and CHD healthcare and society costs in Canada. Using a three-step cost-of-illness approach, including a sensitivity analysis of four scenarios, the research firstly estimated the likelihood of population adherence to pulse-based diets in Canada, secondly determined the percent reduction in T2D and CHD incidence, separately, per daily serving of pulse consumption, and lastly forecasted the potential annual cost savings that would accrue to the Canadian healthcare system and society following improvements in rates of each of the two health conditions of interest. Based on analysis of the current literature, each 1 serving (about 130 g) per day of dietary pulse consumption was found to result in an average of 7% reduction in T2D and 5% reduction in CHD incidence. If 50% of the adult population in Canada consumed the recommended daily servings of pulse, conservative annual direct and indirect savings are predicted to reach CAD$73.0 million for T2D costs and $209 million for CHD costs. If only 5% of the adult population consumed pulses to the recommended amount, total savings would reach CAD$7.3 and $20.9 million annually on costs associated with T2D and CHD, respectively. Further, by-province analyses reveal a total reduction in combined costs of the two health conditions of interest that ranges between CAD$0.1-$0.7 million in Yukon and $14.0-$136.0 million in Ontario, given the worst through best case scenarios. Specific to Manitoba, a total saving in T2D and CHD costs together is forecasted to reach anywhere between CAD$1.4 and $14.3 million annually following the recommended daily intake of pulse foods by 5% and 50% of the province's adult population, respectively. In conclusion, a significant economic benefit for Canada is expected to accompany an improved health status with attainable levels of dietary pulses consumption. Given the extensive economic burden of the Canadian healthcare system (about 12% of GDP in 2012), any reductions in associated expenditures have important budgetary implications. Findings of this research highlight the public expenditure savings of pulse consumption that could be re-assigned to other priority areas, such as education and infrastructure, and are expected to result in increased publicity that could improve demand for natural and commercial pulse products in Canada.

REPORT BACKGROUND AND RATIONALE

In Canada, given the publicly funded nature of the healthcare system, the economic costs of chronic diseases put a considerable burden on national resources. Nutrient deficiency from unhealthy food habits is one of the major causes for such societal costs whereas healthy-style dietary behaviors have the potential to result in substantial healthcare and related cost savings. This study will identify the potential economic benefits of increased consumption of pulse crops in Canada specifically with respect to improvements in type 2 diabetes (T2D) and coronary heart disease (CHD).

The prevalence of T2D and CHD has reached epidemic proportions in recent decades. Together with escalating costs related to healthcare and society's loss of productivity, this made finding effective solutions to reducing incident rates of these chronic illnesses a global public health priority. Worldwide, the prevalence of diabetes reached 9% in adults in 2014, including 90% who were diagnosed with T2D, and an overall US$612 billion in costs. In Canada, a 70% increase in the prevalence of diagnosed diabetes was observed between 1998/99 and 2008/09, with a conservative total cost estimate of CAD$2.5 billion (excluding costs of complications) in 2000 and total direct healthcare costs projected to increase to over CAD$8 billion annually by 2016. Similarly, both globally and in Canada, the prevalence and costs of CHD are substantial. Over 17 million (30%) of all deaths in the world were secondary to CHD in 2008, accompanied by US$863 billion in costs by 2010 and a projected economic burden of 1 trillion by 2030. Likewise, CHD accounted for 29% of all deaths in Canada in 2008, costing the country approximately CAD$21 billion in annual healthcare expenditures.

Pulses, the edible seeds of members of the legume family, such as dry peas, chickpeas, edible beans, and lentils, are nutritionally diverse crops that have been part of the human diet for thousands of years. The Food and Agricultural Organization (FAO) of the United Nations defines pulses as "*Leguminosae* crops harvested exclusively for their grain, including dry beans, peas and lentils". This definition excludes legumes used for oil extraction, such as soybeans and peanuts, or those harvested green for food, such as green beans and green peas. Pulses are produced in many regions, although about 50% of global output is concentrated in 5 countries (India, Canada, Myanmar, China, and Nigeria) in order of output in 2010.

From the nutritional and health perspectives, pulse crops provide a natural food grade ingredient that is rich in dietary fiber, protein, antioxidants, minerals such as iron, zinc, magnesium, and phosphorous, as well as folate and other B-vitamins. As such, they are known to provide a variety of health benefits, including reductions in obesity, diabetes, and CHD rates, and are recommended for intake by food guides in many Western countries. Specific to Canada, the Canadian dietary guidelines encourage the consumption of dietary pulses at the level of 2-3 servings (one serving = ¾ cup or 175 ml of cooked legumes) per day for the adult populations. Still, similar to most Western countries, and although sources of dietary pulse are plentiful as both crops and food products in the marketplace, pulse consumption is far below the recommended level in Canada, with an average intake of 113 g per day in only 13% of the adult populations.

Given the established health benefits of pulses, increasing the population consumption to a healthy value can be considered a powerful tool for policymakers to manage scarce healthcare resources. The potential economic impact of increasing pulse consumption in Canadians' diets can be calculated by taking the proportion of the economic burden related to T2D and CHD that can be avoided by increasing consumptions in Canada. The process to establish this potential value requires an economic simulation involving three steps: i) assessment of a pulse-based food intake success rate; ii) estimation of the T2D and CHD reduction rate; and iii) calculation of the reduction in costs associated with T2D and CHD. Since these steps necessitate the use of some assumptions, supported to the greatest extent possible by scientific peer-reviewed literature, sensitivity surrounding these assumptions must also be investigated. In order to make the expected economic benefits as robust as possible, sensitivity to the efficacy is evaluated under varying assumptions, including worst case, pessimistic, optimistic, and best case scenarios. The end result of the simulation is a range of values that represent the potential economic benefit, expressed in annual cost savings that would accrue to the Canadian healthcare system and society as a result of reductions in prevalence of the two health conditions of interest, gained from increasing the level of dietary pulse in the Canadian population to the optimized consumptions.

Although a number of nutrient and non-nutrient components of pulses have been connected to reductions in risk factors of T2D and CHD worldwide, thus likely contributing to savings in direct and direct costs associated with chronic illnesses, data on the economic value of greater habitual or recommended pulse consumptions are lacking. In light of the readily available and affordable pulse crops, and pulse-based food products, within the Canadian marketplace, the primary objective of this project was to evaluate the potential economic benefits of increased pulse consumption in Canada, as systematically assessed through possible savings in annual costs associated with T2D and CHD incidence, separately. The secondary objective was to evaluate such possible cost savings specific to each province and territory. The following original research manuscript addresses these objectives in a peer-reviewed journal format.

Original Research

TITLE

ECONOMIC BENEFITS OF THE RECOMMENDED DIETARY PULSE CONSUMPTION IN CANADA: A COST-OF-ILLNESS EVALUATION OF TYPE 2 DIABETES AND CARDIOVASCULAR DISEASE POTENTIAL COST SAVINGS

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ABSTRACT

Worldwide, a tremendous social and economic burden accompanies today's dramatic rates of type 2 diabetes (T2D) and coronary heart disease (CHD). Knowledge of lifestyle risk and protective factors is essential in developing preventive strategies that tackle the health and socioeconomic impacts of these diet-related epidemics. Pulses, such as beans, peas, and lentils, are recommended for regular intakes by Canada's Food Guide, and have been associated with improvements in biomarkers of T2D and CHD. The socioeconomic value of pulse consumption has, however, not been investigated. This study aimed to systematically assess the recommended daily level of pulse intake in relation to potential annual healthcare and society cost savings in Canada subsequent to estimated reductions in T2D and CHD rates. Employing a cost-of-illness approach, including a sensitivity analysis of varying scenarios, the proportions of dietary pulse consumers in Canada were identified, the daily percent reduction in T2D and CHD with each serving of intake was determined, and the annual savings in direct and indirect costs were estimated. The recommended level (one serving or 130 g per day) of pulses consumption yielded annual economic savings in a worst case through best case scenarios equal to CAD$7.3 to $73.0 million for T2D costs and $20.9 to 208.6 million for CHD costs. Specific analyses by province/territory suggested total reductions in costs of the two health conditions of interest combined ranging from CAD$0.1-$0.7 million in Yukon to $14.0-$136.0 million in Ontario. This modeling exercise provides first evidence of the possible cost savings, for the Canadian healthcare system, and society, that could be re-assigned to other priority domains, such as education and infrastructure, following the recommended consumption of pulse crops. Findings are expected to deepen the policy authority and public awareness of the concept of healthy eating, and may increase the demand for natural and commercial pulse products in Canada.

Key words: pulses, legumes, peas, beans, lentils, type 2 diabetes, cardiovascular disease, healthcare cost savings, human health, nutrition economics

INTRODUCTION

The interplay between dietary behaviors and modifiable health outcomes is beyond debate, and has the potential to impact economic status at both individual and societal levels (Bibbins-Domingo et al. 2010; Dall et al. 2009; Gyles et al. 2010; McCarron and Heaney 2004; Schmier et al. 2014). Given the soaring costs of healthcare on society worldwide, especially in countries with publicly funded healthcare systems, such as Canada, the impact of healthy-style food choices on costs of chronic disorders is gaining considerable attention. Type 2 diabetes (T2D) and coronary heart disease (CHD) are at present leading dietary-related health concerns and, likewise, two major contributors to considerable economic burdens on healthcare and related resources around the world (World Health Organization 2014).

Empirical evidence suggests that increased consumption of dietary pulses, as part of a generally healthy lifestyle, can contribute to reductions in established risk factors for T2D and CHD, such as circulating cholesterol and glucose concentrations (Anderson and Major 2002). Pulses are the edible seeds of members of the *Leguminosae* family, and are defined by the Food and Agricultural Organization (FAO) of the United Nations as "*Leguminosae* crops harvested exclusively for their grain, including dry beans, peas and lentils" (FAO 1994). Pulse crops have long history in the human diet and are known as rich sources of protein, fibre, and antioxidants, as well as relatively low in carbohydrates and fat (Curran 2012). For this reason, dietary pulses are recommended by several health authorities for prevention of major chronic diseases (Health Canada 2007; Flock and Kris-Etherton 2011; Mann et al. 2004; World Health Organization 2003). Specific to the Canadian guidelines, Canada's Food Guide (CFG) (Health Canada (2007)) recommends 2-3 servings (one serving = ¾ cup or 175 ml of cooked legumes) per day for the adult population. However, although Canada is the second largest pulse producer in the world, consumption of pulses in the country is low, with only thirteen percent of consumers on any given day and an average intake level of 113 g (Mudryj et al. 2012). From the socio-demographic perspectives, further, the highest consumption rate is in the 51-71 year age brackets, with the Canadian-Asian population consuming pulses 3.6 times more than Caucasians.

The potential economic impact of pulses in Canadians' diets may be calculated by taking the proportion of the economic burden related to T2D and CHD that can be avoided by increasing pulse consumption in Canada over current levels of intake. No data on the economic value of greater habitual or recommended pulse consumption are currently available, however. The objective of this project was thus to evaluate the potential economic benefits of increased pulse consumption in Canada and regions thereof, as systematically assessed through possible savings in annual costs associated with T2D and CHD incidence, separately.

MATERIALS AND METHODS

Economic model design

A cost-of-illness model entailing three steps, the *dietary intake success rate (%)*, the *disease reduction rate (%)*, and the *disease cost saving ($)*, each involving a sensitivity analysis of best case, optimistic, pessimistic, and worst case scenarios, was utilized to systematically assess the economic benefits of the recommended (1 serving or about 130 g per day) pulse consumption in

Canada above current consumption levels. First, the proportions of prospective consumers likely to consume the recommended daily serving of pulse in Canada were estimated. Second, the daily percent reduction in T2D and CHD with each serving of pulse intake was determined. And, last, the annual healthcare and related cost savings in association with the reduction in each of the two health conditions of interest were monetized. Scientific and monetary data that formed the basis of estimates in the model were derived upon review of the present literature and recent healthcare cost figures from national databases. The analysis was applied to Canadian men and women ≥18 years of age (Statistics Canada). **Table 1** summarizes the input parameters of the model.

Step 1: ***The success rate***

The first step of this economic model established the current percentages of pulse consumers and consumption levels of pulses (i.e. beans, peas, and lentils) in Canada, as well as the proportions of prospective consumers who are likely to choose the recommended daily servings of pulse-based diets in the country. Although pulses are recommended as part of a healthy diet by government agencies in many Western countries, their consumption remains quite low. In 1999, the food supply of pulses represented 57%, 20%, 18%, and 6% of the world supply in Asia, the Americas, Africa, and Europe, respectively (Schneider 2002). Specific to North America, an average of only 7.9% to 13.1% of the populace has been estimated to consume pulses on any given day (Mitchell et al. 2009; Mudryj et al. 2012), with a median intake level of 0.2 servings daily in the United States (Guenther et al. 2006). In Canada, using cross-sectional data (n = 20,156) from the 2004 Canadian Community Health Survey, Cycle 2.2, Mudryj et al. (Mudryj et al. 2012), examined the prevalence of pulse consumption in adults (≥19 years old) and found that on any given day, only 13% of Canadians consume pulses, with mean intakes of 120 and 105 g per day for men and women, respectively. For that study, pulse consumers across ten Canadian provinces were divided into four groups based on their average level of consumption as follows: 13 g, 47 g, 99 g, and 294 g per day. Additionally, an online survey-based marketing research and 4 focus groups, with 1,100 Canadian households, was conducted in late 2009 by Ipsos Reid, an independent market research company (Ipsos Reid 2010), and revealed that about 60% of Canadians are considered "light" pulse consumers, consuming at least one type of pulse less than once a month to as much as three times per month. Another 20% of Canadians are considered "moderate to heavy" consumers, consuming at least one type of pulse per week. And, about 20% are considered "non-consumers" of pulses, meaning that during the past six months they have not consumed any type of pulse at home or a restaurant. The study (Ipsos Reid 2010) further identified 5 groups of consumers based on their attitude towards pulses, as well as food and health, including individuals who do not have exposure to pulse dishes frequently, but are aware of the health benefits (23%), individuals who consume pulses on a monthly basis, but need reminders for more frequent intakes (23%), individuals who are driven by health and taste of pulses, but do not know how to prepare pulse-based dishes (22%), individuals who consume pulses most frequently (20%), and individuals who do not consume pulses and are not interested in food or health benefits of pulse (12%).

Given these observations, in the current study, a sensitivity analysis of best case, optimistic, pessimistic, and worst case success rate scenarios was modeled to estimate the percent of the population expected to adopt a pulse-rich diet in Canada. The best case scenario assumed a 50%

to represent a long term shift in the dietary habits of Canadians. The optimistic scenario was assumed to be 25% to reflect a medium- to short-term estimate of economic savings possible through increased dietary pulse consumption. The pessimistic scenario was set at 15% to represent a less positive but more practical short- to medium-term estimate of savings. And, the worst case scenario was set at 5% to determine the impact on the cost estimates when assumptions are more pessimistic than normal.

Step 2: ***The disease of interest reduction rate***

The second step estimated the percent reduction in T2D and CHD incidence, separately, per daily servings of pulses. A number of epidemiological studies, randomized controlled trials, and meta-analyses have reported a protective impact of dietary pulse consumption on risk factors of chronic disease. Similar to Step 1 of this analysis, possible scenarios were established regarding reductions in the incidence of T2D and CHD with higher consumptions of pulse crops based on the current English-language medical and nutritional literature. After careful examination of the available literature, the model assumptions were generated based on two recent comprehensive systematic meta-analyses by Afshin et al. (Afshin et al. 2014) and Ha et al. (Ha et al. 2014). Inclusion criteria and quality assessment are included in the meta-analyses of choice. Under the context of this study and the studies reviewed, dietary pulse refers to beans, peas, chickpeas, and lentils.

Estimated effect of dietary pulse consumption on prevalence of type 2 diabetes

The inverse relationship between increased dietary pulse and T2D risk was estimated from a meta-analysis by Afshin et al. (Afshin et al. 2014) based on two prospective cohorts (Meyer et al. 2000; Villegas et al. 2008) that together included over 100,000 participants. There, the consumption of 4 weekly 100-g servings of legumes was associated with an average of 22% (RR = 0.78, 95% CI 0.50-1.24) lower risk of T2D, which translates into just over a 7% reduction per a serving of 130 g per day. This also agrees with observations from a 2009 meta-analysis by Sievenpiper et al. (Sievenpiper et al. 2009), which showed that in 41 randomized controlled long-term clinical trials pulses consumption at an average dosage of 150 g per day was associated with about 0.50% absolute reduction in glycosylated hemoglobin (HbA1c) concentrations. This translates into an 8.6% reduction in risk of T2D per a serving of 130 g per day, based on findings of the UK Prospective Diabetes Study (UKPDS 1998), which estimated that each 1% reduction in HbA1c associates with a 21% decrease in the risk of any endpoint or death related to diabetes.

Estimated effect of dietary pulse consumption on prevalence of coronary heart disease

Akin to the T2D component, data for the estimated CHD risk reduction with the recommended consumption of dietary pulses were derived from a systematic review and meta-analysis of randomized controlled trials (RCTs) by Ha et al. (Ha et al. 2014). There, the authors identified 26 RCTs, involving a total of 1,037 men and women, and demonstrated an average of −0.17 mmol/L (95% CI -0.25 to -0.09) lower LDL-C concentrations with a median dose of 130 g per day of dietary pulse versus control diets. This translates into a 5-6% lower risk of CHD based on previous meta-analyses on the cardiovascular benefits of cholesterol reduction (Cholesterol

Treatment Trialists' (CTT) Collaborators et al. 2012; Robinson et al. 2005). The data also complement findings of similar trends from previous studies (Anderson and Major 2002; Bazzano et al. 2011).

Based on the aforementioned data, our analysis assumed that for each gram increase in dietary pulse consumption, incidence of T2D and CHD would be conservatively decreased by 0.06 and 0.04%, respectively (**Table 1**). For the purpose of this model, it is assumed that the relative risk reduction of T2D and CHD per gram pulse consumption corresponds to a decrease in the population-wide incidence of T2D and CHD of the same magnitude.

Step 3: ***The potential annual cost savings***

The final step of this model forecasted the potential annual cost savings that would accrue to the Canadian healthcare system and society following improvements in rates of each of the two health conditions of interest. In Canada, costs of illnesses are generally broken down into direct and indirect categories. The former refers to hospital care, physician care, and drug expenditures, whereas the latter refers to the dollar value of lost production due to illness, injury, or premature death (i.e. morbidity and mortality).

Overview of costs associated with type 2 diabetes in Canada

The *Economic Burden of Illness in Canada (EBIC) 2005-2008* report (Public Health Agency of Canada 2014) recently provided a comprehensive overview of the cost of diabetes in Canada. The Statistics Canada Consumer Price Index (health and personal care sub-index) was used to inflate the 2008 estimate of CAD$2.3 billion to 2014 levels and yielded CAD$2.5 billion as the best estimated total direct and indirect economic costs of T2D (**Table 2).**

Estimated at CAD$1.3 billion in 2014 dollars, drugs constituted the largest direct costs of T2D, which includes the costs of prescribed and non-prescribed medications purchased in retail stores. Since many different medications are used to treat T2D, it is reasonable that a decrease in the overall incidence of the disease would subsequently lead to a decrease in T2D drug-related costs. Hospitalization costs of T2D, estimated at CAD$527.2 million in 2014 dollars, were calculated on the basis of bed occupation and aggregated by diagnostic category. Generally, hospital costs are largely the fixed costs related to operating and maintaining hospital facilities, as well as the salaries of the medical professionals and support staff. The more variable components of hospitalization include the cost of medications administered to the hospitalized patients, the cost of food and accommodation, and the cost of diagnostic procedures carried out in hospitals. A reduction in the incidence of T2D would be anticipated to lead to fewer hospitalizations resulting from this disorder and, as a consequence, reductions in variable costs. Finally, the physician costs were calculated based on fee-for-service billings submitted to provincial health insurance plans and are allocated on the basis of the primary diagnostic category. For example, if a patient visits a physician's office for a follow-up treatment after a first diagnosis of T2D, this cost would be attributed to the cost of T2D. The estimated cost of T2D-related visits to physicians was approximately CAD$521.4 million in 2014 dollars. It follows that a reduction in overall T2D levels will result in fewer doctor visits, which will reduce these costs. Total indirect costs for T2D were estimated at CAD$155.4 million in 2014 dollars, including $13.2 million for mortality

and $142.2 million for morbidity. In estimating the mortality costs of T2D, *EBIC 2005-2008* report utilized the friction cost approach, which assumes that sick and deceased workers can be replaced after a certain period of time known as the 'friction period'. Cost estimates of this method are normally lower than those derived from the classical human capital method. A reduction in the incidence of T2D is assumed to lead to decreases in both components of the indirect cost valuation.

Analysis of type 2 diabetes cost reduction

The reduction in the cost of T2D was assumed to be linear when a decline in T2D incidence is observed. The exception was for the variable costs related to hospitalization. As described earlier, fixed and variable costs exist in hospitalization. The former is incurred regardless of the prevalence of any disease, whereas the latter is largely affected by the number of admissions. A comprehensive breakdown of hospital care costs in Canada is, to our knowledge, not available. As a result, it was necessary to approximate the portion of hospital costs that are fixed and not affected from reduced incidence of T2D. Previous research has provided a breakdown of fixed and variable costs in American hospitals and found that hospital costs are approximately 84% fixed and 16% variable (Roberts et al. 1999). Thus, for the purpose of this research, it was assumed that a reduction in T2D would not result in reductions in fixed costs of hospitalization, but would facilitate a proportional reduction in the variable costs. This means that each 1% reduction in the incidence of T2D would be followed by a 0.16% reduction in hospital costs.

It is reasonable to assume that fewer individuals with T2D will require less medication for treatment. As such, a proportional reduction was assumed for drug costs. Similarly, given that the physician care costs are based on physician billings, which are in turn based on T2D patient visits to doctors' offices, a reduction in T2D was assumed to lead to a proportional reduction in T2D-related physician costs. Finally, as the number of cases with T2D decreases, costs associated with mortality and morbidity were assumed to follow in a proportional manner. A summary of the relationship between T2D incidence and associated costs is provided in **Table 3**.

Overview of coronary heart disease costs in Canada

The *EBIC 2005-2008* (Public Health Agency of Canada 2014) expense figures were, again, used as the foundation of the estimates of CHD in this analysis; with adjustments to 2014 dollars using the Statistics Canada Consumer Price Index similar to the T2D component. Inflating values from the most recent 2008 estimate of CAD$12.0 billion to 2014 dollars yielded a revised valuation of about CAD$13.0 billion as the best estimated economic cost of CHD in Canada. In the case of CHD, the direct costs as presented by the *EBIC 2005-2008* report include hospital care, drug, and physician visit, whereas the indirect costs include mortality and morbidity. These costs are explained further in the subsections below and summarized in **Table 4**.

The largest direct costs associated with CHD were the hospitalization costs, which were estimated at slightly more than CAD$5.4 billion in 2014 dollars. Again, these fixed costs associate with operating hospital facilities and the staff salaries, while the variable costs associate with drugs administered to the hospitalized patients, food, and diagnostic procedures. Similar to T2D estimates, only the variable costs are expected to decrease with fewer hospitalizations

resulting from reductions in the incidence of CHD. Prescribed drug costs of CHD were estimated at CAD$4.6 billion in 2014 dollars and, similar to the T2D estimates, are logically expected to decrease with better management of the disease. Finally, the physician care costs were CAD$2.5 billion in 2014 dollars and, similar to the drug costs, are expected to decrease with fewer physician visits when CHD rates decrease.

In estimating the CHD-related mortality costs of CAD$98.9 million in 2014 dollars, similar to the analysis for T2D by *EBIC 2005-2008*, these costs were derived using the friction cost approach. It is logical that a reduction in the incidence of CHD and the corresponding decrease in mortality will reduce this cost. Morbidity, or disability, costs arise when productivity is lost due to illness for a period of time. The estimated economic burden of morbidity resulting from CHD in the *EBIC 2005-2008* report was CAD$288.5 million in 2014 dollars. Akin to the mortality component, morbidly costs are expected to decrease with a reduction in the incidence of CHD.

Analysis of coronary heart disease cost reduction

Similar to the T2D cost reduction, our CHD cost reduction analysis assumed a proportional reduction in the variable hospitalization costs, drug costs, and physician costs (**Table 3**). Also similar to the T2D case, morbidity and mortality costs were assumed to have a directly proportional CHD-reduction to cost-reduction relationship. Basically, since the incidence of CHD will decrease, it is a reasonable assumption that a proportional reduction in the deaths and disability from CHD will be observed. As a consequence, the loss of human capital that would ordinarily be incurred from CHD-related death and disability does occur and this facilitates an economic benefit.

RESULTS

Tables 5 and **6** summarize the potential T2D and CHD economic cost savings when the current levels of pulse consumption (0 g per day for men and women) in the 87% of the non-consumers, in addition to the the current levels of consumption (120.1 g per day for men and 105.1 g for women) in the 13% of the pulse consumers in Canada (Mudryj et al. 2012) are increased to levels that correspond to Canada's Food Guide recommended intake (130 g per day) (Health Canada 2007). Under the best case scenario, assuming a 50% success rate and potential economic savings over the long run, our analysis predicted total annual healthcare and related savings of CAD$73.0 million for T2D and $208.6 million for CHD costs. The optimistic scenario, which assumed a 25% success rate and medium- to short-term savings, predicted savings of CAD$36.5 million for T2D and $104.3 million for CHD costs annually. With a 15% success rate and more practical short- to medium-term effects, the pessimistic scenario showed savings of CAD$21.9 million for T2D and $62.6 million for CHD costs. Finally, the worst case scenario of a 5% success rate suggested total annual savings of CAD$7.3 million for T2D and $20.9 million for CHD costs.

Tables 7 and **8** summarize the predicted economic savings in T2D and CHD total costs by province/territory following the recommended intakes of pulses. For T2D, the disease total savings in worst through best case scenarios ranged from CAD$10,000 to $100,000 in Yukon, to

CAD$2.9 to $28.7 million in Ontario (**Table 7**). Similarly, savings in CHD costs were estimated to range between CAD$100,000 and $500,000 in Yukon, and between CAD $10.7 and $107.2 million given worst through best case scenarios with increasing the current pulse consumption rates of Canadian adults to the recommended levels (**Table 8**).

DISCUSSION

Using a three-step cost-of-illness approach based on Canadian data, this nutrition economics research revealed opportunities for significant savings in T2D and CHD costs in Canada following recommended intakes of dietary pulses. Specifically, if 5% to 50% of the adult populations in Canada were to increase their daily servings of pulses, conservative reductions in T2D and CHD healthcare and related costs are predicted to reach anywhere between CAD$30 and $300 million annually.

Available scientific data from epidemiological and randomized controlled studies, as well as meta-analytic research, support the beneficial effect of dietary pulse consumption on established risk factors for T2D (Jenkins et al. 2012; Marinangeli, Kassis, Jones 2009; Marinangeli and Jones 2011; Marinangeli and Jones 2012; Schulze et al. 2004; Sievenpiper et al. 2009) and CHD (Bazzano et al. 2001; Bazzano et al. 2011; Jayalath et al. 2014; Winham, Hutchins, Johnston 2007). Based on this evidence, increasing intakes of pulse crops may result in lower costs associated with the incidence rates of these diet-related illnesses. To our knowledge, no studies to date have examined this relationship between greater intakes of dietary pulses and costs associated with T2D and CHD. The finding that significant economic benefits could result from simple changes in dietary practices is promising and underlines the need for strategies to improve the dietary behaviors of individuals through nutrition education and policy guidelines, supported by lines of acceptable pulse-based products by the food industry.

This work is the first to examine the potential savings in costs attributed to lower rates of T2D and CHD subsequent to the recommended consumptions of dietary pulses in Canada and its provinces/territories. Most recent literature and national databases were reviewed for identification of consumer trends and healthcare-related costs. Isolating the health benefits of dietary pulse consumptions, as reported in the literature, from other lifestyle factors remains a challenging limitation, however.

In conclusion, a substantial economic benefit for Canada is expected to accompany an improved health status with achievable levels of dietary pulse consumption. Given the extensive economic burden of the Canadian public healthcare system, which reached about 12% of GDP in 2012, any reductions in associated costs have important budgetary implications for society. The novel findings of this research are expected to aid in increasing consumer interest in pulse commodities that may result in creating new demands for commercial and natural pulse products in Canada.

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AUTHOR CONTRIBUTIONS

JC and PJ conceived the study question. MA designed the economic model, conducted the monetary analyses, and drafted the manuscript with assistance from CC. All authors contributed to the interpretation of data, critically reviewed the manuscript for important intellectual content, and approved the final version.

LIST OF ABBREVIATIONS

CIHI: Canadian Institute for Health Information; CHD: coronary heart disease; EBIC: Economic Burden of Illness in Canada; NHEX: National Health Expenditure Trends; T2D: type 2 diabetes.

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TABLES

Table 1. Summary of the input parameters for the cost saving assessment model.

Parameter	Men	Women	Source
Current pulse consumption, g per day [proportions of consumers (%)]	120.1 (13.1)	105.1 (13.2)	Mudryj et al. (Mudryj et al. 2012)
Target pulse consumption (1 serving), g per day	130		Health Canada (Health Canada 2007)
T2D reduction per 1 g per day pulse consumption, % [(reduction per serving (%)]	0.06 (7)		Afshin et al (Afshin et al. 2014)
CHD reduction per 1 g per day pulse consumption, % [(reduction per serving (%)]	0.04 (5)		Ha et al (Ha et al. 2014)

Abbreviations: CHD, coronary heart disease; T2D, type 2 diabetes.

Table 2. Summary of type 2 diabetes cost in Canada (CAD $million).

	2008*	2014†
Direct costs		
Hospital	492.7	527.2
Physician	487.3	521.4
Drugs	1,198.2	1,282.1
Total direct costs	**2,178.2**	**2,330.7**
Indirect costs		
Mortality	12.3	13.2
Morbidity	132.9	142.2
Total indirect costs	**145.2**	**155.4**
Total costs	**2,323.4**	**2,486.0**

* From the *Economic Burden of Illness 2005-2008* report (Public Health Agency of Canada 2014). † Current dollars based on adjustments of inflation rates according to Statistics Canada Consumer Price Index.

Table 3. Cost reductions corresponding to each 1% decrease in incidence of type 2 diabetes and coronary heart disease.

	% Reduction
Direct costs	
Hospital*	0.16
Drugs	1.00
Physician care	1.00
Indirect costs	
Mortality	1.00
Morbidity	1.00

* Based on the estimation that 16% of hospitalization costs are variable (i.e. medications and supplies) and 84% are fixed (i.e. salaries, buildings, and equipments) (Roberts et al. 1999).

Table 4. Summary of coronary heart disease cost in Canada (CAD $million).

	2008*	2014†
Direct costs		
Hospital	5,068.0	5,422.8
Drugs	4,272.7	4,571.8
Physician care	2,352.0	2,516.6
Total direct costs	**11,692.7**	**12,511.2**
Indirect costs		
Mortality	92.4	98.9
Morbidity	269.6	288.5
Total indirect costs	**362.0**	**387.3**
Total costs	**12,054.7**	**12,898.5**

* From the *Economic Burden of Illness 2005-2008* report (Public Health Agency of Canada 2014). † Current dollars based on adjustments of inflation rates according to Statistics Canada Consumer Price Index.

Table 5. Potential savings in type 2 diabetes costs among Canadian adults from the recommended dietary pulse consumption (CAD $million).

	Scenario			
	Best case	**Optimistic**	**Pessimistic**	**Worst case**
Direct cost savings				
Hospital	3.0	1.5	0.9	0.3
Physician	18.6	9.3	5.6	1.9
Drugs	45.8	22.9	13.8	4.6
Total direct cost savings	**67.5**	**33.7**	**20.2**	**6.7**
Indirect cost savings				
Mortality	0.5	0.2	0.1	0.0
Morbidity	5.1	2.5	1.5	0.5
Total indirect cost savings	**5.6**	**2.8**	**1.7**	**0.6**
Total cost savings	**73.0**	**36.5**	**21.9**	**7.3**

Data represent T2D-related conservative economic savings following dietary pulse consumption of levels that correspond to Health Canada's recommendations, estimated at 130 g per day for men and women (Health Canada 2007) (**Table 1**). The best case scenario is an estimate of potential savings when 50% of Canadian adults (≥18 years of age) consume the recommended amounts of dietary pulse (1 serving or 130 g) per day. The optimistic scenario is a medium- to short-term pragmatic estimate of potential savings when 25% of adults in Canada consume pulse regularly. The pessimistic scenario is a practical short- to medium-term estimate of cost savings that could follow the dietary pulse consumptions among 15% of adults. The worst case scenario is an estimate of the recommended dietary change among up to 5% of adults in the country.

Table 6. Potential savings in coronary heart disease costs among Canadian adults from the recommended dietary pulse consumption (CAD $million).

	Scenario			
	Best case	**Optimistic**	**Pessimistic**	**Worst case**
Direct cost savings				
Hospital	21.7	10.8	6.5	2.2
Drugs	114.3	57.1	34.3	11.4
Physician care	62.9	31.5	18.9	6.3
Total direct cost savings	**198.9**	**99.5**	**59.7**	**19.9**
Indirect cost savings				
Mortality	2.5	1.2	0.7	0.2
Morbidity	7.2	3.6	2.2	0.7
Total indirect cost savings	**9.7**	**4.8**	**2.9**	**1.0**
Total cost savings	**208.6**	**104.3**	**62.6**	**20.9**

Data represent CHD-related conservative economic savings following dietary pulse consumption of levels that correspond to Health Canada's recommendations, estimated at 130 g per day for men and women (Health Canada 2007) (**Table 1**). The best case scenario is an estimate of potential savings when 50% of Canadian adults (≥18 years of age) consume the recommended amounts of dietary pulse (1 serving or 130 g) per day. The optimistic scenario is a medium- to short-term pragmatic estimate of potential savings when 25% of adults in Canada consume pulse regularly. The pessimistic scenario is a practical short- to medium-term estimate of cost savings that could follow the dietary pulse consumptions among 15% of adults. The worst case scenario is an estimate of the recommended dietary change among up to 5% of adults in the country.

Table 7. Potential savings in type 2 diabetes total cost, by province/territory, from the recommended dietary pulse consumption (CAD $million).

	Scenario			
	Best case	**Optimistic**	**Pessimistic**	**Worst case**
*Total cost savings**				
Newfoundland and Labrador	1.3	0.7	0.4	0.1
Prince Edward Island	0.3	0.2	0.1	0.0
Nova Scotia	2.3	1.1	0.7	0.2
New Brunswick	1.7	0.9	0.5	0.2
Quebec	16.4	8.2	4.9	1.6
Ontario	28.7	14.4	8.6	2.9
Manitoba	3.0	1.5	0.9	0.3
Saskatchewan	2.6	1.3	0.8	0.3
Alberta	9.9	4.9	3.0	1.0
British Columbia	9.7	4.9	2.9	1.0
Yukon	0.1	0.1	0.0	0.0
Northwest Territories	0.2	0.1	0.1	0.0
Nunavut	0.2	0.1	0.1	0.0

The best case scenario is an estimate of potential savings when 50% of Canadian adults (≥18 years of age) consume the recommended amounts of dietary pulse (1 serving or 130 g) per day (Health Canada 2007). The optimistic scenario is a medium- to short-term pragmatic estimate of potential savings when 25% of adults in Canada consume pulse regularly. The pessimistic scenario is a practical short- to medium-term estimate of cost savings that could follow the dietary pulse consumptions among 15% of adults. The worst case scenario is an estimate of the recommended dietary change among up to 5% of adults in the country. * Province estimate for total health expenditure of all diseases combined obtained from the *National Health Expenditure Trends 1975-2014* report (forecast) (Canadian Institute for Health Information 2014). Percentage of total cost (direct + indirect) of 1.2% for diabetes mellitus from the *Economic Burden of Illness 2005-2008* report (Public Health Agency of Canada 2014) was used to estimate the cost of type 2 diabetes (T2D) of each province. Estimates of total cost savings were calculated based on input parameters of **Table 1** with the employment of a 0.83% disease cost reduction corresponding to each 1% decrease in incidence of T2D.

Table 8. Potential savings in coronary heart disease total cost, by province/territory, from the recommended dietary pulse consumption (CAD $million).

	Scenario			
	Best case	**Optimistic**	**Pessimistic**	**Worst case**
*Total cost savings**				
Newfoundland and Labrador	4.9	2.5	1.5	0.5
Prince Edward Island	1.2	0.6	0.4	0.1
Nova Scotia	8.5	4.2	2.5	0.8
New Brunswick	6.4	3.2	1.9	0.6
Quebec	61.2	30.6	18.4	6.1
Ontario	107.2	53.6	32.2	10.7
Manitoba	11.3	5.6	3.4	1.1
Saskatchewan	9.7	4.8	2.9	1.0
Alberta	36.9	18.5	11.1	3.7
British Columbia	36.3	18.1	10.9	3.6
Yukon	0.5	0.3	0.2	0.1
Northwest Territories	0.7	0.3	0.2	0.1
Nunavut	0.7	0.3	0.2	0.1

The best case scenario is an estimate of potential savings when 50% of Canadian adults (≥18 years of age) consume the recommended amounts of dietary pulse (1 serving or 130 g) per day (Health Canada 2007). The optimistic scenario is a medium- to short-term pragmatic estimate of potential savings when 25% of adults in Canada consume pulse regularly. The pessimistic scenario is a practical short- to medium-term estimate of cost savings that could follow the dietary pulse consumptions among 15% of adults. The worst case scenario is an estimate of the recommended dietary change among up to 5% of adults in the country. * Province estimate for total health expenditure of all diseases combined obtained from the *National Health Expenditure Trends 1975-2014* report (forecast) (Canadian Institute for Health Information 2014). Percentage of total cost (direct + indirect) of 6.4% for cardiovascular disease from the *Economic Burden of Illness 2005-2008* report (Public Health Agency of Canada 2014) was used to estimate the cost of coronary heart disease (CHD) of each province. Estimates of total cost savings were calculated based on input parameters of **Table 1** with the employment of a 0.83% disease cost reduction corresponding to each 1% decrease in incidence of CHD.