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Fruit and Vegetable Intake and Body Adiposity among Populations in Eastern Canada: the Atlantic Partnership for Tomorrow's Health Study

Running title: Fruit and Vegetable Intake and Body Adiposity

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Abstract

Objectives: The prevalence of obesity among populations in the Atlantic Provinces is the highest in Canada. Some studies suggest that adequate fruit and vegetable consumption may help body weight management. We assessed the associations between fruit and vegetable intake with body adiposity among individuals who participated in the baseline survey of the Atlantic Partnership for Tomorrow's Health (Atlantic PATH) cohort study.

Methods: We carried out a cross-sectional analysis among 26340 individuals (7979 men and 18361 women) aged 35-69 years who were recruited in the baseline survey of the Atlantic PATH study. Data on fruit and vegetable intake, sociodemographic and behavioural factors, chronic disease, anthropometric measurements, and body composition were included in the analysis.

Results: In the multivariable regression analyses, one standard deviation increment of total fruit and vegetable intake was inversely associated with BMI (-0.12 kg/m^2; 95% CI, -0.19, -0.05), waist circumference (-0.40 cm; 95% CI, -0.58, -0.23), percentage fat mass (-0.30 %; 95% CI, -0.44, -0.17), and fat mass index (-0.14 kg/m^2; 95% CI, -0.19, -0.08). Fruit intake, but not vegetable intake, was consistently inversely associated with anthropometric indices, fat mass, obesity, and abdominal obesity.

Conclusions: Fruit and vegetable consumption was inversely associated with body adiposity among the participant population in Atlantic Canada. This association was primarily attributable to fruit intake. Longitudinal studies and randomized trials are warranted to confirm these observations and investigate the underlying mechanisms.

Strengths and limitations of this study

- Data from a large-scale population-based survey with objectively measured body composition.
- Associations between fruit and vegetable intake with body adiposity measurements were assessed in combination and separately using multivariable regression models.
- Limitations of a cross-sectional analysis with an unrepresentative sample.

Introduction

The increasing prevalence of obesity, a major risk factor for a variety of chronic diseases, including coronary heart disease, stroke, diabetes mellitus, and some cancers, is a critical worldwide public health concern.[1] People living in Atlantic Canada have the highest prevalence of obesity (BMI $\geq$ 30 kg/m^2) among the Canadian population. In 2011, the prevalence of obesity ranged from 24% in Prince Edward Island to 28% in Newfoundland and Labrador. It is predicted that the percentage of people who are overweight or obese will continue to increase.[2] Appropriate strategies to effectively halt the obesity epidemic among populations in this region (and other areas) are of critical public health interest.

Fruits and vegetables are important components of a healthy diet, contributing to a large proportion of an individual's daily intake of vitamins, minerals, and dietary fibre. Health Canada recommends that adults should consume 7-10 servings of a variety of fruits and vegetables per day to reduce the risks of cancer and other chronic diseases.[3] Further, substantial evidence has shown that increased consumption of fruits and vegetables may reduce the risks of mortality from all causes[4] and the development of cardiometabolic disease.[5–8] Interestingly, some systematic reviews have suggested that appropriately increased fruit and vegetable intake may help body weight management by preventing the development of obesity and reducing body weight over time.[9–12] However, one meta-analysis of interventional trials showed that increased fruit and vegetable intake had an effect on weight loss[11]; another study did not find an effect in terms of body weight reduction.[13] A Canadian study found that increased fruit intake was associated with reduced weight gain over a six-year period among participants of the Quebec Family Study.[14] Additionally, some studies suggest that fruit consumption might have a more favourable impact on body weight control than vegetable consumption.[9,15]

We hypothesize that fruit and vegetable consumption may play a role in the obesity epidemic among populations living in Atlantic Canada. The primary aims of this study were to assess: 1) the intake of fruits, vegetables, and 100% fruit or vegetable juice; and 2) associations between fruit, vegetable, and

100% fruit or vegetable juice intake with anthropometric indices and body composition among participants who were enrolled in the baseline survey of the Atlantic Partnership for Tomorrow's Health (Atlantic PATH) study. We further assessed how the consumption of fruit, vegetable, and 100% fruit or vegetable juice were associated with body adiposity measurements by considering these three components as one food group and treating them independently in the multivariable logistic regression analyses.[15,16]

Methods

Study population

The Atlantic PATH study is a part of the Canadian Partnership for Tomorrow Project (CPTP), a pan-Canadian longitudinal cohort study examining the role of genetic, environmental, behavioural and lifestyle factors in the development of cancer and chronic disease.[17] The Atlantic PATH study is a population-based cohort in which study participants were residents of one of the four Atlantic Canadian Provinces (Nova Scotia, New Brunswick, Newfoundland and Labrador, and Prince Edward Island) and aged between 35 and 69 years. Study participants were recruited from the general public through a combination of community outreach and awareness activities, advertising and media campaigns, and invitation. During 2009 to 2015, 31173 Atlantic PATH study participants, including 9445 men and 21728 women, were recruited from the four Atlantic Canada provinces. The study was approved by appropriate Research Ethics Boards in each province. All participants provided written informed consent prior to participation. All data collection procedures followed the research protocol guidelines as approved by the Research Ethics Boards.

We excluded 4833 participants from this analysis as a result of current pregnancy (n=40), missing data on fruit, vegetable, and 100% fruit or vegetable juice (n=816), anthropometric indices (n=4127), and other variables (n=90). The final analysis sample was comprised of 26340 participants (7979 men and 18361 women).

Data collection

Data collection procedures have been reported previously.[18] In brief, a set of standardised questionnaires on sociodemographic, health status, medication use, diet, lifestyle factors, and self-measured anthropometric indices were completed by participants. Physical measurements (including anthropometric indices and body composition) were measured by research nurses at an assessment centre.

Assessment of fruit and vegetable consumption

Consumption of fruit, vegetable, and 100% fruit or vegetable juice were assessed by using three questions: 1) In a typical day, how many servings of vegetable do you eat? One serving is about ½ cup or 125 ml of fresh, frozen, canned, or cooked vegetables. 2) In a typical day, how many servings of fruit do you eat? One serving is about ½ cup or 125 ml of fresh, frozen, or canned fruit. 3) In a typical day, how many servings of 100% fruit or vegetable juice do you drink? One serving is about ½ cup or 125 ml.

Assessment of sociodemographic and behavioural factors

Ethnicity was categorized as white and non-white because there was little ethnic diversity in the cohort. Educational attainment was categorized as high school or lower, college level, and university level or higher. Marital status was grouped as married or living together and single, divorced, separated, or widowed. For smoking behaviour, participants were grouped as non-smoker, former smoker, and current smoker. For alcohol drinking, respondents were classified as abstainer, occasional drinker (>0- ≤ 2-3 times/month), regular drinker (≥ 1 time/week - ≤ 2-3 times/week), and habitual drinker (≥ 4-5 times/week).[18]

Physical activity was assessed by using either the long or short form of the International Physical Activity Questionnaire (IPAQ).[19] For evaluation of total physical activity, we calculated metabolic equivalent minutes per week (MET-min/week) for each participant with data derived from the long and short form questionnaires, respectively. The MET scores were computed according to the IPAQ scoring protocol.[20]

We then ranked the sex-specific total MET scores into tertiles for data derived from the long and short form questionnaires, separately. Levels of total physical activity were classified as low, medium, and high by the low to high MET score tertiles.

Assessment of chronic diseases

Self-reported current medication use was collected and medication data were coded according to the Nova Scotia Formulary (NSF) (www.nspharmacare.ca).[21] The NSF uses the standardised Anatomical Therapeutic Chemical (ATC) Classification System which was developed by the World Health Organization. Participants also reported chronic diseases diagnosed by a physician. For this analysis, we defined chronic disease (yes/no) based upon the following: (a) self-reported diabetes mellitus and/or current use of antidiabetic medications, or (b) self-reported myocardial infarction, stroke and/or current use of CVD medications, or (c) self-reported cancer.

Physical measurements

Body weight, percentage fat mass, fat mass, and fat free mass were measured using the Tanita bioelectrical impedance device (Tanita BC-418, Tanita Corporation of America Inc., Arlington Heights, Illinois). Height was measured by a Seca stadiometer. BMI was calculated as weight in kilograms divided by height in meters squared. We also calculated fat mass index (FMI) and fat free mass index (FFMI) by dividing fat mass and fat free mass in kilograms by height in meters squared, respectively. Waist and hip circumferences were measured by using Lufin steel tape. Obesity was defined as a BMI $\geq$ 30 kg/m^2. Abdominal obesity was defined as a waist circumference $\geq$ 102 cm for men or $\geq$ 88 cm for women.[22]

Among our study participants, measured data were available for 72% of participants for weight and height, 69% for both waist and hip circumferences, and 70% for body composition. For participants who did not have measured anthropometric indices, self-reported measures were utilized in the analyses.

Statistical analyses

We computed Pearson partial correlation coefficients between fruit and vegetable intake and anthropometric measures and body composition with adjustment for age and sex. To examine the associations between fruit and vegetable intake with obesity, we derived z-scores for the intakes of total fruit and vegetable, vegetable, fruit, and fruit or vegetable juice, respectively. We categorized total fruit and vegetable, vegetable, and fruit intake into low, medium, and high levels according to the approximate tertiles, respectively. Fruit or vegetable juice intake was dichotomized (yes/no) as 49% of the participants did not consume fruit or vegetable juice. We utilized multiple linear regression models with Robust M estimator to evaluate the associations between fruit and vegetable intake with BMI, waist circumference, percentage fat mass, and FMI. We employed multiple logistic regression models to compute the odds ratios (OR) and 95% confidence intervals (CI) of having obesity and abdominal obesity across different levels of fruit and vegetable intake. To evaluate the independent associations between consumption of fruit, vegetable, and fruit or vegetable juice with obesity, we performed both the linear and logistic regression analyses using three models: model one was adjusted for age, sex, and province; model two was further adjusted for ethnicity, socioeconomic status, behavioural factors, and chronic disease based on model one; and model three was additionally and mutually adjusted for fruit, vegetable, and fruit or vegetable juice intake based on model two.

Further, as we found a consistent inverse association between daily fruit intake and adiposity, we plotted the associations of fruit intake with BMI, waist circumference, percentage fat mass, and FMI by using the restricted cubic spline (RCS).[23] We performed the RCS plot among participants who reported daily fruit intake $\leq$ 6 servings/day (99.5% of total participants) and utilized three knots located at the 5th, 50th, and 95th percentiles of the fruit intake distribution. All the models were multivariable with adjustment for all of the covariables and the intakes of vegetable and fruit or vegetable juice. Given that energy expenditure has been shown to be strongly and inversely associated with body adiposity,[1,18] we also analysed the interactions between fruit intake and physical activity in relation to risks of obesity and abdominal obesity. In addition, we evaluated whether substituting one standard deviation (SD) of fruit intake for vegetable intake or vice versa might affect obesity risk by using multivariable logistic regression models.[16] We carried out a sensitivity analysis among participants with all measured body adiposity measurements (n=17528) and yielded a similar pattern of results. We, therefore, reported the results for the entire samples. Statistical significance was defined as $P < 0.05$ (two-sided). Data management and analyses were performed with SAS for Windows, version 9.4 (SAS Institute, Cary, North Carolina).

Results

Fruit and vegetable consumption among study participants

Average total fruit and vegetable intake was 5.4 servings per day in the study participants (4.9 servings/day in men and 5.6 servings/day in women). Only 22% of men and 32% of women reported total fruit and vegetable intake ≥ 7 servings/day, respectively (Table 1 and Supplementary Table 1). The correlation between fruit or vegetable juice intake with fruit intake was higher compared with that for vegetable intake. Participants who reported high levels of fruit and vegetable intake were more likely to be females, white, married, have higher levels of education, and engage in higher levels of physical activity. They were also less likely to be current smokers compared with those who reported low levels of fruit and vegetable consumption (data not shown).

Fruit and vegetable consumption and body adiposity

There was a consistently negative correlation between fruit and vegetable intake with body adiposity measures (Supplementary Table 1). There was no statistically significant correlation between fruit and vegetable intake with FFMI.

In the multivariable linear regression analyses, one SD increment of total fruit and vegetable intake was inversely associated with BMI (-0.12 kg/m^2; 95% CI, -0.19, -0.05), waist circumference (-0.40 cm; 95% CI, -0.58, -0.23), percentage fat mass (-0.30 %; 95% CI, -0.44, -0.17), and FMI (-0.14 kg/m^2; 95% CI, -

0.19, -0.08) (Table 2). In the multivariable logistic regression analyses, individuals with high levels of total fruit and vegetable intake had reduced likelihoods of 12% (OR, 0.88; 95% CI, 0.83, 0.94) for having abdominal obesity compared with those with low levels (*P* for trend < 0.001, Table 3).

Independent associations of fruit, vegetable, and fruit or vegetable juice consumption with body adiposity

In the multivariable regression analyses, fruit consumption was consistently inversely associated with adiposity measurements (Table 2 and Figure 1) and the likelihoods for obesity and abdominal obesity (Table 3). Compared with those with low levels of fruit consumption, individuals with medium to high levels of fruit consumption had ORs of 0.92 (95% CI, 0.86, 0.98) and 0.90 (95% CI, 0.84, 0.96) for obesity and 0.97 (95% CI, 0.91, 1.03) and 0.88 (95% CI, 0.82, 0.94) for abdominal obesity, respectively (All *P* for trend < 0.05). These associations remained materially unchanged after further controlling for the intake of vegetable and fruit or vegetable juice. The similar associations were evident for juice intake but were less consistent than those observed for fruit intake. Moreover, fruit consumption was shown to have additive effects with total physical activity in terms of the likelihoods for obesity and abdominal obesity (Supplementary Figure 1).

The inverse association between vegetable consumption and obesity was attenuated and became positive after further controlling for the intakes of fruit and fruit or vegetable juice (Table 3). Further analyses showed that substituting one SD of the intakes of fruit and juice for vegetables resulted in the reduced likelihoods for obesity (Figure 2 and Supplementary Table 2). Conversely, substituting one SD of vegetable intake for fruit and juice led to the increased likelihoods for obesity.

Discussion

In this large-scale, population-based cross-sectional analysis, we found that total daily fruit and vegetable intake among Atlantic Canadians was comparable to those reported from a nationally representative sample of Canadians.[24] We observed that total fruit and vegetable intake was inversely associated with body adiposity. This association appeared to be primarily attributable to fruit consumption. These findings are in line with the previous studies reporting the potentially favourable role of fruit consumption in effective body weight management.[9,14,15] However, after controlling for the consumption of fruit, fruit or vegetable juice, and other covariables, vegetable intake tended to be positively related to obesity. This finding is consistent with that reported in a longitudinal study carried out in American women.[15] However, the mechanisms underlying these observed associations is unclear.

Thus far, substantial evidence appears to show that adequate fruit and vegetable consumption reduces the risk of chronic disease.[25] With respect to body weight management, regular daily fruit consumption may displace energy-dense foods, resulting in attenuated dietary energy density and reduced total energy intake.[26] Fruits have abundant soluble dietary fibres which may enhance post-meal satiety and decrease both glycaemic index and glycaemic load of consumed foods causing lowered energy absorption.[27] Moreover, fruits are rich in phytochemicals that have anti-oxidative and anti-inflammatory effects against the obesity-induced oxidative stress and subclinical inflammation.[25,28] While most vegetables have these characteristics, in multivariable regression analyses, we observed a different association between vegetable intake and obesity from those for fruit consumption.

In our analyses, the association between 100% fruit or vegetable juice and obesity was similar to the association between fruit and obesity. Some longitudinal studies have shown that a vegetable-rich dietary pattern might lead to increased body weight[29] and an unhealthful plant-based diet that was featured with sweetened foods and beverages, refined grains, and potatoes might be related to increased incidence of type 2 diabetes.[30] Regular potato intake, especially french fries, was associated with obesity.[31] These findings may imply that some fatty substances added during the preparation of vegetables and the type of vegetable consumed (e.g., starchy vegetables), might play a role in the positive association between increasing vegetable intake and increasing obesity. Our data appeared to support this hypothesis as oil products and starchy vegetables are seldom used to prepare 100% juice. Nevertheless, further research is needed to clarify the potential role of vegetable intake in obesity development.

To our knowledge, this is the first large-scale, population-based study investigating the associations between fruit and vegetable intake with objectively measured body composition. Our findings imply that fruit and vegetable consumption may need to be assessed separately to evaluate the relationship between fruit and vegetable intake and body weight changes. To investigate the influence of fruit and vegetable intake on body weight management, body fat mass assessment may be considered as an important measurement along with anthropometrics.

The large sample size and the objectively measured body composition are major strengths of this study. Nevertheless, our study has some limitations. Firstly, our study participants were not a representative sample of the populations of Atlantic Canada and the majority were Caucasians. Thus this may limit the generalizability of our study findings to other populations. Secondly, due to the constraints of the data collection, we were not able to calculate the total energy intake of study participants and analyse the associations between different types of fruit and vegetable consumption with the study outcomes. However, we controlled for total physical activity in the multivariable regression analyses and found an additive effect of the interactions between fruit intake and physical activity on obesity risk. These findings suggested that the observed association between fruit intake and obesity risk was independent of energy expenditure. Thirdly, the cross-sectional nature of the study design did not enable us to make a causal inference.

In summary, our findings suggested that higher levels of fruit and vegetable consumption were associated with lower levels of body adiposity. Fruit intake was consistently inversely associated with fat mass and obesity. While evidence regarding the positive health effects of vegetable consumption on chronic disease is substantial,[25] our findings may indicate that further research is needed to investigate whether the types of vegetable consumed and culinary approaches adopted for vegetable preparation are also important for the effective management of body weight. Given four in five men and two in three women in our study populations did not report adequate fruit and vegetable intake, there is a need to implement comprehensive intervention strategies to promote frequent and adequate fruit and vegetable consumption across Atlantic Canada.

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Authors' contributions:

Study conception and design: ZY, LP, and TD

Acquisition, analysis, and interpretation of data and drafting of manuscript: ZY

Critical revision of the article: VD, YC, CF, SG, MK, LP, ES, and TD

All authors have full access to all the data in the study, take responsibility for the integrity of the data and the accuracy of the data analysis, and give final approval of the version to be submitted.

Conflict of interest: None to declare.

Data sharing statement:

No datasets were generated during the current study. Data from the Atlantic PATH study is not publicly available to researchers without an approved data access request to Atlantic PATH, as per the Atlantic PATH consent form and study protocol. While the authors cannot provide data to a third party directly, the dataset can be provided by Atlantic PATH following a data access request approval. Interested researchers should contact Atlantic PATH (http://atlanticpath.ca/).

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Figure legends

Figure 1. Restricted cubic spline plots of the associations between daily fruit intake with body mass index (A), waist circumference (B), percentage fat mass (C), and fat mass index (D) among populations in Atlantic Canada[a].

Solid lines denote β coefficients of BMI (A), waist circumference (B), percentage fat mass (C), and FMI (D); dashed lines denote 95% CIs.

[a]Adjusted for age, sex, province, ethnicity, education, marital status, smoking, alcohol use, physical activity, chronic disease, and intake of vegetable and fruit or vegetable juice.

Figure 2. Odds ratios (95% confidence intervals) for obesity and abdominal obesity after replacing one standard deviation of fruit and fruit or vegetable juice [a].

[a]Adjusted for age, sex, province, ethnicity, education, marital status, smoking, alcohol use, physical activity, and chronic disease.

Table 1. Characteristics of study participants[*]

Characteristics	n	Men (n=7979)	n	Women (n=18361)
Age, year		54.0 (9.3)		52.6 (9.0)
Total fruit and vegetable, serving/day		4.9 (2.7)		5.6 (2.6)
Vegetable, serving/day		2.1 (1.4)		2.7 (1.5)
Fruit, serving/day		1.8 (1.4)		2.3 (1.3)
100% fruit or vegetable juice, serving/day		0.9 (1.1)		0.6 (0.9)
Total fruit and vegetable ≥ 7 servings/day, n (%)		1750 (21.9)		5803 (31.6)
Body weight, kg		85.0 (17.8)		76.7 (17.8)
Body height, cm		171.8 (8.4)		164.4 (6.7)
Body mass index, kg/m^2		28.7 (5.6)		28.4 (6.3)
Waist circumference, cm		97.0 (14.0)		92.7 (15.0)
Hip circumference, cm		104.7 (10.7)		106.1 (12.8)
Waist-to-hip ratio		0.93 (0.10)		0.87 (0.09)
Percentage fat mass, %	5311	30.8 (9.4)	13005	34.7 (8.8)
Fat mass index, kg/m^2	5307	9.1 (4.3)	12997	10.1 (4.4)
Fat free mass index, kg/m^2	5306	19.4 (3.2)	12996	18.0 (3.1)
Province, n (%)				
Nova Scotia		4272 (53.5)		9639 (52.5)
New Brunswick		2283 (28.6)		5424 (29.5)
Newfoundland and Labrador		1194 (15.0)		2630 (14.3)
Prince Edward Island		230 (2.9)		668 (3.6)
Ethnicity, n (%)				
White		7178 (90.0)		16016 (87.2)
Non-white		447 (5.6)		1218 (6.6)
DNK/PNA		354 (4.4)		1127 (6.1)
Education, n (%)				
Less than high school		1550 (19.4)		3293 (17.9)
College level		2978 (37.3)		7799 (42.5)
University level or higher		3430 (43.0)		7217 (39.3)
DNK/PNA		21 (0.3)		52 (0.3)
Marital status, n (%)				
Married or living together		6971 (87.4)		14120 (76.9)
Single, divorced, separated, or widowed		988 (12.4)		4185 (22.8)
DNK/PNA		20 (0.3)		56 (0.3)
Smoking status, n (%)				
Never		3796 (47.6)		9461 (51.5)
Former		3381 (42.4)		7023 (38.2)
Current		763 (9.6)		1719 (9.4)
DNK/PNA		39 (0.5)		158 (0.9)
Alcohol drinking, n (%)				
Abstainer		810 (10.2)		1985 (10.8)
Occasional drinker		2322 (29.1)		8489 (46.2)
Regular drinker		2793 (35.0)		5224 (28.5)
Habitual drinker		1833 (23.0)		2412 (13.1)
DNK/PNA		221 (2.8)		251 (1.4)
Total physical activity, n (%)				
Low		2615 (32.8)		6032 (32.9)
Medium		2725 (34.2)		6144 (33.5)
High		2628 (33.0)		6162 (33.6)
Chronic disease[†]**, yes, n (%)**		2618 (32.8)		4767 (26.0)

Obesity[‡], yes, n (%)	2774	(34.8)	6144	(33.5)
Abdominal obesity[§], yes, n (%)	2590	(32.5)	10951	(59.6)

DNK/PNA, do not know or prefer not to answer.
[*] Data are means (standard deviation) and number of participants (percentage). Percentages may not total 100 due to rounding.
[†] Self-reported diabetes mellitus and/or current use of antidiabetic medications, self-reported cardiovascular disease and/or current use of medications for cardiovascular disease treatment, and self-reported cancer.
[‡] BMI ≥ 30 kg/m^2.
[§] Waist circumference ≥ 102 cm for men and ≥ 88 cm for women.

Table 2. Associations between one standard deviation increment of fruit and vegetable intake with adiposity measurements

	β (95% CI)							
	BMI		Waist circumference		Percentage fat mass		Fat mass index	
Total fruit and vegetable								
Simple model*	-0.18	(-0.25, -0.12)	-0.67	(-0.85, -0.50)	-0.36	(-0.49, -0.23)	-0.16	(-0.21, -0.10)
Multivariable model†	-0.12	(-0.19, -0.05)	-0.40	(-0.58, -0.23)	-0.30	(-0.44, -0.17)	-0.14	(-0.19, -0.08)
Vegetable								
Simple model*	-0.11	(-0.18, -0.05)	-0.52	(-0.70, -0.35)	-0.25	(-0.38, -0.11)	-0.11	(-0.16, -0.05)
Multivariable model†	-0.05	(-0.11, 0.02)	-0.25	(-0.43, -0.08)	-0.18	(-0.31, -0.04)	-0.08	(-0.14, -0.03)
Additional adjustment for fruit and fruit or vegetable juice	-0.01	(-0.08, 0.06)	-0.13	(-0.32, 0.06)	-0.06	(-0.21, 0.08)	-0.03	(-0.10, 0.03)
Fruit								
Simple model*	-0.14	(-0.21, -0.08)	-0.57	(-0.74, -0.39)	-0.35	(-0.48, -0.21)	-0.15	(-0.21, -0.10)
Multivariable model†	-0.09	(-0.16, -0.03)	-0.36	(-0.53, -0.18)	-0.31	(-0.44, -0.17)	-0.14	(-0.19, -0.08)
Additional adjustment for vegetable and fruit or vegetable juice	-0.08	(-0.15, -0.01)	-0.29	(-0.48, -0.10)	-0.27	(-0.42, -0.13)	-0.12	(-0.18, -0.06)
Fruit or vegetable juice								
Simple model*	-0.13	(-0.19, -0.06)	-0.25	(-0.42, -0.07)	-0.13	(-0.26, 0.01)	-0.06	(-0.11, -0.00)
Multivariable model†	-0.12	(-0.18, -0.05)	-0.20	(-0.37, -0.03)	-0.11	(-0.25, 0.02)	-0.05	(-0.10, 0.01)
Additional adjustment for vegetable and fruit	-0.11	(-0.18, -0.05)	-0.17	(-0.35, 0.00)	-0.09	(-0.22, 0.04)	-0.04	(-0.09, 0.02)

BMI, body mass index; CI, confidence interval

* Adjusted for age, sex, and province.

† Adjusted for age, sex, province, ethnicity, education, marital status, smoking, alcohol use, physical activity, and chronic disease.

Table 3. Associations of fruit and vegetable intake with obesity and abdominal obesity

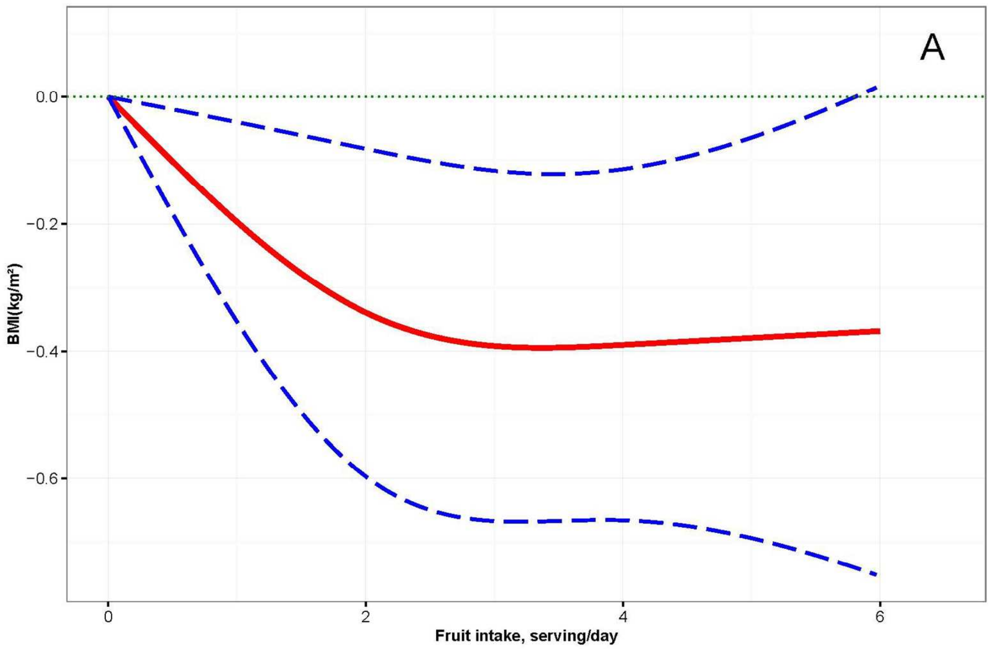
	Levels of fruit and vegetable intake, OR (95% CI)			
	Low	**Medium**	**High**	***P* for trend**
Obesity				
Total fruit and vegetable	< 4 servings/day	≥ 4, < 6 servings/day	≥ 6 servings/day	
Case/n	3714/10308	2732/8377	2472/7655	
Simple model*	1.0 (Reference)	0.90 (0.84, 0.95)	0.88 (0.82, 0.94)	<0.001
Multivariable model†	1.0 (Reference)	0.95 (0.89, 1.01)	0.95 (0.89, 1.02)	0.150
Vegetable	< 2 servings/day	≥ 2, < 3 servings/day	≥ 3 servings/day	
Case/n	2451/6821	2654/7968	3813/11551	
Simple model*	1.0 (Reference)	0.92 (0.85, 0.98)	0.94 (0.88, 1.00)	0.090
Multivariable model†	1.0 (Reference)	0.97 (0.91, 1.04)	1.05 (0.98, 1.12)	0.106
Additional adjustment for fruit and fruit or vegetable juice	1.0 (Reference)	1.01 (0.93, 1.08)	1.11 (1.03, 1.19)	0.004
Fruit	< 1 servings/day	≥ 1, < 2 servings/day	≥ 2 servings/day	
Case/n	3226/8936	2870/8651	2822/8753	
Simple model*	1.0 (Reference)	0.90 (0.84, 0.95)	0.86 (0.80, 0.91)	<0.001
Multivariable model†	1.0 (Reference)	0.92 (0.86, 0.98)	0.90 (0.84, 0.96)	0.003
Additional adjustment for vegetable and fruit or vegetable juice	1.0 (Reference)	0.91 (0.85, 0.97)	0.87 (0.81, 0.93)	<0.001
Fruit or vegetable juice	**No**	**Yes**	***P***	
Case/n	4524/12816	4394/13524		
Simple model*	1.0 (Reference)	0.88 (0.84, 0.93)	<0.001	
Multivariable model†	1.0 (Reference)	0.90 (0.86, 0.95)	<0.001	
Additional adjustment for vegetable and fruit	1.0 (Reference)	0.91 (0.86, 0.96)	<0.001	
Abdominal obesity				
Total fruit and vegetable	< 4 servings/day	≥ 4, < 6 servings/day	≥ 6 servings/day	
Case/n	5307/10308	4348/8377	3886/7655	
Simple model*	1.0 (Reference)	0.88 (0.83, 0.93)	0.80 (0.76, 0.86)	<0.001
Multivariable model†	1.0 (Reference)	0.94 (0.88, 1.00)	0.88 (0.83, 0.94)	<0.001
Vegetable	< 2 servings/day	≥ 2, < 3 servings/day	≥ 3 servings/day	
Case/n	3390/6821	4138/7968	6013/11551	
Simple model*	1.0 (Reference)	0.93 (0.87, 0.99)	0.84 (0.79, 0.89)	<0.001
Multivariable model†	1.0 (Reference)	0.99 (0.92, 1.06)	0.94 (0.88, 1.01)	0.066
Additional adjustment for fruit and fruit or vegetable juice	1.0 (Reference)	1.01 (0.94, 1.09)	0.99 (0.92, 1.06)	0.603
Fruit	< 1 servings/day	≥ 1, < 2 servings/day	≥ 2 servings/day	
Case/n	4479/8936	4562/8651	4500/8753	
Simple model*	1.0 (Reference)	0.93 (0.88, 0.99)	0.82 (0.77, 0.88)	<0.001

Multivariable model†	1.0 (Reference)	0.97 (0.91, 1.03)	0.88 (0.82, 0.94)	<0.001
Additional adjustment for vegetable and fruit or vegetable juice	1.0 (Reference)	0.97 (0.91, 1.04)	0.88 (0.82, 0.94)	<0.001
Fruit or vegetable juice	**No**	**Yes**	***P***	
Case/n	6972/12816	6569/13524		
Simple model*	1.0 (Reference)	0.90 (0.85, 0.95)	<0.001	
Multivariable model†	1.0 (Reference)	0.93 (0.88, 0.98)	0.005	
Additional adjustment for vegetable and fruit	1.0 (Reference)	0.93 (0.88, 0.98)	0.004	

CI, confidence interval; OR, odds ratio.

* Adjusted for age, sex, and province.

† Adjusted for age, sex, province, ethnicity, education, marital status, smoking, alcohol use, physical activity, and chronic disease.



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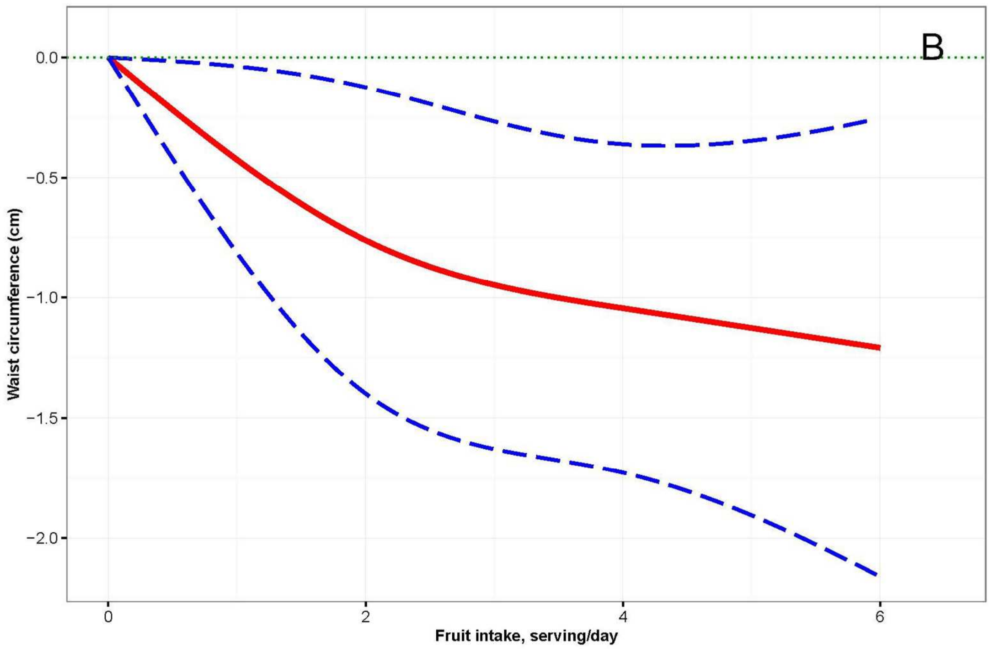

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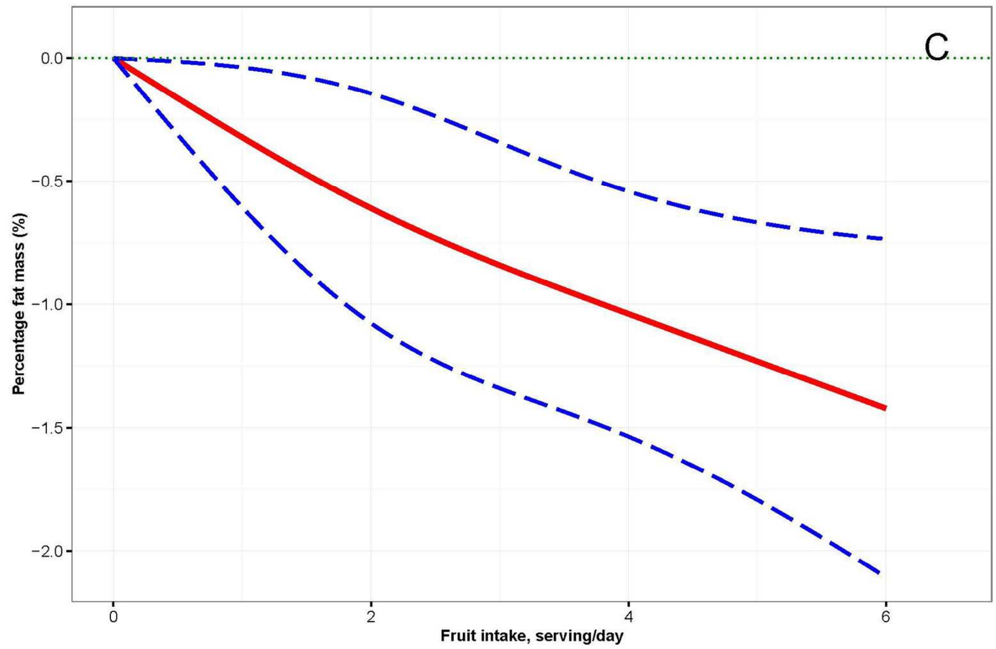

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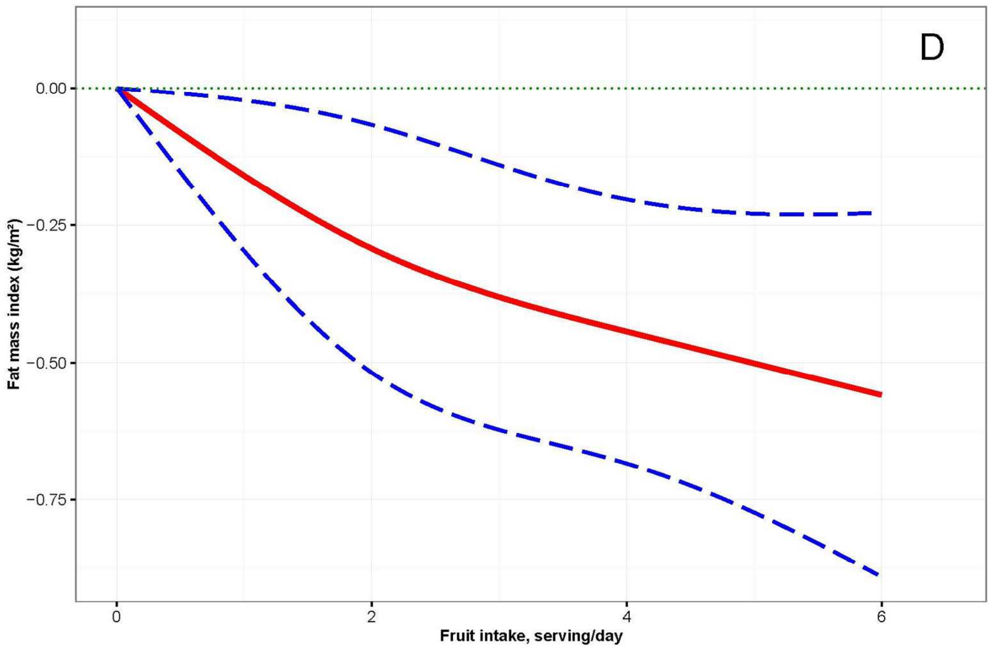

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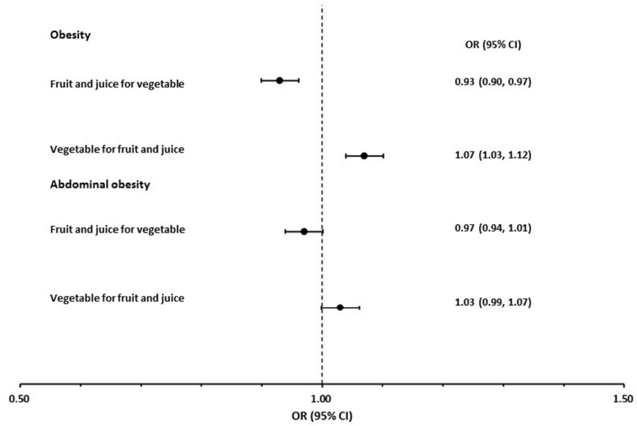

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Supplementary materials

Fruit and Vegetable Intake and Body Adiposity among Populations in Eastern Canada: the Atlantic Partnership for Tomorrow's Health Study

Zhijie M. Yu[1], Vanessa DeClercq[1], Yunsong Cui[1], Cynthia Forbes[1,2], Scott Grandy[2], Melanie Keats[2], Louise Parker[1], Ellen Sweeney[1], Trevor J.B. Dummer[3]

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Supplementary Table 1. Mean intakes of fruit and vegetable and correlation between vegetable and fruit and body adiposity measurements

	n	**Total fruit and vegetable**		**Vegetable**		**Fruit**		**100% fruit or vegetable juice**	
Mean intake (SD), serving/day	26340	5.4 (2.6)		2.5 (1.5)		2.1 (1.3)		0.7 (1.0)	
				Pearson partial correlation coefficients *					
Correlation		**r**	***P***	**r**	***P***	**r**	***P***	**r**	***P***
Vegetable	26340	0.79	<0.001	-	-	-	-	-	-
Fruit	26340	0.77	<0.001	0.41	<0.001	-	-	-	-
100% fruit or vegetable juice	26340	0.43	<0.001	0.03	<0.001	0.08	<0.001	-	-
Body mass index	26340	-0.03	<0.001	-0.03	<0.001	-0.02	<0.001	-0.02	0.001
Waist circumference	26340	-0.04	<0.001	-0.03	<0.001	-0.04	<0.001	-0.01	0.022
Waist-to-hip ratio	26340	-0.04	<0.001	-0.03	<0.001	-0.03	<0.001	-0.01	0.348
Percentage fat mass	18316	-0.04	<0.001	-0.03	<0.001	-0.03	<0.001	-0.01	0.066
Fat mass index	18304	-0.03	<0.001	-0.02	0.005	-0.02	0.002	-0.02	0.030
Fat free mass index	18302	0.00	0.693	0.00	0.916	0.01	0.112	-0.01	0.198

* Adjusted for age and sex.

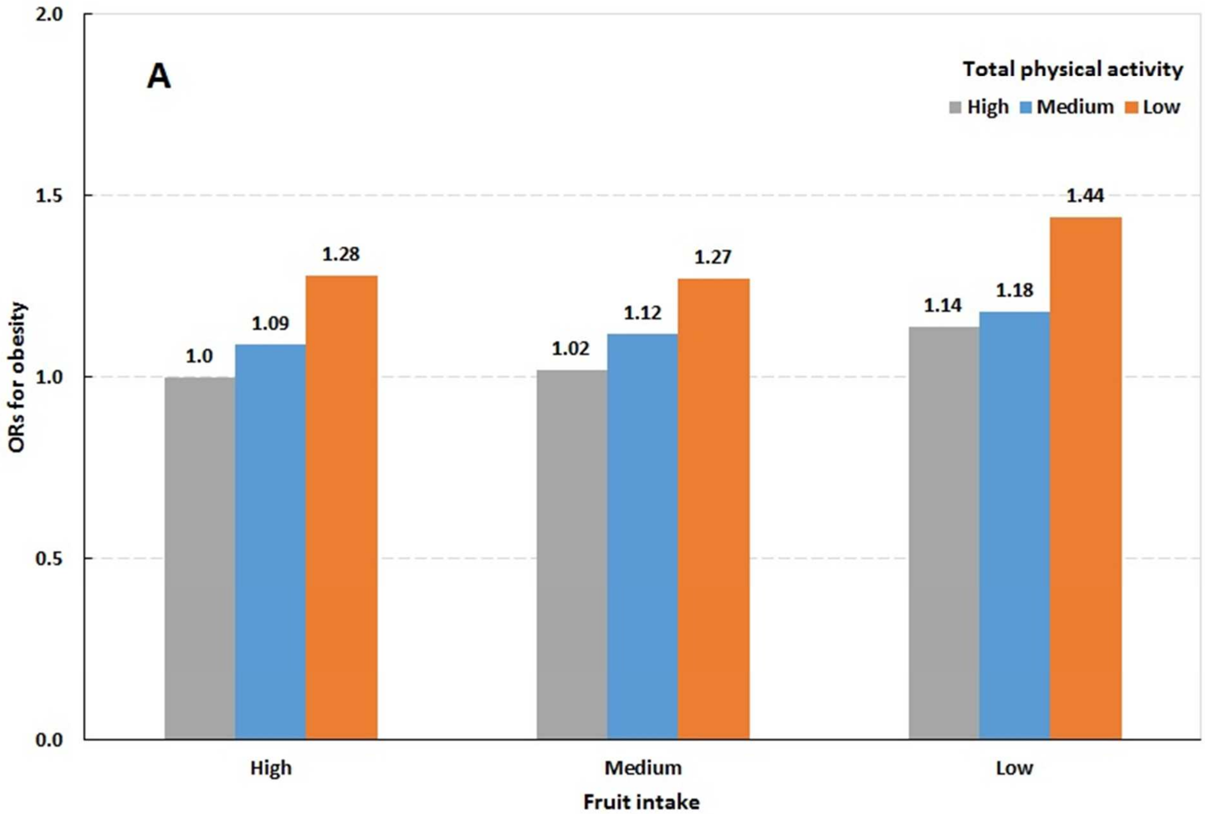
Supplementary Table 2. Odds ratios for obesity and abdominal obesity by alternatively replacing one standard deviation of intakes of vegetable, fruit, and 100% fruit or vegetable juice

Model	Obesity, OR (95% CI)		Abdominal obesity, OR (95% CI)	
Fruit for vegetable				
Simple model*	0.95	(0.91, 1.00)	0.98	(0.93, 1.03)
Multivariable model†	0.92	(0.88, 0.97)	0.95	(0.91, 1.00)
Fruit for juice				
Simple model*	0.99	(0.95, 1.03)	0.96	(0.93, 1.00)
Multivariable model†	0.99	(0.95, 1.03)	0.97	(0.93, 1.01)
Juice for vegetable				
Simple model*	0.97	(0.93, 1.00)	1.02	(0.98, 1.05)
Multivariable model†	0.93	(0.90, 0.97)	0.98	(0.94, 1.02)
Juice for fruit				
Simple model*	1.01	(0.97, 1.06)	1.04	(1.00, 1.08)
Multivariable model†	1.01	(0.97, 1.05)	1.03	(0.99, 1.07)
Vegetable for fruit				
Simple model*	1.05	(1.00, 1.10)	1.02	(0.97, 1.07)
Multivariable model†	1.08	(1.03, 1.14)	1.05	(1.00, 1.10)
Vegetable for juice				
Simple model*	1.04	(1.00, 1.08)	0.99	(0.95, 1.02)
Multivariable model†	1.07	(1.03, 1.12)	1.02	(0.98, 1.06)

CI, confidence interval; OR, odds ratio.

* Adjusted for age, sex, and province.

† Adjusted for age, sex, province, ethnicity, education, marital status, smoking, alcohol use, physical activity, and chronic disease.

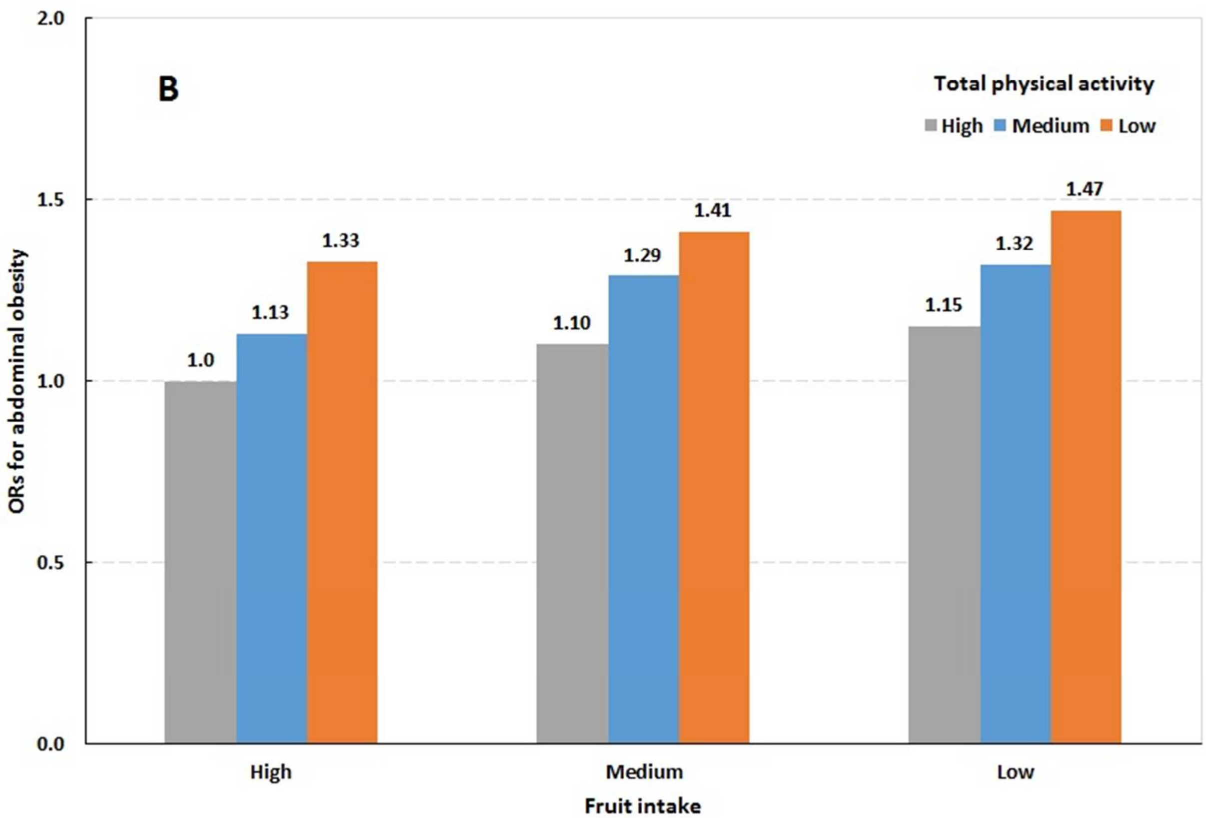


Supplementary Figure 1A. Joint associations of daily fruit intake and physical activity with risks of obesity[a,b].

[a]Adjusted for age, sex, province, ethnicity, education, marital status, smoking, alcohol use, chronic disease, and intakes of vegetable and fruit or vegetable juice.

Participants with the high levels of both fruit intake and total physical activity was the reference group.

[b]*P* for trend < 0.001 and *P* for interaction > 0.05.



Supplementary Figure 1B. Joint associations of daily fruit intake and physical activity with risks of abdominal obesity[a,b].

[a]Adjusted for age, sex, province, ethnicity, education, marital status, smoking, alcohol use, chronic disease, and intakes of vegetable and fruit or vegetable juice.

Participants with the high levels of both fruit intake and total physical activity was the reference group.

[b]*P* for trend < 0.001 and *P* for interaction > 0.05.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6, 7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6, 7
Bias	9	Describe any efforts to address potential sources of bias	*9*
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8, 9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8, 9
		(*b*) Describe any methods used to examine subgroups and interactions	8, 9
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	9
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	6
Outcome data	15*	Report numbers of outcome events or summary measures	Tables 1 and 3 and Supplementary Table 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	All tables
		(*b*) Report category boundaries when continuous variables were categorized	Table 3
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9, Supplementary Table 3 and Figure 1
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Fruit and Vegetable Intake and Body Adiposity among Populations in Eastern Canada: the Atlantic Partnership for Tomorrow's Health Study

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Fruit and Vegetable Intake and Body Adiposity among Populations in Eastern Canada: the Atlantic Partnership for Tomorrow's Health Study

Running title: Fruit and Vegetable Intake and Body Adiposity

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Number of tables: 3; number of figures: 2;

Number of supplementary tables: 2; number of supplementary figure: 1

References: 32

Abstract

Objectives: The prevalence of obesity among populations in the Atlantic Provinces is the highest in Canada. Some studies suggest that adequate fruit and vegetable consumption may help body weight management. We assessed the associations between fruit and vegetable intake with body adiposity among individuals who participated in the baseline survey of the Atlantic Partnership for Tomorrow's Health (Atlantic PATH) cohort study.

Methods: We carried out a cross-sectional analysis among 26340 individuals (7979 men and 18361 women) aged 35-69 years who were recruited in the baseline survey of the Atlantic PATH study. Data on fruit and vegetable intake, sociodemographic and behavioural factors, chronic disease, anthropometric measurements, and body composition were included in the analysis.

Results: In the multivariable regression analyses, one standard deviation increment of total fruit and vegetable intake was inversely associated with BMI (-0.12 kg/m^2; 95% CI, -0.19, -0.05), waist circumference (-0.40 cm; 95% CI, -0.58, -0.23), percentage fat mass (-0.30 %; 95% CI, -0.44, -0.17), and fat mass index (-0.14 kg/m^2; 95% CI, -0.19, -0.08). Fruit intake, but not vegetable intake, was consistently inversely associated with anthropometric indices, fat mass, obesity, and abdominal obesity.

Conclusions: Fruit and vegetable consumption was inversely associated with body adiposity among the participant population in Atlantic Canada. This association was primarily attributable to fruit intake. Longitudinal studies and randomized trials are warranted to confirm these observations and investigate the underlying mechanisms.

Strengths and limitations of this study

- Data from a large-scale population-based survey with objectively measured body composition.
- Associations between fruit and vegetable intake with body adiposity measurements were assessed in combination and separately using multivariable regression models.
- Limitations of a cross-sectional analysis with an unrepresentative sample.

Introduction

The increasing prevalence of obesity, a major risk factor for a variety of chronic diseases, including coronary heart disease, stroke, diabetes mellitus, and some cancers, is a critical worldwide public health concern.[1] People living in Atlantic Canada have the highest prevalence of obesity (BMI ≥ 30 kg/m^2) among the Canadian population. In 2011, the prevalence of obesity ranged from 24% in Prince Edward Island to 28% in Newfoundland and Labrador. It is predicted that the percentage of people who are overweight or obese will continue to increase.[2] Appropriate strategies to effectively halt the obesity epidemic among populations in this region (and other areas) are of critical public health interest.

Fruits and vegetables are important components of a healthy diet, contributing to a large proportion of an individual's daily intake of vitamins, minerals, and dietary fibre. Health Canada recommends that adults should consume 7-10 servings of a variety of fruits and vegetables per day to reduce the risks of cancer and other chronic diseases.[3] Further, substantial evidence has shown that increased consumption of fruits and vegetables may reduce the risks of mortality from all causes[4] and the development of cardiometabolic disease.[5–8] Interestingly, some systematic reviews have suggested that appropriately increased fruit and vegetable intake may help body weight management by preventing the development of obesity and reducing body weight over time.[9–12] However, one meta-analysis of interventional trials showed that increased fruit and vegetable intake had an effect on weight loss[11]; another study did not find an effect in terms of body weight reduction.[13] A Canadian study found that increased fruit intake was associated with reduced weight gain over a six-year period among participants of the Quebec Family Study.[14] Additionally, some studies suggest that fruit consumption might have a more favourable impact on body weight control than vegetable consumption.[9,15]

We hypothesize that fruit and vegetable consumption may play a role in the obesity epidemic among populations living in Atlantic Canada. The primary aims of this study were to assess: 1) the intake of fruits, vegetables, and 100% fruit or vegetable juice; and 2) associations between fruit, vegetable, and

100% fruit or vegetable juice intake with anthropometric indices and body composition among participants who were enrolled in the baseline survey of the Atlantic Partnership for Tomorrow's Health (Atlantic PATH) study. We further assessed how the consumption of fruit, vegetable, and 100% fruit or vegetable juice were associated with body adiposity measurements by considering these three components as one food group and treating them independently in the multivariable logistic regression analyses.[15,16]

Methods

Study population

The Atlantic PATH study is a part of the Canadian Partnership for Tomorrow Project (CPTP), a pan-Canadian longitudinal cohort study examining the role of genetic, environmental, behavioural and lifestyle factors in the development of cancer and chronic disease.[17,18] The Atlantic PATH study is a population-based cohort in which study participants were residents of one of the four Atlantic Canadian Provinces (Nova Scotia, New Brunswick, Newfoundland and Labrador, and Prince Edward Island) and aged between 35 and 69 years. Study participants were recruited from the general public through a combination of community outreach and awareness activities, advertising and media campaigns, and invitation. During 2009 to 2015, 31173 Atlantic PATH study participants, including 9445 men and 21728 women, were recruited from the four Atlantic Canada provinces. The study was approved by appropriate Research Ethics Boards in each province. All participants provided written informed consent prior to participation. All data collection procedures followed the research protocol guidelines as approved by the Research Ethics Boards.

We excluded 4833 participants from this analysis as a result of current pregnancy (n=40), missing data on fruit, vegetable, and 100% fruit or vegetable juice (n=816), anthropometric indices (n=4127), and other variables (n=90). The final analysis sample was comprised of 26340 participants (7979 men and 18361 women).

Data collection

Data collection procedures have been reported previously.[18,19] In brief, a set of standardised questionnaires on sociodemographic, health status, medication use, diet, lifestyle factors, and self-measured anthropometric indices were completed by participants. Physical measurements (including anthropometric indices and body composition) were measured by research nurses at an assessment centre.

Assessment of fruit and vegetable consumption

Consumption of fruit, vegetable, and 100% fruit or vegetable juice were assessed by using three questions: 1) In a typical day, how many servings of vegetable do you eat? One serving is about ½ cup or 125 ml of fresh, frozen, canned, or cooked vegetables. 2) In a typical day, how many servings of fruit do you eat? One serving is about ½ cup or 125 ml of fresh, frozen, or canned fruit. 3) In a typical day, how many servings of 100% fruit or vegetable juice do you drink? One serving is about ½ cup or 125 ml.

Assessment of sociodemographic and behavioural factors

Ethnicity was categorized as white and non-white because there was little ethnic diversity in the cohort. Educational attainment was categorized as high school or lower, college level, and university level or higher. Marital status was grouped as married or living together and single, divorced, separated, or widowed. For smoking behaviour, participants were grouped as non-smoker, former smoker, and current smoker. For alcohol drinking, respondents were classified as abstainer, occasional drinker (>0- ≤ 2-3 times/month), regular drinker (≥ 1 time/week - ≤ 2-3 times/week), and habitual drinker (≥ 4-5 times/week).[19]

Physical activity was assessed by using either the long or short form of the International Physical Activity Questionnaire (IPAQ).[20] For evaluation of total physical activity, we calculated metabolic equivalent minutes per week (MET-min/week) for each participant with data derived from the long and short form questionnaires, respectively. The MET scores were computed according to the IPAQ scoring protocol.[21]

We then ranked the sex-specific total MET scores into tertiles for data derived from the long and short form questionnaires, separately. Levels of total physical activity were classified as low, medium, and high by the low to high MET score tertiles.

Assessment of chronic diseases

Self-reported current medication use was collected and medication data were coded according to the Nova Scotia Formulary (NSF) (www.nspharmacare.ca).[22] The NSF uses the standardised Anatomical Therapeutic Chemical (ATC) Classification System which was developed by the World Health Organization. Participants also reported chronic diseases diagnosed by a physician. For this analysis, we defined chronic disease (yes/no) based upon the following: (a) self-reported diabetes mellitus and/or current use of antidiabetic medications, or (b) self-reported myocardial infarction, stroke and/or current use of CVD medications, or (c) self-reported cancer.

Physical measurements

Body weight, percentage fat mass, fat mass, and fat free mass were measured using the Tanita bioelectrical impedance device (Tanita BC-418, Tanita Corporation of America Inc., Arlington Heights, Illinois). Height was measured by a Seca stadiometer. BMI was calculated as weight in kilograms divided by height in meters squared. We also calculated fat mass index (FMI) and fat free mass index (FFMI) by dividing fat mass and fat free mass in kilograms by height in meters squared, respectively. Waist and hip circumferences were measured by using Lufin steel tape. Obesity was defined as a BMI $\geq$ 30 kg/m^2. Abdominal obesity was defined as a waist circumference $\geq$ 102 cm for men or $\geq$ 88 cm for women.[23]

Among our study participants, measured data were available for 72% of participants for weight and height, 69% for both waist and hip circumferences, and 70% for body composition. For participants who did not have measured anthropometric indices, self-reported measures were utilized in the analyses.

Statistical analyses

We computed Pearson partial correlation coefficients between fruit and vegetable intake and anthropometric measures and body composition with adjustment for age and sex. To examine the associations between fruit and vegetable intake with obesity, we derived z-scores for the intakes of total fruit and vegetable, vegetable, fruit, and fruit or vegetable juice, respectively. Z-scores enable us to combine scores from the exposure variables that have different means, standard deviations, and ranges. Further, the procedure standardizes the distributions of the exposure variables and for this analysis, increased the statistical power in both the linear and logistic regression analyses when the exposure variables were treated as a continuous variable. We categorized total fruit and vegetable, vegetable, and fruit intake into low, medium, and high levels according to the approximate tertiles, respectively. Fruit or vegetable juice intake was dichotomized (yes/no) as 49% of the participants did not consume fruit or vegetable juice. We utilized multiple linear regression models with Robust M estimator to evaluate the associations between fruit and vegetable intake with BMI, waist circumference, percentage fat mass, and FMI. We employed multiple logistic regression models to compute the odds ratios (OR) and 95% confidence intervals (CI) of having obesity and abdominal obesity across different levels of fruit and vegetable intake. To evaluate the independent associations between consumption of fruit, vegetable, and fruit or vegetable juice with obesity, we performed both the linear and logistic regression analyses using three models: model one was adjusted for age, sex, and province; model two was further adjusted for ethnicity, socioeconomic status, behavioural factors, and chronic disease based on model one; and model three was additionally and mutually adjusted for fruit, vegetable, and fruit or vegetable juice intake based on model two.

Further, as we found a consistent inverse association between daily fruit intake and adiposity, we plotted the associations of fruit intake with BMI, waist circumference, percentage fat mass, and FMI by using the restricted cubic spline (RCS).[24] We performed the RCS plot among participants who reported daily fruit intake ≤ 6 servings/day (99.5% of total participants) and utilized three knots located at the 5^{th}, 50^{th}, and

95th percentiles of the fruit intake distribution. All the models were multivariable with adjustment for all of the covariables and the intakes of vegetable and fruit or vegetable juice. Given that energy expenditure has been shown to be strongly and inversely associated with body adiposity,[1,19] we also analysed the interactions between fruit intake and physical activity in relation to risks of obesity and abdominal obesity. In addition, we evaluated whether substituting one standard deviation (SD) of fruit intake for vegetable intake or vice versa might affect obesity risk by using multivariable logistic regression models.[16] We carried out a sensitivity analysis among participants with all measured body adiposity measurements (n=17528) and yielded a similar pattern of results. We, therefore, reported the results for the entire samples. Statistical significance was defined as $P < 0.05$ (two-sided). Data management and analyses were performed with SAS for Windows, version 9.4 (SAS Institute, Cary, North Carolina).

Results

Fruit and vegetable consumption among study participants

Average total fruit and vegetable intake was 5.4 servings per day in the study participants (4.9 servings/day in men and 5.6 servings/day in women). Only 22% of men and 32% of women reported total fruit and vegetable intake ≥ 7 servings/day, respectively (Table 1 and Supplementary Table 1). The correlation between fruit or vegetable juice intake with fruit intake was higher compared with that for vegetable intake. Participants who reported high levels of fruit and vegetable intake were more likely to be females, white, married, have higher levels of education, and engage in higher levels of physical activity. They were also less likely to be current smokers compared with those who reported low levels of fruit and vegetable consumption (data not shown).

Fruit and vegetable consumption and body adiposity

There was a consistently negative correlation between fruit and vegetable intake with body adiposity measures (Supplementary Table 1). There was no statistically significant correlation between fruit and vegetable intake with FFMI.

In the multivariable linear regression analyses, one SD increment of total fruit and vegetable intake was inversely associated with BMI (-0.12 kg/m^2; 95% CI, -0.19, -0.05), waist circumference (-0.40 cm; 95% CI, -0.58, -0.23), percentage fat mass (-0.30 %; 95% CI, -0.44, -0.17), and FMI (-0.14 kg/m^2; 95% CI, -0.19, -0.08) (Table 2). In the multivariable logistic regression analyses, individuals with high levels of total fruit and vegetable intake had reduced likelihoods of 12% (OR, 0.88; 95% CI, 0.83, 0.94) for having abdominal obesity compared with those with low levels (*P* for trend < 0.001, Table 3).

Independent associations of fruit, vegetable, and fruit or vegetable juice consumption with body adiposity

In the multivariable regression analyses, fruit consumption was consistently inversely associated with adiposity measurements (Table 2 and Figure 1) and the likelihoods for obesity and abdominal obesity (Table 3). Compared with those with low levels of fruit consumption, individuals with medium to high levels of fruit consumption had ORs of 0.92 (95% CI, 0.86, 0.98) and 0.90 (95% CI, 0.84, 0.96) for obesity and 0.97 (95% CI, 0.91, 1.03) and 0.88 (95% CI, 0.82, 0.94) for abdominal obesity, respectively (All *P* for trend < 0.05). These associations remained materially unchanged after further controlling for the intake of vegetable and fruit or vegetable juice. The similar associations were evident for juice intake but were less consistent than those observed for fruit intake. Moreover, fruit consumption was shown to have additive effects with total physical activity in terms of the likelihoods for obesity and abdominal obesity (Supplementary Figure 1).

The inverse association between vegetable consumption and obesity was attenuated and became positive after further controlling for the intakes of fruit and fruit or vegetable juice (Table 3). Further analyses showed that substituting one SD of the intakes of fruit and juice for vegetables resulted in the reduced likelihoods for obesity (Figure 2 and Supplementary Table 2). Conversely, substituting one SD of vegetable intake for fruit and juice led to the increased likelihoods for obesity.

Discussion

In this large-scale, population-based cross-sectional analysis, we found that total daily fruit and vegetable intake among Atlantic Canadians was comparable to those reported from a nationally representative sample of Canadians.[25] We observed that total fruit and vegetable intake was inversely associated with body adiposity. This association appeared to be primarily attributable to fruit consumption. These findings are in line with the previous studies reporting the potentially favourable role of fruit consumption in effective body weight management.[9,14,15] However, after controlling for the consumption of fruit, fruit or vegetable juice, and other covariables, vegetable intake tended to be positively related to obesity. This finding is consistent with that reported in a longitudinal study carried out in American women.[15] However, the mechanisms underlying these observed associations is unclear.

Thus far, substantial evidence appears to show that adequate fruit and vegetable consumption reduces the risk of chronic disease.[26] With respect to body weight management, regular daily fruit consumption may displace energy-dense foods, resulting in attenuated dietary energy density and reduced total energy intake.[27] Fruits have abundant soluble dietary fibres which may enhance post-meal satiety and decrease both glycaemic index and glycaemic load of consumed foods causing lowered energy absorption.[28] Moreover, fruits are rich in phytochemicals that have anti-oxidative and anti-inflammatory effects against the obesity-induced oxidative stress and subclinical inflammation.[26,29] While most vegetables have these characteristics, in multivariable regression analyses, we observed a different association between vegetable intake and obesity from those for fruit consumption.

In our analyses, the association between 100% fruit or vegetable juice and obesity was similar to the association between fruit and obesity. Some longitudinal studies have shown that a vegetable-rich dietary pattern might lead to increased body weight[30] and an unhealthful plant-based diet that was featured with sweetened foods and beverages, refined grains, and potatoes might be related to increased incidence of type 2 diabetes.[31] Regular potato intake, especially french fries, was associated with obesity.[32] These findings may imply that some fatty substances added during the preparation of vegetables and the type of vegetable consumed (e.g., starchy vegetables), might play a role in the positive association between increasing vegetable intake and increasing obesity. Our data appeared to support this hypothesis as oil products and starchy vegetables are seldom used to prepare 100% juice. Nevertheless, further research is needed to clarify the potential role of vegetable intake in obesity development.

To our knowledge, this is the first large-scale, population-based study investigating the associations between fruit and vegetable intake with objectively measured body composition. Our findings imply that fruit and vegetable consumption may need to be assessed separately to evaluate the relationship between fruit and vegetable intake and body weight changes. To investigate the influence of fruit and vegetable intake on body weight management, body fat mass assessment may be considered as an important measurement along with anthropometrics.

The large sample size and the objectively measured body composition are major strengths of this study. Nevertheless, our study has some limitations. Firstly, our study participants were recruited as volunteers of the Atlantic PATH cohort, therefore, our study sample was not a representative sample of the populations of Atlantic Canada. The majority were Caucasians and about 70% of study participants were females.[18] Thus, this may limit the generalizability of our current cross-sectional study findings to other populations. Secondly, due to the constraints of the data collection, we were not able to calculate the total energy intake of study participants and analyse the associations between different types of fruit and vegetable consumption with the study outcomes. However, we controlled for total physical activity in the multivariable regression analyses and found an additive effect of the interactions between fruit intake and physical activity on obesity risk. These findings suggested that the observed association between fruit intake and obesity risk was independent of energy expenditure. Thirdly, though we collected data on the habitual fruit, vegetable, and 100% juice intake, the cross-sectional nature of the study design did not enable us to make either temporal or causal inference.

In summary, our findings suggested that higher levels of fruit and vegetable consumption were associated with lower levels of body adiposity. Fruit intake was consistently inversely associated with fat mass and obesity. While evidence regarding the positive health effects of vegetable consumption on chronic disease is substantial,[26] our findings may indicate that further research is needed to investigate whether the types of vegetable consumed and culinary approaches adopted for vegetable preparation are also important for the effective management of body weight. Given four in five men and two in three women in our study populations did not report adequate fruit and vegetable intake, there is a need to implement comprehensive intervention strategies to promote frequent and adequate fruit and vegetable consumption across Atlantic Canada.

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Authors' contributions:

Study conception and design: ZY, LP, and TD

Acquisition, analysis, and interpretation of data and drafting of manuscript: ZY

Critical revision of the article: VD, YC, CF, SG, MK, LP, ES, and TD

All authors have full access to all the data in the study, take responsibility for the integrity of the data and the accuracy of the data analysis, and give final approval of the version to be submitted.

Conflict of interest: None to declare.

Data sharing statement:

No datasets were generated during the current study. Data from the Atlantic PATH study is not publicly available to researchers without an approved data access request to Atlantic PATH, as per the Atlantic PATH consent form and study protocol. While the authors cannot provide data to a third party directly, the dataset can be provided by Atlantic PATH following a data access request approval. Interested researchers should contact Atlantic PATH (http://atlanticpath.ca/).

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Figure legends

Figure 1. Restricted cubic spline plots of the associations between daily fruit intake with body mass index (A), waist circumference (B), percentage fat mass (C), and fat mass index (D) among populations in Atlantic Canada[a].

Solid lines denote β coefficients of BMI (A), waist circumference (B), percentage fat mass (C), and FMI (D); dashed lines denote 95% CIs.

[a]Adjusted for age, sex, province, ethnicity, education, marital status, smoking, alcohol use, physical activity, chronic disease, and intake of vegetable and fruit or vegetable juice.

Figure 2. Odds ratios (95% confidence intervals) for obesity and abdominal obesity after replacing one standard deviation of fruit and fruit or vegetable juice [a].

[a]Adjusted for age, sex, province, ethnicity, education, marital status, smoking, alcohol use, physical activity, and chronic disease.

Table 1. Characteristics of study participants*

Characteristics	n	Men (n=7979)		n	Women (n=18361)	
Age, year		54.0	(9.3)		52.6	(9.0)
Total fruit and vegetable, serving/day		4.9	(2.7)		5.6	(2.6)
Vegetable, serving/day		2.1	(1.4)		2.7	(1.5)
Fruit, serving/day		1.8	(1.4)		2.3	(1.3)
100% fruit or vegetable juice, serving/day		0.9	(1.1)		0.6	(0.9)
Total fruit and vegetable ≥ 7 servings/day, n (%)		1750	(21.9)		5803	(31.6)
Body weight, kg		85.0	(17.8)		76.7	(17.8)
Body height, cm		171.8	(8.4)		164.4	(6.7)
Body mass index, kg/m^2		28.7	(5.6)		28.4	(6.3)
Waist circumference, cm		97.0	(14.0)		92.7	(15.0)
Hip circumference, cm		104.7	(10.7)		106.1	(12.8)
Waist-to-hip ratio		0.93	(0.10)		0.87	(0.09)
Percentage fat mass, %	5311	30.8	(9.4)	13005	34.7	(8.8)
Fat mass index, kg/m^2	5307	9.1	(4.3)	12997	10.1	(4.4)
Fat free mass index, kg/m^2	5306	19.4	(3.2)	12996	18.0	(3.1)
Province, n (%)						
Nova Scotia		4272	(53.5)		9639	(52.5)
New Brunswick		2283	(28.6)		5424	(29.5)
Newfoundland and Labrador		1194	(15.0)		2630	(14.3)
Prince Edward Island		230	(2.9)		668	(3.6)
Ethnicity, n (%)						
White		7178	(90.0)		16016	(87.2)
Non-white		447	(5.6)		1218	(6.6)
DNK/PNA		354	(4.4)		1127	(6.1)
Education, n (%)						
Less than high school		1550	(19.4)		3293	(17.9)
College level		2978	(37.3)		7799	(42.5)
University level or higher		3430	(43.0)		7217	(39.3)
DNK/PNA		21	(0.3)		52	(0.3)
Marital status, n (%)						
Married or living together		6971	(87.4)		14120	(76.9)
Single, divorced, separated, or widowed		988	(12.4)		4185	(22.8)
DNK/PNA		20	(0.3)		56	(0.3)
Smoking status, n (%)						
Never		3796	(47.6)		9461	(51.5)
Former		3381	(42.4)		7023	(38.2)
Current		763	(9.6)		1719	(9.4)
DNK/PNA		39	(0.5)		158	(0.9)
Alcohol drinking, n (%)						
Abstainer		810	(10.2)		1985	(10.8)
Occasional drinker		2322	(29.1)		8489	(46.2)
Regular drinker		2793	(35.0)		5224	(28.5)
Habitual drinker		1833	(23.0)		2412	(13.1)
DNK/PNA		221	(2.8)		251	(1.4)
Total physical activity, n (%)						
Low		2615	(32.8)		6032	(32.9)
Medium		2725	(34.2)		6144	(33.5)
High		2628	(33.0)		6162	(33.6)
Chronic disease†, yes, n (%)		2618	(32.8)		4767	(26.0)

Obesity[‡], yes, n (%)	2774	(34.8)	6144	(33.5)
Abdominal obesity[§], yes, n (%)	2590	(32.5)	10951	(59.6)

DNK/PNA, do not know or prefer not to answer.

[*] Data are means (standard deviation) and number of participants (percentage). Percentages may not total 100 due to rounding.

[†] Self-reported diabetes mellitus and/or current use of antidiabetic medications, self-reported cardiovascular disease and/or current use of medications for cardiovascular disease treatment, and self-reported cancer.

[‡] BMI ≥ 30 kg/m^2.

[§] Waist circumference ≥ 102 cm for men and ≥ 88 cm for women.

Table 2. Associations between one standard deviation increment of fruit and vegetable intake with adiposity measurements

	β (95% CI)							
	BMI		Waist circumference		Percentage fat mass		Fat mass index	
Total fruit and vegetable								
Simple model*	-0.18	(-0.25, -0.12)	-0.67	(-0.85, -0.50)	-0.36	(-0.49, -0.23)	-0.16	(-0.21, -0.10)
Multivariable model†	-0.12	(-0.19, -0.05)	-0.40	(-0.58, -0.23)	-0.30	(-0.44, -0.17)	-0.14	(-0.19, -0.08)
Vegetable								
Simple model*	-0.11	(-0.18, -0.05)	-0.52	(-0.70, -0.35)	-0.25	(-0.38, -0.11)	-0.11	(-0.16, -0.05)
Multivariable model†	-0.05	(-0.11, 0.02)	-0.25	(-0.43, -0.08)	-0.18	(-0.31, -0.04)	-0.08	(-0.14, -0.03)
Additional adjustment for fruit and fruit or vegetable juice	-0.01	(-0.08, 0.06)	-0.13	(-0.32, 0.06)	-0.06	(-0.21, 0.08)	-0.03	(-0.10, 0.03)
Fruit								
Simple model*	-0.14	(-0.21, -0.08)	-0.57	(-0.74, -0.39)	-0.35	(-0.48, -0.21)	-0.15	(-0.21, -0.10)
Multivariable model†	-0.09	(-0.16, -0.03)	-0.36	(-0.53, -0.18)	-0.31	(-0.44, -0.17)	-0.14	(-0.19, -0.08)
Additional adjustment for vegetable and fruit or vegetable juice	-0.08	(-0.15, -0.01)	-0.29	(-0.48, -0.10)	-0.27	(-0.42, -0.13)	-0.12	(-0.18, -0.06)
Fruit or vegetable juice								
Simple model*	-0.13	(-0.19, -0.06)	-0.25	(-0.42, -0.07)	-0.13	(-0.26, 0.01)	-0.06	(-0.11, -0.00)
Multivariable model†	-0.12	(-0.18, -0.05)	-0.20	(-0.37, -0.03)	-0.11	(-0.25, 0.02)	-0.05	(-0.10, 0.01)
Additional adjustment for vegetable and fruit	-0.11	(-0.18, -0.05)	-0.17	(-0.35, 0.00)	-0.09	(-0.22, 0.04)	-0.04	(-0.09, 0.02)

BMI, body mass index; CI, confidence interval

* Adjusted for age, sex, and province.

† Adjusted for age, sex, province, ethnicity, education, marital status, smoking, alcohol use, physical activity, and chronic disease.

Table 3. Associations of fruit and vegetable intake with obesity and abdominal obesity

	Levels of fruit and vegetable intake, OR (95% CI)			
	Low	Medium	High	*P* for trend
Obesity				
Total fruit and vegetable	< 4 servings/day	≥ 4, < 6 servings/day	≥ 6 servings/day	
Case/n	3714/10308	2732/8377	2472/7655	
Simple model*	1.0 (Reference)	0.90 (0.84, 0.95)	0.88 (0.82, 0.94)	<0.001
Multivariable model†	1.0 (Reference)	0.95 (0.89, 1.01)	0.95 (0.89, 1.02)	0.150
Vegetable	< 2 servings/day	≥ 2, < 3 servings/day	≥ 3 servings/day	
Case/n	2451/6821	2654/7968	3813/11551	
Simple model*	1.0 (Reference)	0.92 (0.85, 0.98)	0.94 (0.88, 1.00)	0.090
Multivariable model†	1.0 (Reference)	0.97 (0.91, 1.04)	1.05 (0.98, 1.12)	0.106
Additional adjustment for fruit and fruit or vegetable juice	1.0 (Reference)	1.01 (0.93, 1.08)	1.11 (1.03, 1.19)	0.004
Fruit	< 1 servings/day	≥ 1, < 2 servings/day	≥ 2 servings/day	
Case/n	3226/8936	2870/8651	2822/8753	
Simple model*	1.0 (Reference)	0.90 (0.84, 0.95)	0.86 (0.80, 0.91)	<0.001
Multivariable model†	1.0 (Reference)	0.92 (0.86, 0.98)	0.90 (0.84, 0.96)	0.003
Additional adjustment for vegetable and fruit or vegetable juice	1.0 (Reference)	0.91 (0.85, 0.97)	0.87 (0.81, 0.93)	<0.001
Fruit or vegetable juice	**No**	**Yes**	***P***	
Case/n	4524/12816	4394/13524		
Simple model*	1.0 (Reference)	0.88 (0.84, 0.93)	<0.001	
Multivariable model†	1.0 (Reference)	0.90 (0.86, 0.95)	<0.001	
Additional adjustment for vegetable and fruit	1.0 (Reference)	0.91 (0.86, 0.96)	<0.001	
Abdominal obesity				
Total fruit and vegetable	< 4 servings/day	≥ 4, < 6 servings/day	≥ 6 servings/day	
Case/n	5307/10308	4348/8377	3886/7655	
Simple model*	1.0 (Reference)	0.88 (0.83, 0.93)	0.80 (0.76, 0.86)	<0.001
Multivariable model†	1.0 (Reference)	0.94 (0.88, 1.00)	0.88 (0.83, 0.94)	<0.001
Vegetable	< 2 servings/day	≥ 2, < 3 servings/day	≥ 3 servings/day	
Case/n	3390/6821	4138/7968	6013/11551	
Simple model*	1.0 (Reference)	0.93 (0.87, 0.99)	0.84 (0.79, 0.89)	<0.001
Multivariable model†	1.0 (Reference)	0.99 (0.92, 1.06)	0.94 (0.88, 1.01)	0.066
Additional adjustment for fruit and fruit or vegetable juice	1.0 (Reference)	1.01 (0.94, 1.09)	0.99 (0.92, 1.06)	0.603
Fruit	< 1 servings/day	≥ 1, < 2 servings/day	≥ 2 servings/day	
Case/n	4479/8936	4562/8651	4500/8753	
Simple model*	1.0 (Reference)	0.93 (0.88, 0.99)	0.82 (0.77, 0.88)	<0.001

Multivariable model†	1.0 (Reference)	0.97 (0.91, 1.03)	0.88 (0.82, 0.94)	<0.001
Additional adjustment for vegetable and fruit or vegetable juice	1.0 (Reference)	0.97 (0.91, 1.04)	0.88 (0.82, 0.94)	<0.001
Fruit or vegetable juice	**No**	**Yes**	***P***	
Case/n	6972/12816	6569/13524		
Simple model*	1.0 (Reference)	0.90 (0.85, 0.95)	<0.001	
Multivariable model†	1.0 (Reference)	0.93 (0.88, 0.98)	0.005	
Additional adjustment for vegetable and fruit	1.0 (Reference)	0.93 (0.88, 0.98)	0.004	

CI, confidence interval; OR, odds ratio.

* Adjusted for age, sex, and province.

† Adjusted for age, sex, province, ethnicity, education, marital status, smoking, alcohol use, physical activity, and chronic disease.

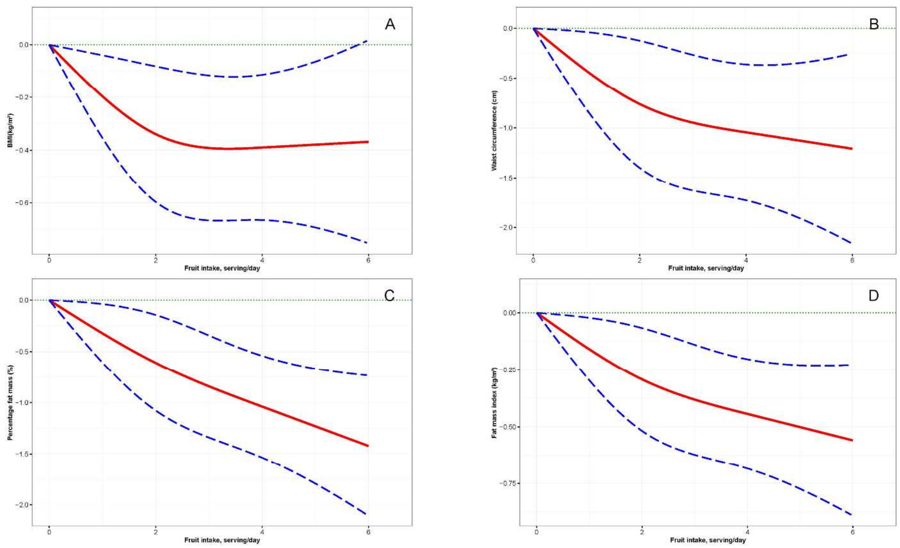

Figure 1.

338x190mm (300 x 300 DPI)

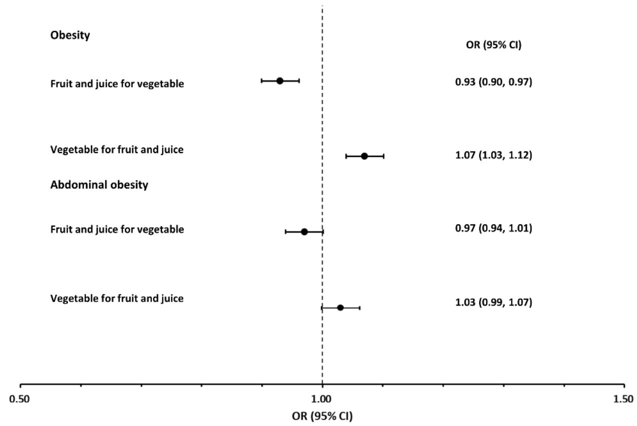

Figure 2.

338x190mm (300 x 300 DPI)

Supplementary materials

Fruit and Vegetable Intake and Body Adiposity among Populations in Eastern Canada: the Atlantic Partnership for Tomorrow's Health Study

Zhijie M. Yu[1], Vanessa DeClercq[1], Yunsong Cui[1], Cynthia Forbes[1,2], Scott Grandy[2], Melanie Keats[2], Louise Parker[1], Ellen Sweeney[1], Trevor J.B. Dummer[3]

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Supplementary Table 1. Mean intakes of fruit and vegetable and correlation between vegetable and fruit and body adiposity measurements

	n	Total fruit and vegetable		Vegetable		Fruit		100% fruit or vegetable juice	
Mean intake (SD), serving/day	26340	5.4 (2.6)		2.5 (1.5)		2.1 (1.3)		0.7 (1.0)	
		*Pearson partial correlation coefficients**							
Correlation		**r**	***P***	**r**	***P***	**r**	***P***	**r**	***P***
Vegetable	26340	0.79	<0.001	-	-	-	-	-	-
Fruit	26340	0.77	<0.001	0.41	<0.001	-	-	-	-
100% fruit or vegetable juice	26340	0.43	<0.001	0.03	<0.001	0.08	<0.001	-	-
Body mass index	26340	-0.03	<0.001	-0.03	<0.001	-0.02	<0.001	-0.02	0.001
Waist circumference	26340	-0.04	<0.001	-0.03	<0.001	-0.04	<0.001	-0.01	0.022
Waist-to-hip ratio	26340	-0.04	<0.001	-0.03	<0.001	-0.03	<0.001	-0.01	0.348
Percentage fat mass	18316	-0.04	<0.001	-0.03	<0.001	-0.03	<0.001	-0.01	0.066
Fat mass index	18304	-0.03	<0.001	-0.02	0.005	-0.02	0.002	-0.02	0.030
Fat free mass index	18302	0.00	0.693	0.00	0.916	0.01	0.112	-0.01	0.198

* Adjusted for age and sex.

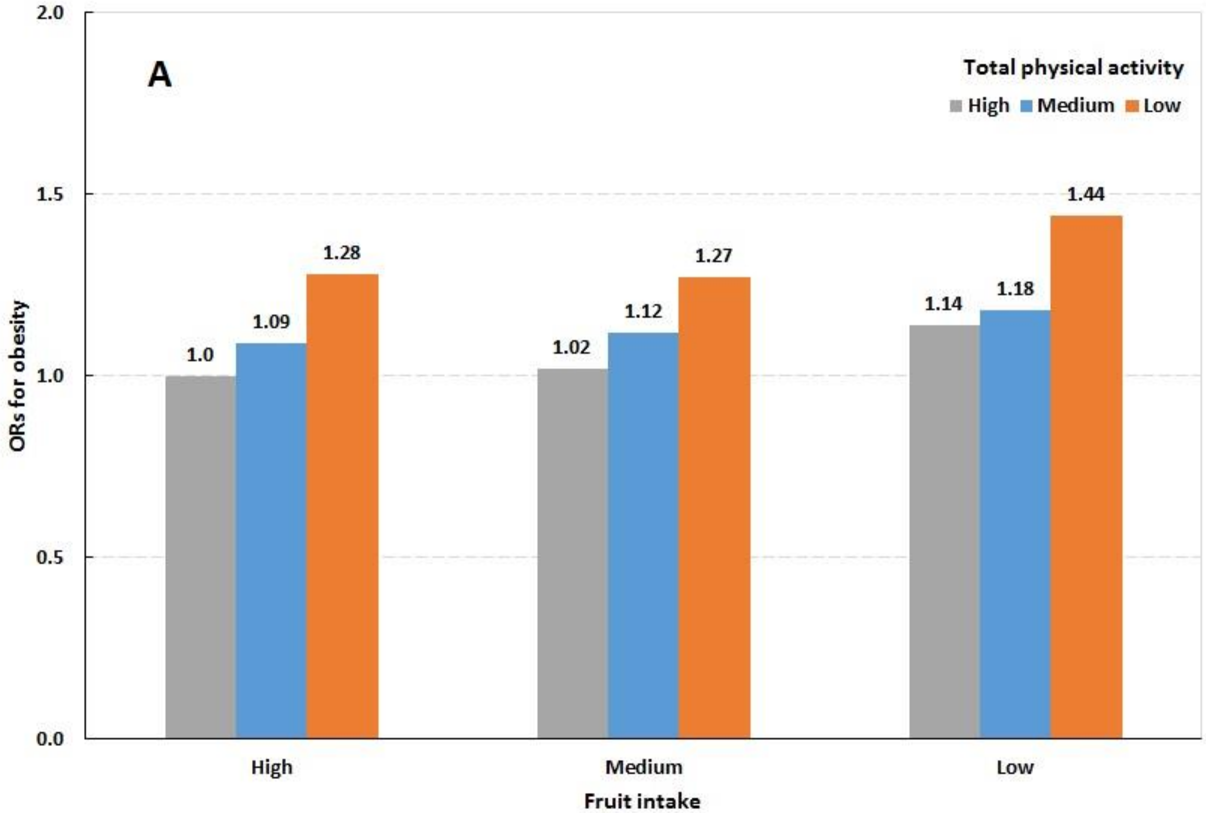
Supplementary Table 2. Odds ratios for obesity and abdominal obesity by alternatively replacing one standard deviation of intakes of vegetable, fruit, and 100% fruit or vegetable juice

Model	Obesity, OR (95% CI)		Abdominal obesity, OR (95% CI)	
Fruit for vegetable				
Simple model*	0.95	(0.91, 1.00)	0.98	(0.93, 1.03)
Multivariable model†	0.92	(0.88, 0.97)	0.95	(0.91, 1.00)
Fruit for juice				
Simple model*	0.99	(0.95, 1.03)	0.96	(0.93, 1.00)
Multivariable model†	0.99	(0.95, 1.03)	0.97	(0.93, 1.01)
Juice for vegetable				
Simple model*	0.97	(0.93, 1.00)	1.02	(0.98, 1.05)
Multivariable model†	0.93	(0.90, 0.97)	0.98	(0.94, 1.02)
Juice for fruit				
Simple model*	1.01	(0.97, 1.06)	1.04	(1.00, 1.08)
Multivariable model†	1.01	(0.97, 1.05)	1.03	(0.99, 1.07)
Vegetable for fruit				
Simple model*	1.05	(1.00, 1.10)	1.02	(0.97, 1.07)
Multivariable model†	1.08	(1.03, 1.14)	1.05	(1.00, 1.10)
Vegetable for juice				
Simple model*	1.04	(1.00, 1.08)	0.99	(0.95, 1.02)
Multivariable model†	1.07	(1.03, 1.12)	1.02	(0.98, 1.06)

CI, confidence interval; OR, odds ratio.

* Adjusted for age, sex, and province.

† Adjusted for age, sex, province, ethnicity, education, marital status, smoking, alcohol use, physical activity, and chronic disease.

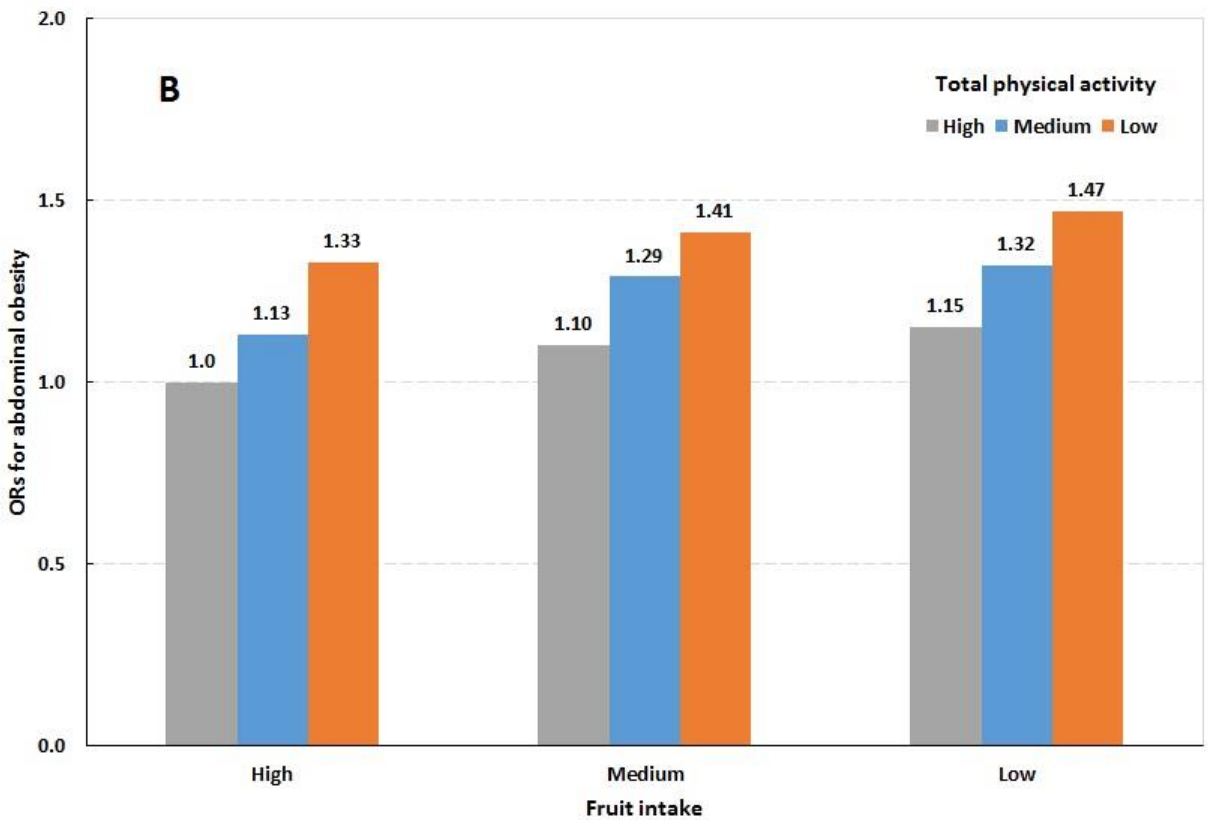


Supplementary Figure 1A. Joint associations of daily fruit intake and physical activity with risks of obesity[a,b].

[a]Adjusted for age, sex, province, ethnicity, education, marital status, smoking, alcohol use, chronic disease, and intakes of vegetable and fruit or vegetable juice.

Participants with the high levels of both fruit intake and total physical activity was the reference group.

[b]P for trend < 0.001 and P for interaction > 0.05.



Supplementary Figure 1B. Joint associations of daily fruit intake and physical activity with risks of abdominal obesity[a,b].

[a]Adjusted for age, sex, province, ethnicity, education, marital status, smoking, alcohol use, chronic disease, and intakes of vegetable and fruit or vegetable juice.

Participants with the high levels of both fruit intake and total physical activity was the reference group.

[b]*P* for trend < 0.001 and *P* for interaction > 0.05.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6, 7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6, 7
Bias	9	Describe any efforts to address potential sources of bias	*9*
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8, 9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8, 9
		(*b*) Describe any methods used to examine subgroups and interactions	8, 9
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	9
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	6
Outcome data	15*	Report numbers of outcome events or summary measures	Tables 1 and 3 and Supplementary Table 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	All tables
		(*b*) Report category boundaries when continuous variables were categorized	Table 3
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9, Supplementary Table 3 and Figure 1
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.