Dietary intake and prospective changes in cardiometabolic risk factors in children and youth

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Dietary intake and prospective changes in cardiometabolic risk factors in children and youth

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Abstract

Only few studies examined the effect of diet on prospective changes in cardiometabolic (CM) risk factors in children and youth despite its importance for understanding the role of diet early in life for cardiovascular disease in adulthood. To test the hypothesis that dietary intake is associated with prospective changes in CM risk factors, we analyzed longitudinal observations of 448 students from 14 schools in Canada who were 10 to 17 years of age and followed for 2 years. We applied mixed effect regression to examine the associations of dietary intake at baseline with changes in body mass index (BMI), waist circumference (WC), systolic and diastolic blood pressure (SBP and DBP), and insulin sensitivity score (ISS) between baseline and follow-up while adjusting for age, sex, and physical activity. Dietary fat at baseline was associated with increases in SBP and DBP Z-scores (per 10 grams increase in dietary fat per day: $\beta=0.03$; $p<0.05$) and WC ($\beta=0.31$ cm; $p<0.05$) between baseline and follow-up. Every additional gram of sodium intake at baseline was associated with an increase in DBP Z-score of 0.04 ($p<0.05$) between baseline and follow-up. Intake of sugar, vegetables and fruit, and fibre were not associated with changes in CM risk factors in a statistically significant manner. Our findings suggest that a reduction in the consumption of total dietary fat and sodium may contribute to the prevention of excess body weight and hypertension in children and youth, and their cardiometabolic sequelae later in life.

Keywords: Diet, cardiometabolic risks factors, adolescents, longitudinal study, public health, obesity

Introduction

Type 2 diabetes and cardiovascular disease (CVD) are contemporary public health concerns both globally (Fuster et al. 2011; World Health Organization 2014) and in Canada (Canadian Diabetes Association 2010). Mortality resulting from CVD has declined in the past decades but remains the second leading cause of death in Canada (Statistics Canada 2012a, 2012b). In contrast, the prevalence of diagnosed diabetes has increased by 70% between 1998/99 and 2008/09 (Public Health Agency of Canada 2011). Type 2 diabetes and CVD are mostly consequences of increases in cardiometabolic (CM) risk factors including hypertension, hyperglycemia, excess body weight, dyslipidemia and insulin resistance (Leiter et al. 2011; Vanuzzo et al. 2008) which in turn are affected by diet, physical activity and other lifestyle risk factors.

Dietary recommendations for children and youth focus primarily on achieving nutrient adequacy for optimal growth by specifying the amount of macro and micro nutrients, food groups, fibre, sodium and sugar content, among others (Health Canada 2007b; US Department of Health and Human Services 2011). Limited empirical evidence exists whether these dietary recommendations may reduce CM risk among children and youth. Evidence of an effect on CM risk factors in childhood or adolescence would support the hypothesis that dietary intake early in life determines cardiovascular disease in adulthood. Persson et al and Yang et al demonstrated associations of dietary sodium with diastolic and systolic blood pressure, respectively for children and youth (Persson 1984; Yang et al. 2012). He and MacGregor conducted a meta-analysis and concluded that salt reduction may be effective in reducing blood pressure (He and MacGregor 2006). Other than sodium, consumption of fat, sugar, vegetables and fruit has been less studied with regards to its effects on CM risk factors among children and youth. In addition,

the limited existing studies among children and youth focused on overweight and blood pressure and less on abdominal obesity and insulin sensitivity (Bigornia et al. 2015; Riccardi et al. 2004). Therefore, the importance of dietary factors for changes in CM risk among children and youth is not broadly established and in need of further studies.

The objective of this study was to investigate whether specific aspects of dietary intake are associated with prospective changes in CM risk factors in children and youth. We hypothesized that the dietary intake of vegetables and fruit, fat, fibre, milk, sodium and added sugar are associated with the development of cardiometabolic risk factors in children and youth.

Methods and Materials

Study design and population

This study was a secondary analysis of a 2-year prospective cohort study of physical activity and cardiometabolic health in youth, the Healthy Hearts study, with data collection in the school years 2008/2009, 2009/2010 and 2010/2011. At baseline, this study invited 2189 students in grades 5 to 10 from 14 secondary schools of the Black Gold School District that includes both rural and urban schools located approximately 50 km south of Edmonton, Alberta, Canada (Forbes et al. 2012). All students provided assent, and their parents or guardians provided signed informed consent. Participants completed a web-based 24-hour recall of dietary intake (Web-SPAN) (Storey et al. 2009), had measures of CM risk factors, and were given accelerometers to wear for 7 days. Because of the complex school schedules and limited resources, challenges with data collection scheduling did not allow all students to complete all measures at each of the baseline and follow-up visits. Students with at least one follow-up visit were included in the current analyses. As such, some students contributed one follow-up visit and others contributed two follow-up visits. After excluding individuals who reported an energy intake of ≤ 500 or $\geq$

5000 kilocalories (kcal) per day, a total of 448 students had complete dietary and physical activity data at baseline and had complete information of at least one CM risk factors at baseline and follow-up. Ethics approvals for the original data collection and the present secondary data analyses were obtained from the Human Research Ethics Board at the University of Alberta.

Exposure measures

Web-SPAN includes a validated web-based 24-hour diet recall to measure weekday dietary intake. The tool provides product images for more than 500 food items to assist in the judgment of portion sizes. It also provides cues for frequently missed food items such as toppings and beverages (Hanning et al. 2009; Storey et al. 2009). Nutrient analysis was conducted using the ESHA Food Processor (version 7.9; ESHA Research, Salem, Ore., USA) and the 2001 Canadian Nutrient File database (Health Canada 2007a). Food group servings of vegetables and fruit (including fresh, canned, frozen fruit and vegetables, and 100% juice) and milk (including all milk products) were calculated according to Eating Well with Canada's Food Guide (Health Canada 2011). Other food components including total fat, added sugar, fibre, and sodium intake were expressed in grams. In selecting these food items we considered the availability of the dietary information, the recommendations of the United State Department of Health and Humen Services on optimum intake from these food groups for growing children (US Department of Health and Humen Services 2011), and their role as a risk factor of chronic disease (Johns et al. 2015; Odegaard et al. 2012). All dietary components were standardized to calorie intake based on the average estimated energy requirement for Canadian boys and girls aged 10-18 years of 2400 kcal and 1900 kcal, respectively (Health Canada 2014).

Outcome measures

The main outcome measures were Body Mass Index and waist circumference Z score. Secondary outcomes were systolic and diastolic blood pressure Z score and insulin sensitivity.

Anthropometric measurements were collected with students dressed in light clothing without shoes. Study personnel used a stadiometer (Seca Portable Stadiometer Model 214) for height measurement, a scale (Seca 882 Digital Floor scale) for weight measurement which were calibrated each morning. Measurements were recorded to the nearest 0.1 cm for height and 0.1 kg for weight. Two measurements were obtained for each participant, and the mean value of two measurements was calculated.

Body Mass Index (BMI) was computed as weight/height^2 (kg/m^2). BMI Z scores were calculated based on normative data from the Centers for Disease Control and Prevention growth charts (Centers for Disease Control and Prevention 2010). A child was categorized as being thin/normal weight, overweight, or obese according to the new cut offs generated by International Obesity Task Force (IOTF) from 2 to 18 years (Cole and Lobstein 2012).

Waist Circumference (WC) was measured in duplicate using a standard tape measure at the level of the iliac crest to the nearest 0.5 cm at the end of normal expiration according to guidelines established by McCarthy et al (McCarthy et al. 2001). Clinical cutoffs used to determine abnormal levels were: waist $\geq$ 90th percentile for age and sex (Fernández et al. 2004).

Blood Pressure (BP) was assessed in triplicate at one-minute intervals and in the sitting position after students laid quietly on a portable bed for 5 minutes prior to measurements. Technicians who had been trained and certified according to the American Heart Association guidelines for pediatrics (McCrindle 2010) took the measurements using an automated device (Hypertension Diagnostic Imaging, Eagan, MN). To reduce BP reactivity or habituation, the first reading was

not considered (Parati and Mancia 2006). The mean value of the two readings was calculated from the remaining readings. BP percentiles specific for age, sex, and height Z score were computed according to the National High Blood Pressure Education Program (NHBPEP) approach (National High Blood Pressure Education Program 2005). High BP was defined as systolic BP (SBP) or diastolic BP (DBP) of at least the 95th percentile; and high-normal as SBP or DBP of more or equal to the 90th percentile but less than the 95th percentile specific for sex, age, and height. In the current study in order to calculate the BP Z score a sex- and age-specific equation introduced by the National Heart, Lung, and Blood Institute was applied (National High Blood Pressure Education Program 2005).

Insulin Sensitivity Score (ISS) was measured noninvasively using the ^{13}C glucose breath test. This procedure has been validated in adults (Lewanczuk et al. 2004) and children (Jetha et al. 2009). The ^{13}C -labeled glucose mixture was ingested after an overnight fast and the incremental rise in $^{13}\text{CO}_2$ 90 min after ingestion was used as an index of insulin-mediated glucose disposal (Mizrahi et al. 2010). The ^{13}C insulin sensitivity score ($^{13}\text{CISS}$) was calculated as the difference in ^{13}C content between the baseline and the 90-min breath sample (Forbes et al. 2012). Higher ISS values indicate better insulin sensitivity.

Potential Confounders

Age, sex, year of participation in the study, baseline value of physical activity and BMI Z score (the latter except when analyzed as an outcome) were considered as potential confounders. Age and sex were only considered in our multivariable regression analyses with waist circumference and ISS as outcome variables since BMI and BP Z scores are standardized for age and sex. Moreover, year of participation in the study was used as a confounder wherein SBP was the outcome variable due to adjusting for the significant drop in SBP in 2009. Physical activity (PA)

was measured using waist-mounted accelerometers over a period of 7 days (Actical: B101270-B101375; Respironics, Seattle WA). Raw PA counts were acquired in 15-second epochs and converted into minutes of PA using a specially designed software program (KineSoft) (Esliger et al. 2010). Sequences of consecutive zero counts ≥ 60 min were considered non-wear and excluded from the analyses. Inclusion criteria for the final analyses were a minimum of 3 days of wear with at least 480 registered minutes (8 h) per day. We classified raw counts per minute (c.p.m.) into sedentary time (<100 c.p.m.), light (100–1499 c.p.m.), moderate (1500–6499 c.p.m.) and vigorous (>6500 c.p.m.) PA intensities (Colley et al. 2011; Comte et al. 2013). The sum of moderate to vigorous physical activity minutes (MVPA) was used in statistical analyses.

Data analysis

Independent samples t tests were used to examine the differences in CM risk factors between students with complete and students with incomplete information. Sex-stratified baseline characteristics of students were reported and the significant differences between two sexes were tested by independent sample t test or Mann Whitney U test for continuous normally- or not-normally distributed variables, respectively. Categorical variables were analyzed using chi square test. We analyzed the repeated measurements in the five outcomes of interest (BMI, WC, SBP, DBP, ISS) collected in 2008, 2009, and 2010 using mixed effects linear regression models. All outcome variables were normally distributed. To adjust for school-level clustering of student observations we applied multilevel regression methods. The univariate regression models quantified the associations of each dietary component at baseline (data in 2008 or 2009) with the five CM outcomes at follow-up (one year later, 2009 or 2010). Multivariable models adjusted for baseline values of key confounders, including baseline adiposity and physical activity. Age and sex were also included to the models for waist circumference (cm) and ISS. Interaction analysis

was conducted for each model to identify significant sex specific difference in the results. All analyses were completed using STATA (version 13, Stata Corporation, TX, USA). P-value <0.05 was considered statistically significant.

Results

Table 1 shows that participating students were on average 12.5 ± 1.6 years old, 21% were overweight or obese, 8.5% were abdominally obese, and 9.3% had hypertension or pre-hypertension. The majority of participating students were female (60%). Of all students, 55.5% had diets with added sugar contributing to more than 10% of calories and 32.8% with fat contributing to more than 35% of calories. The average consumption of vegetables and fruit (4.9 servings/day), milk (2.4 servings/day), and fibre (14.6 g/day) was less than the recommended intake. Of all students 47% reportedly consumed more than the recommended 2.3 g of sodium per day. Nearly 40% of the cohort achieved the recommended 60 minutes of moderate to vigorous physical activity daily. At baseline, DBP, ISS, sodium intake, fat intake, and MVPA were significantly different for girls and boys. DBP was higher whereas ISS was lower in boys in comparison to girls. Boys consumed more fat and sodium and more physically active compared to girls. These differences were statistically significant (Table 1).

We observed no statistically significant differences in the SBP Z scores, DBP Z scores, BMI Z scores, and WC between the 448 students enrolled in our study and those 127 students with missing or incomplete information. ISS was higher among students with complete information compared to those with missing or incomplete information (16.8 ± 5.07 vs 15.2 ± 4.45 , $p < 0.01$).

Univariate analysis did not reveal any statistically significant associations of dietary intake with SBP Z scores, DBP Z scores, BMI Z scores, and WC. Table 2 shows the multivariable associations and reveals that consumption of every additional 10 grams of dietary fat per day at

baseline was associated with an increase of 0.03 in SBP Z score (which approximates a 0.48 mmHg increase in SBP), an increase of 0.03 in DBP Z score (which approximates a 0.24 mmHg increase in DBP), and an increase of 0.31 cm in waist circumference for every one year of follow-up (p-value=0.050, 0.028, and 0.025, respectively). Table 2 also shows that daily intake of one additional gram of sodium at baseline was associated with an increase of 0.04 in DBP Z score (which approximates a 0.31 mmHg increase in DBP) per year of follow-up (p-value=0.021). Table 2 further shows that consumption of every additional 10 grams of total fat per day at baseline was associated with 0.38 decrease in ISS (p-value=0.001), however, this association was no longer statistically significant after adjusting for age, sex, physical activity, and baseline adiposity (data not shown in Table 2). Added sugar, vegetables and fruit intake, and fibre were not associated with any of the CM risk factors. Stratification of the above analyses by sex did not reveal any statistically significant associations likely because of the limited sample size. Likewise, interactions between sex and exposures did not reveal any statistically significant associations.

Discussion

This study of dietary intake and prospective changes in CM risk factors revealed several novel associations relevant to dietary recommendations for children and youth. Firstly, during the 2 years of follow-up of the study, we observed that higher intake of dietary fat was associated with increases in SBP, DBP and WC, and with decreases in insulin sensitivity. Secondly, we observed that higher intake of sodium was associated with increases in DBP. Further, we observed that some key dietary factors, specifically added sugar, and vegetables and fruit, were not associated with CM risk factors in childhood and adolescence.

Consistent with findings of population-based surveys, we observed that relatively few students meet dietary recommendations (Brady et al. 2000; Garriguet 2007; Statistics Canada 2013). The intake of vegetables and fruit, milk, and fibre of students in the Healthy Hearts Study was below what is recommended (Health Canada 2010, 2011). The intake of sodium exceeded the recommended intake (2.3 g/d) for 56% of students (Health Canada 2010) and the intake of dietary fat exceeded the upper limit (35% of the total energy intake) of the recommended range for 32.8% of students (Health Canada 2012). The World Health Organization recommends that less than 10% of calorie intake comes from sugar (WHO Technical Report Series 2003). Less than half of the students met this recommendation. Collectively, these observations underline the sad state of affairs in terms of poor compliance with dietary recommendations by children and youth.

We observed that the prevalence of 9.3% for pre-hypertension and hypertension in this cohort of students which is substantially higher than the national average of 3.7% (Statistics Canada 2014). This may be related to the high sodium intake as a key determinant of blood pressure. We confirmed the existence of the role of sodium for prospective changes in DBP in the present study which seems consistent with findings from epidemiological studies that showed that children with a higher salt intake have a higher systolic (Yang et al. 2012) or diastolic (Persson 1984) blood pressure or both (He and MacGregor 2006). It remains unclear whether salt has a differential effect on systolic and diastolic blood pressure. We also observed that, in addition to sodium intake, dietary fat intake was associated with increases in SBP and DBP. This observation is consistent with those of other prospective (Simons-Morton et al. 1997) and cross sectional studies (Colin-Ramirez et al. 2009). In a Finish follow-up study from an age of 7 months to 15 years, saturated fat-reduced diets decreased the mean SBP and DBP values of both

girls and boys by approximately 1 mm Hg (Niinikoski et al. 2009). Although some of the dietary fat compositions have beneficial impacts such as monounsaturated fatty acid or polyunsaturated fatty acid, studies have reported that total fat intakes exceeding 35% (Colin-Ramirez et al. 2009) or 37% (Roberts et al. 2012) of total calorie intake are associated with higher blood pressure (Colin-Ramirez et al. 2009; Roberts et al. 2012). We also observed that dietary fat intake was associated with a prospective increase in waist circumference. Although cross-sectional studies have shown an association of dietary fat intake with obesity and CM risk in children and youth (Maffeis et al. 1996; Nguyen et al. 1996; Raj and Kumar 2010; Stallmann-Jorgensen et al. 2007), the influence of dietary fat on changes in abdominal fat has not been previously reported for children and youth. Therefore, fat content of the diet is important to both abdominal obesity and blood pressure in childhood and adolescence.

Insulin resistance is an established risk factor for type 2 diabetes, cardiovascular diseases, and other metabolic conditions (Bremer et al. 2009; Kynde et al. 2010). Our univariate analysis indicated a reverse association of total fat intake and ISS. Although other studies reported similar results (Riccardi et al. 2004; Vessby et al. 2001), our multivariable analysis revealed associations that were no longer statistically significant. This latter may be an issue of sample size or length of follow-up. Several mechanisms have been suggested for the relationship between high dietary fat intake and decreased insulin sensitivity. High dietary fat consumption may incur obesity and herewith insulin resistance or may affect fasting hyperinsulinemia directly (Mayer et al. 1993). Also, the type of fatty acids in cell membranes could affect insulin action by changing insulin receptor binding, affinity, ion permeability and thereby cell signaling (Riccardi et al. 2004).

Strengths and limitations

The current study has several strengths, including a relatively large sample of children and youth, followed for two years with diets reportedly similar as the national average. We also acknowledge study limitations. Dietary intake was assessed using a single 24-hour recall on a weekday which may not provide the best estimates of usual dietary intake. Although the 24-hour recall tool had been validated and had shown good agreement with respect to total energy intake, macronutrients and key micronutrients compared to dietitian-administered 24-hour recall (Minaker et al. 2006), a single assessment has limited external validity and may not well represent usual dietary intake throughout childhood (Bingham 1991). This may have been the result of the fact that our web-based tool provided images of portion sizes. Another limitation is the short follow-up of youth. One or two years of follow-up may not be sufficient to detect significant changes in CM risk factors and therefore limit the ability to detect associations. The use of the ^{13}C breath test may not been validated extensively with the gold standard clamp technique in this age group, yet, it provides a useful noninvasive assessment of insulin sensitivity (Lewanczuk et al. 2004). We also acknowledge limitations resulting from residual confounding and study bias. Though we had shown that those who were lost to follow-up or who withdrew from the study were not different from those who retained in the study, we may not exclude the existence of selection bias. Furthermore, we had trained our interviewers and made use of standardized protocol and questionnaires, however, we should not exclude the existence of some information bias. Finally, we acknowledge that recall bias is an inherent limitation of dietary research.

Conclusions

In this group of children and youth, we observed that dietary fat intake was associated with unfavorable prospective changes in SBP, DBP, WC, and ISS in the relatively short observational period of two years. Additionally, sodium intake was associated with a prospective increase in DBP. Public health implications of these findings include the continuation of the general recommendation of reducing dietary fat and sodium intake along with existing recommendations to increase physical activity among children and youth to reduce their future risk for type 2 diabetes and CVD. Implications in terms of research include the need for longitudinal studies with longer follow-up to better capture the importance of dietary intake for the development of CM risks factors.

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Competing interests

The authors declare that they have no competing interests.

Authors' contribution

JM is the principal investigator of Healthy Hearts Study. SS, PV, KM, and JM conceived the research idea. SS conducted the statistical analysis and interpreted the data and wrote the manuscript draft. JE and PV helped to analyze and interpret the data. All authors critically reviewed and edited the paper. All authors read and approved the final manuscript.

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Table Captions

Table 1. Baseline characteristics of students participating in the Healthy Hearts Study

Table 2. Association of dietary intake with prospective changes in cardiometabolic outcome among students participating in the Healthy Hearts Study

Draft

Table 1

Baseline Characteristics	Girls (n=269)	Boys (n=179)	Total (n=448)
Age (m±SD)	12.50±1.53	12.56±1.64	12.53±1.58
Systolic Blood Pressure Z score (m±SD)	0.28±0.75	0.35±0.70	0.31±0.73
Hypertensive ¹ (n)%	(11)4.09	(8)4.47	(19)4.24%
Pre-hypertensive	(14)5.20	(9)5.03	(23)5.13%
Normal	(244)90.71	(162)90.50	(406)90.63%
Diastolic Blood Pressure Z score ²	-0.61±0.52*	-0.48±0.49*	-0.56±0.51
BMI Z score (m±SD)	0.35±0.85	0.46±0.93	0.39±0.88
Obese ³ (n)%	(12)4.46	(11)6.15	(23)5.13%
Overweight	(37)13.75	(35)19.55	(72)16.07%
Normal/Thin	(220)81.78	(133)74.30	(353)78.79%
Waist Circumference (cm, m±SD)	70.92±9.82	70.75±10.46	70.85±10.08
≥90th ⁴ (n)%	(24)8.96	(14)7.82	(38)8.50 %
<90th	(244)91.04	(165)92.18	(409)91.50%
Insulin Sensitivity Score (m±SD) ⁵	17.36±4.91*	15.74±5.19*	16.74±5.08
Dietary Intake			
Fat (g/d, m±SD)	62.47±33.21*	74.88±42.80*	67.43±37.78
≥35% of total calorie intake ⁶ (n)%	(82)30.48	(65)36.31	(147)32.81%
<35% of total calorie intake	(187)69.52	(114)63.69	(301)67.19%
Vegetables and fruit (servings/d, m±SD)	4.75±3.37	4.81±3.41	4.81±3.41
≥6 servings/d ⁷ (n)%	(74)27.51	(59)32.96	(133)29.69%
<6 servings/d	(195)72.49	(120)67.04	(315)70.31%
Milk (serving/d, m±SD)	2.37±1.88	2.53±2.03	2.43±1.94
≥3 servings/d ⁸ (n)%	(93)34.57	(63)35.20	(156)34.82%
<3 servings/d	(176)65.43	(116)64.80	(292)65.18%
Sodium (g/d, m±SD)	2.28±1.32**	2.70±1.42**	2.45±1.38
≥2.3 g/d ⁹ (n)%	(107)39.78**	(104)58.10**	(211)47.10%
<2.3 g/d	(162)60.22**	(75)41.90**	(237)52.90%
Added Sugar (g/d, m±SD)	53.72±44.21	62.35±47.80	57.19±45.83
≥10% of total calorie ¹⁰ (n)%	(150)55.76	(99)55.31	(249)55.58%
<10% of total calorie	(119)44.24	(80)44.69	(199)44.42%
Fibre (g/d, m±SD)	14.02±7.34	15.47±8.60	14.60±7.89
Total Calorie Intake (kcal/d, m±SD)	1764±696	2052±875	1879±785
Moderate to Vigorous Physical Activity (min/d, m±SD)	52.7±21.3**	60.4±24.5**	55.8±22.9
≥60 min/d ¹¹ (n)%	(92)34.20*	(87)48.60*	(179)39.96%
<60 min/d	(177)65.80*	(92)51.40*	(269)60.04%

Abbreviations: SD, Standard Deviation; m, mean; min, minutes; cm, centimeters; g, gram; d, day; n, number

Independent sample t test and Mann-Whitney U test were used for continuous normally- or not-normally distributed variables, respectively. Chi square test was used for categorical variables.

* P-value < 0.01

** P-value < 0.001

¹ Blood pressure categories according to National High Blood Pressure Education Program.

² There was only one participants categorized as pre-hypertensive and no participant as hypertensive.

³ Weight status categories according to the 2012 cut offs of International Obesity Task Force (IOTF).

⁴ Percentiles According to age and sex specific cut offs generated in 2004.

⁵ Insulin Sensitivity Score was measured noninvasively using the ¹³C glucose breath test.

⁶ The recommendation is no more than 25-35% of daily total calorie intake from fat

⁷ The recommendation is more than 6 servings/d of fruit and vegetable

⁸ The recommendation is between 3-4 servings/d of milk and alternatives

⁹ The upper level intake is in no more than 2.3 g/d

¹⁰ World Health Organization recommends no more than 10% of total daily calorie should be from free sugar

¹¹ According to Canadian physical activity guidelines, youth aged 12–17 years should accumulate at least 60 minutes of moderate- to vigorous-intensity physical activity daily

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Table 2

Dietary intake at baseline	Multivariable Model ¹		Multivariable Model ¹		Univariate Model
			β (95% CI)		
	SBP Z score (n=310)	DBP Z score (n=310)	BMI Z score (n=330)	WC (n=310)	ISS ² (n=232)
Dietary fat (per 10g/d)	0.03(0.00004, 0.06)*	0.03(0.003, 0.05)*	0.009(-0.006, 0.02)	0.31(0.08, 0.58)*	-0.27(-0.42, -0.12)**
Vegetables and fruit (serving/d)	-0.007(-0.02, 0.008)	-0.002(-0.01, 0.008)	-0.002(-0.008, 0.005)	-0.04(-0.17, 0.08)	0.04(-0.05, 0.14)
Fibre (per 10g/d)	-0.03(-0.12, 0.04)	0.02(-0.04, 0.07)	0.02(-0.02, 0.05)	-0.25(-0.93, 0.44)	-0.27(-0.77, 0.23)
Milk (serving/d)	-0.009(-0.04, 0.02)	0.0003(-0.02, 0.02)	0.004(-0.01, 0.02)	0.15(-0.14, 0.43)	-0.16(-0.09, 0.29)
Sodium (g/d)	0.008(-0.03, 0.05)	0.04(0.006, 0.07)*	-0.003(-0.02, 0.02)	-0.03(-0.45, 0.38)	-0.21(-0.49, 0.06)
Added Sugar (per 10g/d)	-0.001(-0.01, 0.01)	0.002(-0.007, 0.01)	0.002(-0.004, 0.007)	-0.08(-0.20, 0.03)	0.07(-0.02, 0.17)

Abbreviation: SBP, Systolic blood pressure; DBP, Diastolic blood pressure; BMI, Body mass index; WC, Waist circumference; ISS, Insulin sensitivity score; CI, Confidence Interval.

¹ Multivariable mixed effect analysis of each dietary component with SBP, DBP, BMI, and WC.

- Model with SBP and DBP as outcome variables were controlled for baseline values of BMI Z score, physical activity, and SBP or DBP. Model with SBP as outcome variable was also adjusted for the year of participation in the study.
- The model with WC as outcome was adjusted for age, sex, and baseline values for BMI Z score, WC, and physical activity whereas the model with BMI as outcome was adjusted for baseline values of BMI Z score and physical activity.

² Insulin Sensitivity Score was measured noninvasively using the ¹³C glucose breath test.

* P-value < 0.05

** P-value <0.01