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QUANTITATIVE RESEARCH

The association between the cost and quality of diets of children in Canada

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Abstract

Objectives To examine the association between the cost and quality of diets of grade 5 children in Alberta, Canada.

Methods We used survey data of 2731 grade 5 students (10–11 years of age), collected between March and June 2014. This survey included the Harvard Youth Adolescent Food Frequency Questionnaire which captures information on intake of 147 food items. On the basis of these food items, we calculated the diet quality, using the Diet Quality Index-International (DQI) and Canada's Food Guide, and costs by accessing prices from four Canadian grocery retailers. We applied linear regression to determine the association of diet quality with costs.

Results We estimated the cost of a child's diet to be CAD $13.19 per day. For the 12% of children with a low diet quality, these costs were $12.12 and for the 66% of children with moderate and 22% with high diet quality, these costs were $13.27 and $13.51, respectively. For every one-unit increase in DQI, the cost of the diet increased by seven cents per day. Diets that met the recommendations for vegetables and fruit and for meat and alternatives were respectively 53 cents and $1.39 higher relative to diets not meeting these recommendations. Costs for unessential food items constituted $1.39 per day.

Conclusion We observed a gradient whereby diets of better quality are costlier. For low-income households, this may lead to a genuine barrier to healthy eating. Initiatives that target unhealthy unessential foods may create the financial space for households to purchase pricier healthier options. Such initiatives may also alleviate future health care costs.

Résumé

Objectifs Examiner les associations entre le coût et la qualité du régime alimentaire d'élèves de 5e année en Alberta, au Canada.

Méthode Nous avons utilisé des données d'enquête sur 2 731 élèves de 5e année (10-11 ans) recueillies entre mars et juin 2014. L'enquête comportait le questionnaire de Harvard sur la fréquence de consommation des produits alimentaires des jeunes adolescents, qui saisit des informations sur la consommation de 147 produits alimentaires. En fonction de ces produits, nous avons calculé la qualité du régime à l'aide de l'indice Diet Quality Index-International (DQI) et du Guide alimentaire canadien, et le coût du régime en obtenant les prix des aliments auprès de quatre détaillants alimentaires canadiens. Nous avons procédé par régression linéaire pour déterminer l'association entre la qualité du régime et son coût.

Résultats Nous avons estimé le coût du régime d'un enfant à 13,19 $ CAN par jour. Pour les 12 % d'enfants dont la qualité du régime était faible, ce coût était de 12,12 $, et pour les 66 % d'enfants dont la qualité du régime était modérée et les 22 % dont la qualité du régime était élevée, il était de 13,27 $ et de 13,51 $, respectivement. Pour chaque augmentation d'une unité de l'indice DQI, le coût du régime augmentait de 7 ¢ par jour. Les régimes qui respectaient les recommandations d'apport en légumes et fruits et en viandes et substituts coûtaient respectivement 53 ¢ et 1,39 $ de plus que les régimes ne respectant pas ces recommandations. Le coût des produits alimentaires non essentiels représentait 1,39 $ par jour.

Conclusion Nous avons observé un gradient, à savoir que les régimes de meilleure qualité coûtent plus cher. Pour les ménages à faible revenu, cela peut constituer un véritable obstacle à une saine alimentation. Des initiatives ciblant les aliments non essentiels malsains pourraient créer l'espace financier suffisant pour que ces ménages achètent des aliments plus chers, mais plus sains. De telles initiatives pourraient aussi réduire les coûts futurs en soins de santé.

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Keywords Food prices · Diet quality · Social determinants of health · Food Insecurity · Canada's Food Guide · Public health · Children · Nutrition · Health economics

Mots-clés Prix des aliments · Qualité du régime alimentaire · Déterminants sociaux de la santé · Insécurité alimentaire · Guide alimentaire canadien · Santé publique · Enfants · Nutrition · Économie de la santé

Introduction

Since the late 1970s, the prevalence of overweight and obesity has been rising among children and adolescents in Canada (Roberts et al. 2012). The 2016 report from the Standing Senate Committee on Social Affairs, Science and Technology indicated that 20% of children were overweight and 13% were obese (Ogilvie et al. 2016). For the Canadian province of Alberta, the 2004 prevalence of overweight and obese children and youth was 14.3% and 7.5%, respectively (Moffatt and Coupland 2005). By 2014, the prevalence of overweight and obesity combined had increased to 36.0% (Maximova et al. 2016). Excess body weight in childhood has been linked to poor emotional health, diminished social well-being, and lower health-related quality of life. In addition, excess body weight in childhood generally tracks into adulthood, increasing the risk for various chronic diseases (Roberts et al. 2012). Primary prevention of excess body weight in childhood, such as through the promotion of healthy eating, is therefore a public health priority to Canada (Ogilvie et al. 2016).

Higher costs of healthful food items are considered a barrier to healthy eating and good health (Maillot et al. 2007). This has been reported in the research fields of economics (Drewnowski and Darmon 2005), marketing (Lennernäs et al. 1997), and consumer behaviour and health promotion (Cabanac 1995). In this research, varying descriptors of healthfulness have been used, ranging from definitions based on single nutrients (e.g., amount of iron, vitamins, fat, or sugar) to whole diet indicators (Rao et al. 2013), including the Healthy Eating Index (Beydoun et al. 2015; Ryden and Hagfors 2011; Schröder et al. 2006), the Diet Quality Index (Caivano 2013), the Mean Adequacy Ratio (Kumcu and Kaufman 2011), and adherence to the Mediterranean diet (Schröder et al. 2006; Drewnowski and Eichelsdoerfer 2009). Whereas several studies have shown that healthier diets are more costly (Darmon et al. 2004; Bernstein et al. 2010), others have failed to confirm this finding (Goulet et al. 2008; Mitchell et al. 2000). In the absence of good estimates for the association between the cost and quality of children's diets in the Canadian context, we examined this association in a large population-based sample of Canadian children to provide public health decision makers and practitioners with actionable information to direct promotion of healthy eating among Canadian children.

Methods

Participants and recruitment

For the current study, we used data that were collected as part of the 2014 REALKids Alberta survey. The sampling frame of this survey includes elementary schools in Alberta that have grade 5 students and used a one-stage stratified design with balanced sampling of schools in metropolitan areas, city, and rural-town regions. For the 2014 survey, 143 schools agreed to participate. These had been surveyed between March 2014 and June 2014. A total of 4992 parent surveys and parent consent forms were given to fifth graders to take home and give to their parents. Of the total of 3284 consent forms that were returned, 2958 showed parents' consent for their child to participate in the survey. The parents survey included questions on the socio-economic situation at home (household income, parental educational attainment, and food security information). After excluding students who were absent from school on the day of data collection and excluding those students who provided incomplete information on dietary intake, responses of a total of 2866 students could be considered for the current analyses (57% response and completion rate). The students were surveyed on various topics, such as physical activity and screen-time, and had their height, weight, and arm span measured. The survey instruments can be found on the REAL Kids Alberta project website: http://www.realkidsalberta.ca.

Dietary intake

The students also completed the Harvard Youth Adolescent Food Frequency Questionnaire (FFQ) that has 147 food items organized into seven categories (beverages, dairy products, main dishes, miscellaneous foods, breads and cereals, fruit and vegetables, and snacks and desserts). Children were asked to indicate their usual intake of each food using five frequency options ranging from "never/less than once per month" to "five or more times per week" or "one or more times per day." We used portion sizes information from Canada's Food Guide (the version that was in effect at the time of data collection) and nutrient information from the 2007 Canadian Nutrient File database (Government of Canada. Canadian nutrient file 2007). The responses to the FFQ with the portion size and nutrient information enabled us to calculate the average daily

intake for each student. In total, 2851 children completed the FFQ, and among these, 120 respondents reported daily energy intakes either below 500 kcal/day or above 5000 kcal/day (Chu et al. 2013). As per established recommendations for the analyses of FFQ data, we excluded these respondents, leaving a final sample of 2731 children.

Dietary quality

We used the Diet Quality Index-International (DQI) as a measure of diet quality. It is a measure of healthfulness of a diet based on four components: variety, adequacy, moderation, and overall balance (Kim et al. 2003). Dietary variety (subscore 0 to 20) captures diversity in food choices and protein sources, such as meat, poultry, fish, dairy, beans, and eggs. Dietary adequacy (subscore 0 to 40) captures the adequate intake of food groups and nutrients, such as vegetables, grains, fibres, proteins, Fe (iron), Ca (calcium), and vitamin C. Dietary moderation (subscore 0 to 30) evaluates foods that are a risk for chronic diseases, such as foods with fat, cholesterol, and sodium. Last, overall balance (subscore 0 to 10) captures the proportion of energy from carbohydrates, protein, and fat, as well as the fatty acid composition. The DQI has been broadly applied in the Canadian context. More details can be found elsewhere (Kim et al. 2003). The four subscores are summed, resulting in the overall DQI score that ranges from 0 to 100 (Kim et al. 2003). Values < 50 are considered to represent poor diet quality, and values between 50 and 70 and above 70 are considered to represent moderate and high diet quality, respectively (Ryden and Hagfors 2011; Caivano 2013).

The DQI has been previously used as a measure of diet quality for children in Canada (Veugelers et al. 2005), the United States (Kim et al. 2003), China (Kim et al. 2003), and Korea (Kim and Bae 2010). The DQI has been widely used because it incorporates both nutrient and food perspectives of the diet in the assessment score, which provides a means to describe the diversity of consumption that also allows comparisons of diet quality across countries (Kim et al. 2003). Caivano et al. (2013) added that the index includes moderation components intended to characterize foods that may represent a risk when consumed in excess, and adequacy components that include sources of essential nutrients and bioactive compounds to help individuals meet their nutritional requirements (Caivano 2013).

Canada's Food Guide

As a resource for people over the age of 2 years, the version of Canada's Food Guide (CFG) that was in effect at the time of data collection provides recommendations to meet nutritional needs and to prevent obesity and chronic diseases. These recommendations focus on four groups: vegetables and fruit, grain products, milk and alternatives, and meat and alternatives. It recommends the number of servings from each of these food groups per day and is specific to life stage and sex. We grouped respondents according to whether they met the food group recommendations or not and estimated the cost of a diet for these groups.

Retail food price determination

To calculate the costs of the diet, we collected regular prices for each of the 147 food items included in the FFQ from four major grocery retailers in Alberta (Real Canadian Superstore, Wal-Mart, Sobeys, and Save-On-Foods). These four retailers are accessible in most parts of Alberta. All prices were collected in December 2016 using the stores' websites or, if not available online, by visiting the grocery store retailer in the Edmonton, Alberta area. The costs of the diet were estimated based on the assumption that all foods consumed by the students were purchased from a grocery store. For food items where both brand name and generic options were available, prices for both types were collected and the average was used as the final price. For food items where stores had availability of more than one brand name and/or generic options, the lowest cost option from each category (brand or generic) was chosen. Main dishes such as burritos, lasagna, pizza, chicken nuggets, fish sticks, meat balls, and eggrolls were priced based on frozen pre-prepared foods. For all sandwiches and burgers, we assumed that white bread was used and fill-ins were portion sizes either from the CFG or Canada Nutrient File. Package sizes (e.g., 1 L of juice) are available through the Consumer Price Index (CPI) survey (Statistics Canada 2016). The CPI uses the basket of goods approach that aims to compare a consistent base of products from year to year. For those package sizes not available through the CPI, we accessed the Ontario Nutritious Food Basket (NFB) (Ministry of Health Promotion 2010). The Ontario NFB contains a variety of foods with specified package sizes. Where information was not available in either of these resources, we used professional judgement. The cost of Goods and Services Tax (GST) (5%) was also added for some foods, such as soft drinks, snacks, and desserts (e.g., popsicles, muffins, potato chips) and frozen pre-prepared main dishes (e.g., chicken nuggets, hot dogs), as per the GST/HST Memoranda Series Guidelines (Government of Canada 2017). All cost calculations also considered food refuse, which applies to foods such as vegetables, fruit, and meat. The Canadian Nutrient File indicates quantities of food that are ready to eat; therefore, for those foods that contain refuse during purchase, the portion sizes were recalculated to reflect the amount of food purchased (Government of Canada. Canadian nutrient file 2007).

We calculated the price of a portion of each food in the FFQ by taking the price of the package multiplied by the food portion size either from CFG or the Canada Nutrient File and subsequently divided this value by the package size.

The daily dietary costs were standardized for a 2000 kcal diet in order to capture diet quality rather than diet quantity (Ryden and Hagfors 2011) and to minimize the influence of systematic under- and overreporting (Livingstone and Black 2003), which is a well-documented phenomenon for FFQs (Willett 2000). The cost per 2000 kcal was calculated by dividing the daily cost by the estimated daily energy intake in kcal and multiplying this by 2000 kcal.

We calculated the average daily cost for each food category in the FFQ for every participating child. For example, we calculated the daily cost of vegetables and fruit by adding together the daily cost of each food in the vegetables and fruit category for each child.

Statistical analysis

We examined differences in costs of the diet across categories of diet quality, either based on the DQI or the CFG food group recommendations, using the chi-square test, *t* test, and one-way ANOVA. We applied univariate and multivariable linear regressions to quantify the relationships between cost of the diet and DQI. In the multivariable analyses, we adjusted for the confounding potential of gender, household income, food security, parental education, energy intake, urbanization status, and body weight status. *P* values below 0.05 were considered to be statistically significant and all costs are in Canadian dollars (CAD) using 2016 values. All statistical analyses were performed using Stata IC version 14 (StataCorp, College Station, TX, USA). The Health Research Ethics Board of the University of Alberta had approved the REAL Kids Alberta data collection and consent procedures, as well as the current study.

Results

The population characteristics by diet quality are presented in Table 1. Moderate diet quality was most commonly observed in this population (66%) followed by high diet quality (22%) and low diet quality (12%). Children from food insecure households were more likely to consume low-quality diets.

Table 2 shows that the cost of a child's diet was on average CAD $13.19 per day. These costs were $12.12 (SD 3.5), $13.27 (SD 3.0), and $13.51 (SD 2.9) for children with poor, moderate, and high diet quality, respectively. These differences in costs by diet quality were statistically significant ($p < 0.001$). Costs for main dishes were the main contributor to the costs, followed by costs for dairy products and vegetables and fruit (Table 2). The contribution of costs for vegetables and fruit was higher among children reporting a high diet quality compared with those reporting a low diet quality ($p < 0.001$). Table 2 further shows that the costs of the diets of children who met the recommendations for grain products were 42 cents less ($12.84–$13.26) compared with those who did not meet these recommendations ($p < 0.05$). In contrast, the diets of children who met the recommendations for vegetables and fruit and for meat and alternatives ($p < 0.001$) were more expensive relative to the diets of those who did not meet the recommendations (53 cents more for meeting the recommendations for vegetables and fruit, and $1.39 more for meat and alternatives). The costs of unessential foods constituted $1.39 per day for the entire sample; this value was higher ($1.51) in the subgroup of children with low diet quality (Table 2). The costs of diets of children who did not meet any recommendations were less than those who met one or more recommendations ($p < 0.05$).

Table 3 shows that for every one unit increase in DQI, the cost of the diet increases by seven cents (first column, beta coefficient = 0.07; $p < 0.001$). When the analysis was adjusted for demographic and socio-economic factors, this relationship did not change (Table 3, second column, beta coefficient = 0.07; $p < 0.001$). Higher parental income was associated with higher costs of diet, but no other demographic and socio-economic factors contributed to the costs in a statistically significant manner (Table 3).

Discussion

In the current study, we showed that healthier diets come with a price: We estimated that the cost of a diet of high quality was CAD $1.39 ($13.51–$12.12) higher than that of a diet of low quality. Though seemingly modest, for a household with 2 children, this daily difference would accumulate to approximately $83 per month and $1014 per year. These higher costs may constitute a substantive barrier for socio-economically disadvantaged subgroups in choosing a healthy diet (Rao et al. 2013); however, these higher costs seem trivial compared with health care costs for treatment and management of diseases attributable to poor nutrition. The latter were estimated to be $13.8 billion per year for Canada (Lieffers et al. 2018) and $2556 for every Canadian with obesity (Krueger et al. 2015). This illustrates that investments in diets of high quality substantially reduce health care costs.

Consistent with other reports (Darmon and Drewnowski 2015; Andrieu et al. 2006; Garriguet 2007), we observed that most Canadian children do not meet Canada Food Guide recommendations. We estimated that 26% of children met the recommendations for vegetables and fruit, 66% the recommendations for meat and alternatives, and only 8% met recommendations for all 4 food groups. We also showed that diets of those who met these food group recommendations are more expensive: Diets of those children who met recommendations for vegetables and fruit were 53 cents per day higher, and diets of those who met the recommendations for meat and alternatives were $1.39 higher. We estimated the costs for unessential food items like sugar-sweetened

Table 1 Population characteristics by diet quality of grade 5 students in Alberta, Canada

	All participants	Low diet quality	Moderate diet quality	High diet quality
	2731	325 (12%)	1792 (66%)	614 (22%)
Sex, *n* (%)				
Girls	1458 (53%)	172 (12%)	938 (64%)	348 (24%)
Boys	1273 (47%)	153 (12%)	854 (67%)	266 (20%)
Parental income, *n* (%)				
≤ $50,000	326 (19%)	46 (14%)	211 (65%)	69 (21%)
$50,001–$75,000	237 (14%)	23 (9%)	159 (67%)	55 (23%)
$75,001–$100,000	302 (18%)	32 (11%)	207 (69%)	63 (21%)
≥ $100,001	838 (49%)	88 (11%)	567 (68%)	183 (22%)
Parental education, *n* (%)				
High school or less	676 (26%)	80 (12%)	438 (65%)	158 (23%)
Community/technical college	963 (37%)	117 (12%)	648 (67%)	198 (21%)
University degree	949 (37%)	107 (11%)	618 (65%)	224 (24%)
Food security, *n* (%)				
Worry that food would run out before getting money to buy more				
Yes	265 (10%)	40 (15%)	161 (61%)	64 (24%)
No	2270 (90%)	260 (11%)	1515 (67%)	495 (22%)
The food bought did not last and no money to buy more				
Yes	159 (6%)	23 (14%)	100 (63%)	36 (23%)
No	2364 (94%)	272 (12%)	1566 (66%)	526 (22%)
Urbanization status, *n* (%)				
Metropolitan	839 (31%)	94 (11%)	537 (64%)	208 (25%)
Rural or town	1387 (51%)	160 (12%)	938 (68%)	289 (21%)
City	505 (18%)	71 (14%)	317 (63%)	117 (23%)
Body weight status, *n* (%)				
Normal	2449 (65%)	296 (12%)	1601 (65%)	552 (23%)
Overweight	163 (27%)	20 (12%)	113 (69%)	30 (18%)
Obese	119 (8%)	9 (8%)	78 (66%)	32 (27%)

beverages and snacks at $1.39 per day. This amount is in the same ballpark as the abovementioned cost differences of diets that do meet versus diets that do not meet recommendations for vegetables and fruit and for meat and alternatives. Therefore, there is a double win to effective health promotion initiatives that achieve reductions in the consumption of these unessential food items: (1) a reduction in the consumption of these unessential food items that are mostly of low diet quality will improve the overall diet quality and (2) a reduction in the purchasing of these unessential food items will create the financial space to pay for the higher costs of diets that meet the recommendations for vegetables and fruit and/or for meat and alternatives.

The group that is likely to be affected by higher dietary costs when opting for healthier diets is the low socio-economic status (SES) groups. However, in our study, we cannot make such a conclusion; children whose parents earned $75,000 and less consumed less expensive diets but not all families in this broad income range should be characterized as low-income earners. Other studies have found that people with low income spend less on food (Inglis et al. 2009) and have less healthy food purchasing behaviour (Turrell et al. 2009), indicating the likelihood of lower actual dietary costs with lower income. However, Waterlander and colleagues found no difference in dietary costs among adults of varying income levels (Waterlander et al. 2010).

Our observation that healthier diets are more expensive is consistent with those of various other studies (Waterlander et al. 2010; Drewnowski et al. 2004) though not all (Drewnowski and Eichelsdoerfer 2009), despite the fact that these studies vary with respect to dietary assessment methods and criteria for diet quality. Some of these studies had price differences expressed per unit of energy (calories). Rao et al. (2013) argued that when expressed per calorie, price differences are less meaningful because healthy food items such as fruit and vegetables tend to have a low energy density (Rao et al. 2013). In the current study, we avoided expressing price differences per calorie. As dietary assessment method, we had

Table 2 Costs of the diet and its components of grade 5 students in Alberta by categories of diet quality

	All participants	Average cost	Low diet quality	Moderate diet quality	High diet quality
Daily cost, mean (SD)**	2731	13.19 (3.0)	12.12 (3.5)	13.27 (3.0)	13.51 (2.9)
FFQ food categories					
Unessential foods (snack foods/desserts, pop, iced tea, and fruit punch); mean (SD)**	2503	1.39 (0.7)	1.51 (0.86)	1.42 (0.67)	1.26 (0.58)
Vegetables and fruits; mean (SD)**	2496	1.91 (1.1)	1.20 (0.84)	1.77 (0.97)	2.71 (1.23)
Breads and cereals; mean (SD)**	2585	0.51 (0.3)	0.43 (0.24)	0.50 (0.25)	0.59 (1.0)
Dairy products; mean (SD)**	2656	2.62 (1.7)	2.99 (2.4)	2.72 (1.6)	2.32 (1.4)
Main dishes; mean (SD) **	2413	6.76 (2.8)	6.11 (3.1)	6.93 (2.6)	6.65 (2.6)
Adherence to Canada's Food Guide recommendations	***n* (%)**	**Average cost (SD)**			
Vegetables and fruit**					
Yes	711 (26%)	13.58 (2.9)			
No	2020 (74%)	13.05 (3.1)			
Grain products*					
Yes	494 (18%)	12.84 (2.5)			
No	2237(82%)	13.26 (3.2)			
Milk and alternatives					
Yes	1217 (45%)	13.20 (2.7)			
No	1514 (55%)	13.18 (3.3)			
Meat and alternatives**					
Yes	1806 (66%)	13.84 (2.9)			
No	925 (34%)	11.91 (3.0)			
Number of Canada Food Guide food groups met					
0*	534 (20%)	11.91 (3.0)			
1	968 (35%)	13.35 (3.3)			
2	643 (23%)	13.82 (2.9)			
3	370 (14%)	13.51 (2.7)			
4	216 (8%)	13.15 (2.2)			

All costs are in 2016 Canadian dollars. *FFQ*, Food Frequency Questionnaire

*$p < 0.05$, **$p < 0.001$: statistical differences in costs by diet quality (using the chi-square test) and by meeting the CFG recommendations (using the *t* test)

used a food frequency questionnaire, a method that is known to be inaccurate in assessing energy intake. This would have added to the concern by Rao et al. (2013). However, as per established recommendations for the analyses of food frequency questionnaire data, we adjusted for energy intake (Willett 2000). This adjustment, to a large extent, accommodates inaccuracies in energy assessment and allowed us to better capture diet quality rather than diet quantity. Repeating our analyses without this adjustment (data not shown) though did reveal similar risk estimates as the one presented.

Although several studies concluded that healthier diets cost more, the price is not the only factor and some would argue not the primary factor that determines our food choices (Glanz et al. 1998; French et al. 1999). Glanz et al. compared taste, nutritional quality, cost, convenience, and weight management and concluded that taste was the primary consideration when choosing food items, followed by cost, nutritional quality, convenience, and weight management (Glanz et al. 1998). These latter four factors may also be important in determining food choice as long as food is considered tasty (Glanz et al. 1998). However, low-income families may still put price first (Ryden and Hagfors 2011). A study by French et al. also showed that snack taste was the most important factor for snack choice among adolescents and adults, followed by price (French et al. 1999).

The current study, to our knowledge, represents the most comprehensive assessment of the association between price and diet quality in Canadian children. Limitations to our study are noted. The prices were collected in December, which may not be representative of prices during other seasons, particularly with respect to perishable foods. Likewise, all food prices were obtained from grocery stores, online, and in the Edmonton area, which are not representative of grocery prices

Table 3 Association of the diet quality index and demographic and socio-economic factors with the cost of the diet of grade 5 students in Alberta

	Univariable model		Multivariable model	
	β coefficient	95% CI	β coefficient	95% CI
DQI	0.07**	0.05–0.08	0.07**	0.05–0.09
Gender				
Girls	Ref		Ref	
Boys	− 0.30*	− 0.53 to − 0.07	− 0.15	− 0.44–0.14
Parental income				
≤ $50,000	Ref		Ref	
$50,001–$75,000	− 0.03	− 0.54–0.48	− 0.02	− 0.56–0.51
$75,001–$100,000	0.55*	0.08–1.03	0.52*	0.00–1.03
≥ $100,001	0.73**	0.34–1.12	0.65*	0.19–1.10
Food security				
Worry that food would run out before getting money to buy more				
Yes	Ref		Ref	
No	0.56*	0.17–0.94	0.64	− 0.05–1.33
The food bought did not last and no money to buy more				
Yes	Ref		Ref	
No	0.28	− 0.21–0.77	− 0.57	− 1.40–0.26
Parental education				
High school or less	Ref		Ref	
Community/technical college	0.29	− 0.00–0.60	0.07	− 0.32–0.46
University degree	0.41*	0.11–0.72	0.01	− 0.40–0.41
Urbanization status				
Metropolitan	Ref		Ref	
Rural or town	0.22	− 0.03–0.49	0.1	− 0.25–0.44
City	0.58**	0.24–0.91	0.25	− 0.17–0.68
Body weight status				
Normal	Ref		Ref	
Overweight	0.29	− 0.20–0.77	0.6	− 0.15–1.22
Obese	− 0.13	− 0.69–0.43	− 0.6	− 1.28–0.1

DQI, Diet Quality Index; all costs are in 2016 Canadian dollars. The multivariable model was adjusted for all variables listed in the table and for calorie intake
*$p < 0.05$, **$p < 0.001$

elsewhere in the country, particularly in Northern regions. By working with grocery prices, we assumed that the households included in the current study are effective in finding low prices and do not choose the often higher prices for the similar products offered in corner stores, vending machines, and sit-down and fast food restaurants. Also, our assumption that foods and beverages were purchased at a grocery store does not account for situations where foods and beverages were obtained from food service and school settings. We also assumed that all mixed dishes (e.g., pizza) were frozen prepared foods, which may not have been the case. In addition, assumptions about portion size consumed and package size purchased had to be made. Other limitations of the current study relate to the use of the food frequency questionnaire. Though food frequency questionnaires are the superior method to assess "usual intake" and though the Harvard Youth Adolescent Food Frequency Questionnaire is widely used and validated for use among US adolescents (Rockett et al. 1995; Rockett et al. 1997), we acknowledge limitations in the accuracy in estimating energy intake (as discussed above) and the potential for bias. For example, children with obesity are reportedly more likely to under-report intake relative to their normal-weight peers (Livingstone and Black 2003). Given these limitations, we caution the interpretation of these study findings and recommend more research into the association between cost and diet quality.

Conclusion

We observed a gradient whereby diets of better quality are costlier. For low-income households, the additional cost may represent a genuine barrier to healthy eating. Policies and programs to assist these households in choosing healthier foods

should be a priority. Health promotion initiatives that target the consumption of unhealthy unessential food may be particularly effective as these also create the financial space for households to pay for the higher costs of diets recommended by Canada's Food Guide. Such initiatives, when effective, will also alleviate future health care costs for the treatment and management of chronic diseases attributable to diets of poor quality.

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Compliance with ethical standards

The Health Research Ethics Board of the University of Alberta had approved the REAL Kids Alberta data collection and consent procedures, as well as the current study.

Conflict of interest The authors declare that they have no conflict of interest.

Disclaimer All interpretations and opinions in the current study are those of the authors.

References

Andrieu, E., Darmon, N., & Drewnowski, A. (2006). Low-cost diets: more energy, fewer nutrients. *European Journal of Clinical Nutrition, 60*(3), 434–436.

Bernstein, A. M., Bloom, D. E., Rosner, B. A., Franz, M., & Willett, W. C. (2010). Relation of food cost to healthfulness of diet among US women. *American Journal of Clinical Nutrition, 92*(5), 1197–1203.

Beydoun, M. A., Fanelli-Kuczmarski, M. T., Allen, A., Beydoun, H. A., Popkin, B. M., Evans, M. K., et al. (2015). Monetary value of diet is associated with dietary quality and nutrient adequacy among urban adults, differentially by sex, race and poverty status. *PLoS ONE, 10*(11), e0140905.

Cabanac, M. (1995). Palatability vs. money: experimental study of a conflict of motivations. *Appetite, 25*(1), 43–49.

Caivano, S. (2013). Semramis Martins lvares Domene. *Diet quality index for healthy food choices. Revista de Nutrio, 6*, 693–699.

Chu, Y. L., Farmer, A., Fung, C., Kuhle, S., & Veugelers, P. (2013). Fruit and vegetable preferences and intake among children in Alberta. *Canadian Journal of Dietic Practice and Research: A Publication of Dietitians of Canada = Revue Canadienne De La Pratique Et De La Recherche En Dietetique: Une Publication Des Dietetistes Du Canada, 74*(1), 21–27.

Darmon, N., & Drewnowski, A. (2015). Contribution of food prices and diet cost to socioeconomic disparities in diet quality and health: a systematic review and analysis. *Nutrition Review, 73*(10), 643–660.

Darmon, N., Briend, A., & Drewnowski, A. (2004). Energy-dense diets are associated with lower diet costs: a community study of French adults. *Public Health Nutrition, 7*(1), 21–27.

Drewnowski, A., & Darmon, N. (2005). Food choices and diet costs: an economic analysis. *The Journal of nutrition, 135*(4), 900–904.

Drewnowski, A., & Eichelsdoerfer, P. (2009). The Mediterranean diet: does it have to cost more? *Public Health Nutrition, 12*(9A), 1621–1628.

Drewnowski, A., Darmon, N., & Briend, A. (2004). Replacing fats and sweets with vegetables and fruits–a question of cost. *American Journal of Public Health, 94*(9), 1555–1559.

French, S. A., Story, M., Hannan, P., Breitlow, K. K., Jeffery, R. W., Baxter, J. S., et al. (1999). Cognitive and demographic correlates of low-fat vending snack choices among adolescents and adults. *Journal of the American Dietetic Association, 99*(4), 471–474.

Garriguet, D. Canadians' eating habits. Health reports 2007 18(2), 17. Available at http://www.ncbi.nlm.nih.gov/pubmed/17578013 (Accessed February 11, 2017).

Glanz, K., Basil, M., Maibach, E., Goldberg, J., & Snyder, D. (1998). Why Americans eat what they do: taste, nutrition, cost, convenience, and weight control concerns as influences on food consumption. *Journal of the American Dietetic Association, 98*(10), 1118–1126.

Goulet, J., Lamarche, B., & Lemieux, S. (2008). A nutritional intervention promoting a Mediterranean food pattern does not affect total daily dietary cost in North American women in free-living conditions. *The Journal of nutrition, 138*(1), 54.

Government of Canada. Charge the GST/HST, 2016. Available at https://www.canada.ca/en/services/taxes/gsthst.html (Accessed January 3, 2017).

Government of Canada. Canadian nutrient file, (2007). Available at: https://food-nutrition.canada.ca/cnf-fce/index-eng.jsp (Accessed December 2, 2016).

Inglis, V., Ball, K., & Crawford, D. (2009). Does modifying the household food budget predict changes in the healthfulness of purchasing choices among low- and high-income women? *Appetite, 52*(2), 273–279.

Kim, M. H., & Bae, Y. J. (2010). Evaluation of diet quality of children and adolescents based on nutrient and food group intake and diet quality index-international. *Korean Journal of Community Nutrition, 15*, 1–14.

Kim, S., Haines, P. S., Siega-Riz, A., & Popkin, B. M. (2003). The Diet Quality Index-International (DQI-I) provides an effective tool for cross-national comparison of diet quality as illustrated by China and the United States. *The Journal of Nutrition, 133*(11), 3476–3484.

Krueger, H., Krueger, J., & Koot, J. (2015). Variation across Canada in the economic burden attributable to excess weight, tobacco smoking and physical inactivity. *Canadian journal of public health = Revue canadienne de santé publique, 106*(4), e171–e177.

Kumcu A, Kaufman PR. Food spending adjustments during recessionary times. Amber Waves, 2011. Available at: http://econpapers.repec.org/article/agsuersaw/120969.htm (Accessed November 6, 2016).

Lennernäs, M., Fjellström, C., Becker, W., Giachetti, I., Schmitt, A., Remaut de Winter, A., et al. (1997). Influences on food choice perceived to be important by nationally-representative samples of adults in the European Union. *European Journal of Clinical Nutrition, 51 Suppl 2*(6), S8–S15.

Lieffers, J., Ekwaru, J. P., Ohinmaa, A., & Veugelers, P. J. (2018). The economic burden of not meeting food recommendations in Canada: the cost of doing nothing. *PLoS ONE, 13*(4), e0196333.

Livingstone, M. B. E., & Black, A. E. (2003). Markers of the validity of reported energy intake. *The Journal of Nutrition, 133 Suppl 3*(3), 895S–920S.

Maillot, M., Darmon, N., Darmon, M., Lafay, L., & Drewnowski, A. (2007). Nutrient-dense food groups have high energy costs: an econometric approach to nutrient profiling. *The Journal of Nutrition, 137*(7), 1815–1820.

Maximova, K., Faught, E., Khan, M., McComber, T., Taylor, J., & Veugelers, P. (*2016*). Upward trends in the prevalence of overweight and obesity among children in three Canadian provinces. *CMAJ : Canadian Medical Association Journal = Journal De L'Association Medicale Canadienne, 188*(13), E320. https://doi.org/10.1503/cmaj.150854.

Ministry of Health Promotion. (2010). *Nutritious food basket*. Ontario: Queen's Printer for Ontario.

Mitchell, D. C., Shannon, B. M., Mckenzie, J., Smiciklas-Wright, H., Miller, B. M., & Tershakovec, A. M. (2000). Lower fat diets for children did not increase food costs. *Journal of Nutrition Education, 32*(2), 100–103.

Moffatt, E., & Coupland, K, (2005). *Childhood overweight and obesity-summary of evidence from the cost of obesity in Alberta report*. Available at: http://www.albertahealthservices.ca/poph/hi-poph-surv-phids-childhood-overweight-obesity-2010.pdf (Accessed October 10, 2016).

Ogilvie, K.K. A Senate Committee report on Obesity in Canada has put forward 21 concrete recommendations for an effective federal-led plan to combat obesity. Available at https://policyoptions.irpp.org/2016/03/03/its-time-for-the-federal-government-to-take-a-leadership-role-on-rising-obesity-rates/ (Accessed 23 October 2019).

Rao, M., Afshin, A., Singh, G., & Mozaffarian, D. (2013). Do healthier foods and diet patterns cost more than less healthy options? A systematic review and meta-analysis. *BMJ OPEN, 3*, e004277.

Roberts, K. C., Shields, M., de Groh, M., Aziz, A., & Gilbert, J. (2012). Overweight and obesity in children and adolescents: results from the 2009 to 2011 Canadian health measures survey. *Health Reports, 23*(3), 37 Available at: http://www.ncbi.nlm.nih.gov/pubmed/23061263 (Accessed November 2, 2016).

Rockett, H. R., Wolf, A. M., & Colditz, G. A. (1995). Development and reproducibility of a food frequency questionnaire to assess diets of older children and adolescents. *Journal of the American Dietetic Association, 95*, 336–340.

Rockett, H. R., Breitenbach, M., Frazier, A. L., Witschi, J., Wolf, A. M., Field, A. E., & Colditz, G. A. (1997). Validation of a youth/adolescent food frequency questionnaire. *Preventive Medicine, 26*(6), 808–816.

Ryden, P. J., & Hagfors, L. (2011). Diet cost, diet quality and socio-economic position: how are they related and what contributes to differences in diet costs? *Public Health Nutrition, 14*(9), 1680–1692.

Schröder, H., Marrugat, J., & Covas, M. I. (2006). High monetary costs of dietary patterns associated with lower body mass index: a population-based study. *International Journal of Obesity, 30*(10), 1574–1579.

Statistics Canada. Food and other selected items, average retail prices, 2017. Available at: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/econ155a-eng.htm (Accessed December 5, 2016).

Turrell, G., Bentley, R., Thomas, L. R., Jolley, D., Subramanian, S., & Kavanagh, A. M. (2009). A multilevel study of area socio-economic status and food purchasing behaviour. *Public Health Nutrition, 12*(11), 2074–2083.

Veugelers, P. J., Fitzgerald, A. L., & Johnston, E. (2005). Dietary intake and risk factors for poor diet quality among children in Nova Scotia. *Canadian Journal of Public Health / Revue Canadienne de Sante'e Publique, 96*(3), 212–216.

Waterlander, W. E., de Haas, W. E., van Amstel, I., Schuit, A. J., Twisk, J. W. R., Visser, M., et al. (2010). Energy density, energy costs and income - how are they related? *Public Health Nutrition, 13*(10), 1599–1608.

Willett, W. C. (2000). Accuracy of food-frequency questionnaires. *The American Journal of Clinical Nutrition, 72*(5), 1234–1235.