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Evidence synthesis

Neighbourhood retail food outlet access, diet and body mass index in Canada: a systematic review

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Abstract

Introduction: There is growing interest in the role of food environments in suboptimal diet and overweight and obesity. This review assesses the evidence for the link between the retail food environment, diet quality and body mass index (BMI) in the Canadian population.

Methods: We conducted a systematic keyword search in two bibliometric databases. We tabulated proportions of conclusive associations for each outcome and exposure of interest. Absolute and relative measures of exposure to the food environment were compared and theoretical framing of the associations noted. We assessed two key methodological issues identified a priori—measurement of BMI, and validation of the underlying retail food environment data.

Results: Seventeen studies were included in the review. There was little evidence of a food environment–diet quality relationship and modest evidence of a food environment–BMI relationship. Relative measures of the food environment were more often associated with an outcome in the expected direction than absolute measures, but many results were inconclusive. Most studies adopted ecological theoretical frameworks but methodologies were similar regardless of stated theoretical approaches. Self-reported BMI was common and there was no "gold standard" database of food outlets nor a consensus on best ways to validate the data.

Conclusion: There was limited evidence of a relationship between the food environment and diet quality, but stronger evidence of a relationship between the food environment and BMI for Canadians. Studies with broad geographic scope that adopt innovative methods to measure diet and health outcomes and use relative measures of the food environment derived in geographic information systems are warranted. Consensus on a gold standard food environment database and approaches to its validation would also advance the field.

Keywords: *retail food environment, body mass index, diet quality, systematic review, Canada*

Highlights

- Seventeen studies that investigated the food environment and its relationship to diet quality or body mass index in Canada met inclusion criteria for systematic review.
- There was little evidence of a relationship between the neighbourhood food environment and diet, possibly due to error and bias in diet quality measurement.
- There was modest evidence of a relationship between the neighbourhood food environment and body mass index.
- Relative measures perform better than absolute measures of food environment exposure.
- There is no consensus on a "gold standard" food outlet database nor on approaches to field validation of these databases.

Introduction

Despite the decline of diseases of undernutrition in developed countries, dietary quality remains suboptimal in Canada.[1] Evidence from the 2004 Canadian Community Health Survey – Nutrition confirms that a majority of Canadians do not meet their minimum recommended intake of fruits and vegetables, and many exceed the upper recommended limit of sodium and fat intake and have high total energy intake.[2,3] Modern food production enables excess consumption of nutrient-poor and energy-dense food[4] and Canadians rank high among the world's top consumers of unhealthy foods.[5] This diet may pose a large health burden on the population, given the importance of dietary quality to disease prevention and management.

Diet is among the most important modifiable risk factors for morbidity and mortality worldwide because of its impact on chronic disease development.[6] In Canada, high rates of overweight and obesity and a secular trend of rising type 2 diabetes prevalence have persisted over the past decade.[7,8] There are growing calls for

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multilevel interventions to optimize diet considering that individual dietary choices are likely to be constrained by "upstream" determinants such as socioeconomic status (SES), market structures and environments.[4] It is suggested that the retail food environment supports or impedes people's capacity to make healthy eating choices, making them a target for intervention. First, however, we need to establish if retail food environments are associated with eating behaviour and body mass index (BMI). We are now able to examine this on a large scale with geographic information systems (GIS) and other statistical software. Dimensions of the food environment include availability and quality of food within retailers, accessibility of food outlets within a geographic area, food affordability and media and advertising related to food products.[9]

Scoping reviews rapidly describe key concepts and underpinnings of a research area and often provide an overview of the type, extent and quantity of research in a particular field, while systematic reviews examine a more focussed question, adding quality evaluation and recommendations based on a synthesis of the evidence.[10] Minaker and colleagues recently published a scoping review[11] on Canadian food environment research. The authors assessed quantitative and qualitative studies, conceptual papers and commentaries, and included 88 papers in their review. They reported that studies typically address the socioeconomic patterning of food environments or the association between food environments and diet, weight or health outcomes such as cardiovascular disease. The literature is characterized by measurement inconsistency, a lack of longitudinal and intervention studies and little geographic variability, with a scarcity of studies on rural and Indigenous communities. Another scoping review[12] on urban form and health in Canada found that most studies that examined food environment access measures and health outcomes such as weight status, cardiovascular disease and diabetes reported at least one statistically significant association.

There have been five international systematic reviews since 2010[13-17] on the associations between neighbourhood food environments and health-related outcomes. These reviews suggest low to moderate evidence of an association between the food environment and outcomes such as obesity and diet, with predominately null results, wide variation in the measurement of the food environment and a focus on the United States. Canadian and American food environments differ importantly. For example, low-income areas devoid of healthy food outlets are less widespread in Canada than in the United States.[11] However, low-income areas with an overabundance of already prepared, easily accessible, calorie-dense foods are common in Canada.[11] To date, there has been no *systematic* review on the food environment and its relationship to diet quality or BMI in Canada. The neighbourhood retail food environment is an object of study internationally, and this review will add to the literature with a Canadian focus.

The aim of this paper is to systematically review the evidence on relationships between neighbourhood access to food outlets, diet quality and BMI in the Canadian context. A second aim is to compare the utility of absolute measures (e.g. proximity of an outlet type to home, density of an outlet type within a geographic area) and relative measures (e.g. proportion of healthy food outlets within a geographic area) of the food environment.

Methods

Search strategy

We developed a search strategy in consultation with a librarian and in compliance with PRISMA guidelines. Title, abstract and MeSH terms were searched in PubMed and title and abstract terms were searched in Scopus, not restricting the start point and including published articles through to January 2019. PubMed specializes in biomedical and public health literature from MEDLINE and Scopus provides a range of peer-reviewed articles from a variety of disciplines. We developed three independent search blocks to address articles relating to diet, BMI and cardiometabolic disease (Table 1). While we were only interested in diet and BMI outcomes, we used the cardiometabolic search block for completeness to identify any studies that may have been missed in the diet and BMI search blocks.

Inclusion and exclusion criteria

ACS and AB reviewed titles and abstracts using EndNote X7 software (Clarivate Analytics, Philadelphia, PA, USA). Articles were included if (1) the study population was Canadian; (2) both an access-related measure of the food environment derived from GIS and a diet or BMI outcome were assessed; (3) the effect estimates were reported; and (4) the exposure to food outlets represented the home neighbourhood. To avoid double counting results, we excluded articles if they reported associations on the same cohort as an included study and used a similar methodology. Either the most recent or most comprehensive study was used. We then reviewed full texts based on the inclusion and exclusion criteria, and identified additional references through citation tracking.

Quality assessment and data extraction

Data were extracted using a standardized form. Included results were based on the authors' final model or the model with the most relevant covariates, as judged by the reviewer. We assessed the type of conceptual framework that the authors used and we considered whether studies were alert to some quality concerns of food environment studies raised by Cobb et al.,[13] namely the issue of self-reported BMI and validation of the food outlet dataset. Cobb et al. included self-selection as important for quality assessment in studies with a neighbourhood-level potential determinant, but food environment studies rarely, if ever, account for the purposeful choice of individuals to move into an area with a favourable or an unfavourable food environment. We return to this point in the discussion section.

We considered markers of diet quality (continuous diet quality scores, fruit and vegetable intake (FVI) and fast food consumption) and BMI as separate outcomes. The exposures of interest for this review were less healthy retail food outlets (fast food restaurants, convenience stores and summary measures of "less healthy food retail"), healthier retail food outlets (grocery stores, supermarkets, fruit and vegetable stores, and summary measures of "healthier food retail"), and non–fast food restaurants. Our expectation was that greater exposure to less healthy retail food outlets would be associated with poorer diet quality and higher BMI, and that greater exposure to healthier retail food outlets would be associated with better diet and lower BMI. For studies that reported effect sizes between levels of exposure, we considered the two most extreme groupings (i.e. the highest vs. the lowest quartile). We then compared the

TABLE 1
Search blocks developed for the systematic search of the literature on the food environment, diet and body mass index in Canada

Diet	((((fruit* [Title/Abstract] OR vegetable* [Title/Abstract] OR diet [Title/Abstract] OR diets [Title/Abstract] OR dietary [Title/Abstract] OR eating [Title/Abstract] OR nutrition [Title/Abstract] OR consumption [Title/Abstract] OR intake [Title/Abstract]) AND ((food environment [Title/Abstract] OR nutrition environment [Title/Abstract] OR retail food [Title/Abstract] OR food desert [Title/Abstract] OR food swamp [Title/Abstract] OR food availability [Title/Abstract] OR foodscape [Title/Abstract] OR local food [Title/Abstract] OR (("neighbourhood" [All Fields] OR "residence characteristics" [MeSH Terms] OR ("residence" [All Fields] AND "characteristics" [All Fields]) OR "residence characteristics" [All Fields] OR "neighborhood" [All Fields]) AND food [Title/Abstract]) OR "neighborhood food" [Title/Abstract] OR fast food access [Title/Abstract] OR food access [Title/Abstract]) OR "fast foods" [MeSH Terms])) AND "canada" [MeSH Terms]) NOT school [Title/Abstract])
BMI	(((((obesity [Title/Abstract] OR body mass index [Title/Abstract] OR waist circumference [Title/Abstract]) OR "overweight" [MeSH Terms]) AND ((food environment [Title/Abstract] OR nutrition environment [Title/Abstract] OR retail food [Title/Abstract] OR food desert [Title/Abstract] OR food swamp [Title/Abstract] OR food availability [Title/Abstract] OR foodscape [Title/Abstract] OR local food [Title/Abstract] OR (("neighbourhood" [All Fields] OR "residence characteristics" [MeSH Terms] OR ("residence" [All Fields] AND "characteristics" [All Fields]) OR "residence characteristics" [All Fields] OR "neighborhood" [All Fields]) AND food [Title/Abstract]) OR "neighborhood food" [Title/Abstract] OR fast food access [Title/Abstract] OR food access [Title/Abstract]) OR "fast foods" [MeSH Terms])) AND "canada" [MeSH Terms]) NOT school [Title/Abstract])
CVD	((((cardiovascular [Title/Abstract] OR diabetes [Title/Abstract] OR hypertension [Title/Abstract] OR cardiometabolic [Title/Abstract] OR heart [Title/Abstract]) AND ((food environment [Title/Abstract] OR nutrition environment [Title/Abstract] OR retail food [Title/Abstract] OR food desert [Title/Abstract] OR food swamp [Title/Abstract] OR food availability [Title/Abstract] OR foodscape [Title/Abstract] OR local food [Title/Abstract] OR (("neighbourhood" [All Fields] OR "residence characteristics" [MeSH Terms] OR ("residence" [All Fields] AND "characteristics"[All Fields]) OR "residence characteristics" [All Fields] OR "neighborhood" [All Fields]) AND food [Title/Abstract]) OR "neighborhood food" [Title/Abstract] OR fast food access [Title/Abstract] OR food access [Title/Abstract]) OR "fast foods" [MeSH Terms])) AND "canada" [MeSH Terms]) NOT school [Title/Abstract])

Abbreviations: BMI, body mass index; CVD, cardiovascular diseases.
Note: The variation of search string for Scopus is not shown in this table.

associations between absolute and relative food environment measures. Recent studies have argued that relative measures provide a better conceptualization of the food environment by allowing for the simultaneous exposure of healthier and less healthy retail food outlets.[18,19]

We were principally interested in main full-sample effects to synthesize the literature with clarity owing to the many different ways that results were stratified. There is a tendency in the Canadian food environment literature to stratify results based on common attributes (e.g. sex, city), but we recognize that it is possible to generate findings with multiple tests and we were concerned that the reduction in sample size might result in a reduction in study power. Therefore, we reported the full sample associations when they were provided and calculated pooled full sample results if only stratified results were reported. This means that the pooled full sample results that we calculated for this review are not found in the original papers. We also calculated the 95% confidence intervals for studies that reported the effect size with standard deviations or standard errors.

Results

The search yielded a total of 430 unique abstracts, and two additional articles were identified through citation tracking. After reviewing titles and abstracts, we identified 24 for full-text review, of which 17 fulfilled eligibility criteria (Figure 1). Mercille et al. (2016)[20] was excluded because the authors reported associations for the same cohort as the original Mercille et al. (2012)[21] study. Lebel et al.[22] was excluded because the authors reported associations for the same cohort as Kestens et al.[23] and used a similar methodology, although it included fewer exposure measures.

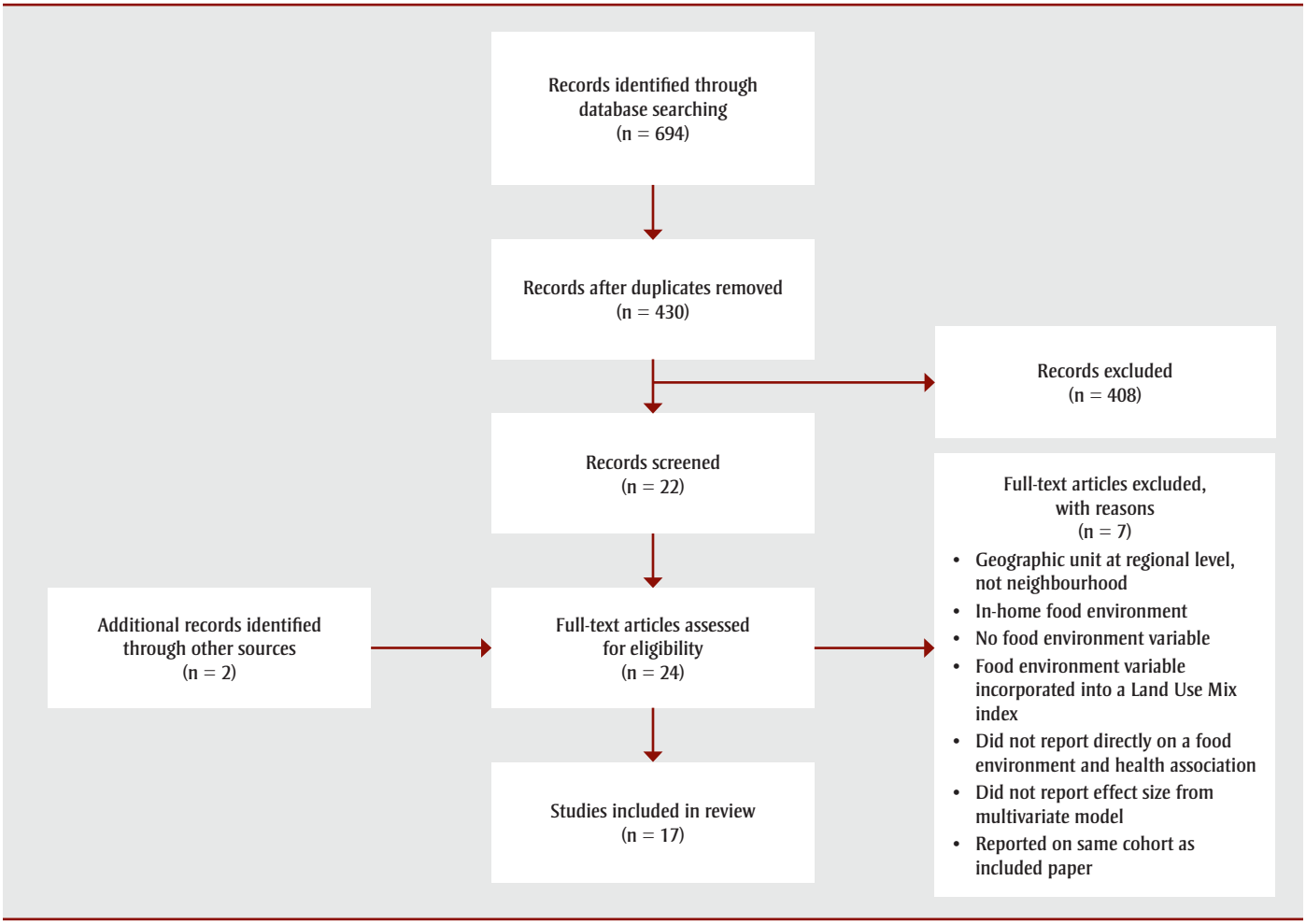
Of the 17 studies retained, 13 examined adults[18,19,21,23-32] and four examined children or adolescents.[33-36] All employed a cross-sectional design. Eight studies investigated diet-related outcomes,[18,21,24,26-28,33,36] eight studies investigated BMI[19,23,25,29-31,34,35] and one study investigated both diet-related and BMI outcomes.[32] Twelve studies examined the food environment within one city,[24,26-36] two in two cities[21,23] and two in four to five cities.[18,19] One study examined the food environment across Canada.[25]

All of the studies employed GIS-derived measures of the food environment. Thirteen studies included density measures[18,19,23-25,28-30,32-36] (e.g. count, count per area), four included proximity measures[32-34,36] (e.g. distance to nearest supermarket), two included presence measures,[26,27] and seven included relative measures[18,19,21,23,31,32,36] (e.g. proportion of healthier outlets). Seven of the studies used a combination of these measures.[18,19,23,32-34,36]

Data sources for food outlets and their locations were proprietary business databases (n = 10)[18,19,21,23,25,26,28-30,36] or municipal health or planning lists (n = 7).[24,27,31-35] Of the proprietary business databases, four used the 2005 Tamec Inc. Zipcom database,[21,23,28,36] two used Enhanced Points of Interest Files distributed by DMTI Spatial,[18,26] one used Infogroup Canada,[25] one used Dun & Bradstreet Canada,[19] and two studies combined multiple data sources.[29,30] Geographic units to characterize the neighbourhood food environment exposure measures consisted of buffers around participants' home addresses, postal codes or larger neighbourhood units such as census tracts or forward sortation areas. Buffer sizes ranged from 400 m to 1600 m.

Five studies[27,29,30,34,36] implied or specified the use of an ecological model that assumes multilevel determinants of behaviour, including environmental influences. Ten studies[18,19,21,23-26,31,33,35] implied or specified the use of an ecological model and included at least some discussion about how the food environment fits into this model. Two studies[28,32] described and referenced a food environment–specific ecological model that has been previously established in the literature. One of these referenced the model developed by Glanz et al.,[9] distinguishing between the community nutrition environment (food outlet access) and the consumer nutrition

FIGURE 1
PRISMA flow diagram of included studies



environment (e.g. in-store food availability, food affordability and food quality) and highlighting perceptions of the food environment as a possible mediator of associations. The other considered Cohen and Farley's[37] work on eating behaviour as a response to cues for eating in modern food environments, highlighting reward sensitivity as an important individual attribute that may encourage people to respond to unhealthy cues.

Diet quality scores

Studies that investigated associations between the food environment and diet quality scores are shown in Table 2. Participants in He et al.[33] completed the Block Kids 2004 Food Frequency Questionnaire to assess diet over the past 12 months and create modified Healthy Eating Index – 2005 scores. Participants in McInerney et al.[26] completed the online Canadian Diet History Questionnaire II for food consumed in the past 12 months and participants in Minaker et al.[32] completed diet records to obtain Healthy Eating Index scores adapted for Canada. Participants in Nash et al.[27] completed a food frequency questionnaire for the past month to obtain Diet Quality Index for Pregnancy scores, modified for Canadian dietary guidelines. Participants in Mercille et al. (2012)[21] completed a food frequency questionnaire to assess food consumption over the previous 12 months and generate "Western" and "prudent" diet scores.

Absolute measures of exposure to outlets hypothesized to be less healthy were associated with diet quality scores in the expected direction one of seven times (14%) and relative measures representing the proportion of unhealthy outlets were associated with diet quality scores in the expected direction one of three times (33%). Absolute measures of exposure to outlets hypothesized to be healthier were associated with diet quality scores in the expected direction one of three times (33%) and relative measures of exposure representing the proportion of healthier outlets were associated with diet quality scores in the expected direction zero of two times (0%). Absolute measures of exposure to non–fast food restaurants were not associated with a diet quality score in the two associations tested (0%). The results that were not associated with diet quality score outcomes in the expected direction were either inconclusive or close to being conclusive in the expected direction.

Fruit and vegetable intake

Studies that investigated associations between the food environment and fruit and vegetable intake are shown in Table 3. Clary et al.[18] and Chum et al.[24] both assessed FVI using questions that are found in the Canadian Community Health Survey Food Frequency Questionnaire. Van Hulst et al.[36] used mean values of

TABLE 2
Associations between the food environment and diet quality scores

Author (year)/study/ population (*n*)	Outcome	Exposure operationalization	Findings (CI)	Covariates	Validity of food outlet database reported? *Author comments*
LESS HEALTHY FOOD OUTLET EXPOSURE (Fast food restaurant [FFR], convenience store [CS], "less healthy food retail")					
Absolute measures (1/7 results are associated with continuous diet quality scores in the expected direction)					
McInerney et al. (2016)[26] Pathways to Health, adults 20+ (*n = 446*)	Continuous diet quality score (HEI-C) (higher is better)	Presence of CS or multiproduct stores (yes/no) within 400 m network buffer	β = 0.44 (−2.37, 3.25) *No conclusive association was identified between the presence of a CS or multiproduct store and the diet quality score.*	Sex, age, ethnic origin, marital status, dependant at home, highest education, gross household income, smoking status, car available, dog ownership, self reported mental and physical health, hours spent sitting per day, hours spent in the neighbourhood during a typical week	Yes (done by a secondary study in Montréal). *"Montréal researchers found approximately a 77% reliability (agreement between the database and ground audit for destination existence, name, and location)."*
Minaker et al. (2013)[32] NEWPATH, adults 19+ (*n = 1170*)	Continuous diet quality score (HEI-C) (higher is better)	Distance (km) from FFR	β = 0.84 (−1.43, 3.11)[a] *No conclusive association was identified between living an additional km away from a FFR and the diet quality score.*	Age, education level, household income, household car ownership	No. *"Follow up direct observation was employed to ensure accuracy."*
		Distance (km) from CS	β = 2.06 (−0.49, 4.61)[a] *No conclusive association was identified between living an additional km away from a CS and the diet quality score.*		
Nash et al. (2013)[27] Prenatal Health Project, pregnant women (*n = 2086*)	Canadian Diet Quality Index for Pregnancy (higher is better)	Presence of FFR (yes/no) within 500 m of home	β = −1.26, $p < .09$ *No conclusive association was identified between the presence of a FFR and the diet quality score.*	Residency in Canada, marital status, parity, education level, nausea severity, exercise, smoking during pregnancy, anxiety, social support from family, social support from friends	No. *"Locations were previously verified by site visits and alternative directory listings, and the accuracy of the geocoding was confirmed using 30-cm resolution orthophotography."*
He et al. (2012)[33] Survey, students 11–14 (*n = 632*)	Continuous diet quality score (HEI) (higher is better)	Distance (km) from FFR	β = 1.10 (−0.17, 2.37) *No conclusive association was identified between living 1 km or more from a FFR vs. less than 1 km away and the diet quality score.*	Gender, education, neighbourhood distress scores	No. *"Validated by researchers through telephone calls, field surveys and inspection of aerial photographs, and geocoded to the building's address."*
		Distance (km) from CS	**β = 1.80 (0.25, 3.35)** *Living 1 km or more from a CS vs. living less than 1 km away is associated with a 1.80 unit higher diet quality score.*		
		Count of FFR within 1 km buffer of home	β = 0.80 (−0.67, 2.27) *No conclusive association was identified between a decrease from 3+ to 0 FFRs and the diet quality score.*		
Relative measures (1/3 results are associated with continuous diet quality scores in the expected direction)					
Minaker et al. (2013)[32] NEWPATH, adults 19+ (*n = 1170*)	Continuous diet quality score (HEI-C) (higher is better)	RFEI (FFR + CS / supermarkets + produce vendors) within 1 km of home	β = −0.10 (−0.20, 0.00)[a] *The upper bound of the confidence interval is just above zero (before rounding), so an additional unit increase in RFEI may be associated with a 0.10 unit lower diet quality score.*	Age, education level, household income, household car ownership	No. *"Follow up direct observation was employed to ensure accuracy."*

Continued on the following page

TABLE 2 (continued)
Associations between the food environment and diet quality scores

Author (year)/study/ population (*n*)	Outcome	Exposure operationalization	Findings (CI)	Covariates	Validity of food outlet database reported? *Author comments*
Mercille et al. (2012)[21] VoisiNuAge, older adults 68–84 (*n = 751*)	Continuous prudent diet score (higher is better)	FFR/all restaurants within 500 m network buffer	**β = −0.96 (−1.85, −0.08)** *An increase in the percentage of restaurants that are FFRs is associated with a 0.96 unit lower prudent diet score.*	Sex, age, country of birth, marital status, education, family income, SF-36 (quality of life) Physical Component, depression, functional status, SF-36 Social Functioning, index of social support, number of children living nearby, % in area below low income cut-off, % in area speaking neither French nor English, % in area with university degree	Yes (done by a secondary study in Montréal). *"A validation study of this database indicated percentage agreement of 0.77, sensitivity of 0.84 and positive predictive value of 0.90 for food stores relative to field visits to verify or refute the presence of listed commercial outlets."*
	Continuous Western diet score (lower is better)	FFR/all restaurants within 500 m network buffer	β = 0.10 (−0.75, 0.95) *No conclusive association was identified between an increase in the percentage of restaurants that are FFRs and Western diet score.*		
HEALTHIER FOOD OUTLET EXPOSURE (grocery store [GS], supermarket [S], fruit & vegetable store [FVS], "healthier food outlet")					
Absolute measures (1/3 results are associated with continuous diet quality scores in the expected direction)					
McInerney et al. (2016)[26] Pathways to Health, adults 20+ (*n = 446*)	Continuous diet quality score (HEI-C) (higher is better)	Presence of S or GS (yes/no) within 400 m network buffer	β = −0.86 (−4.50, 2.77) *No conclusive association was identified between the presence of a S or GS and the diet quality score.*	Sex, age, ethnic origin, marital status, dependant at home, highest education, gross household income, smoking status, car available, dog ownership, self reported mental and physical health, hours spent sitting per day, hours spent in the neighbourhood during a typical week	Yes (done by a secondary study in Montréal). *"Montréal researchers found approximately a 77 % reliability (agreement between the database and ground audit for destination existence, name, and location)."*
Minaker et al. (2013)[32] NEWPATH, adults 19+ (*n = 1170*)	Continuous diet quality score (HEI-C) (higher is better)	Distance (km) from GS	**β = −1.46 (−2.67, −0.25)**[a] *An additional km away from a GS is associated with a 1.46 unit lower diet quality score.*	Age, education level, household income, household car ownership	No. *"Follow up direct observation was employed to ensure accuracy."*
He et al. (2012)[33] Survey, students 11–14 (*n = 632*)	Diet quality score (HEI) (higher is better)	Distance (km) from S	β = 0.16 (−1.64, 1.96) *No conclusive association was identified between living in the highest compared to the lowest tertile of distance away from a S and the diet quality score.*	Gender, education, neighbourhood distress scores	No. *"Validated by researchers through telephone calls, field surveys and inspection of aerial photographs, and geocoded to the building's address."*
Relative measures (0/2 results are associated with continuous diet quality scores in the expected direction)					
Mercille et al. (2012)[21] VoisiNuAge, older adults 68–84 (*n = 751*)	Continuous prudent diet score (higher is better)	Healthy/all food stores within 500 m network buffer	β = −0.25 (−0.96, 0.45) *No conclusive association was identified between an increase in the percentage of healthy food stores and the prudent diet score.*	Sex, age, country of birth, marital status, education, family income, SF-36 Physical Component, depression, functional status, SF-36 Social Functioning, index of social support, number of children living nearby, % in area below low-income cut-off, % in area speaking neither French nor English, % in area with university degree	Yes (done by a secondary study in Montréal). *"A validation study of this database indicated percentage agreement of 0.77, sensitivity of 0.84 and positive predictive value of 0.90 for food stores relative to field visits to verify or refute the presence of listed commercial outlets."*
	Continuous Western diet score (lower is better)	Healthy/all food stores within 500 m network buffer	β = −0.28 (−0.96, 0.41) *No conclusive association was identified between an increase in the percentage of healthy food stores and the Western diet score.*		

Continued on the following page

three 24-hour dietary recalls. Clary et al.[18] transformed the results into daily consumptions to obtain a FVI variable, while Chum et al.[24] and Van Hulst[36] categorized FVI into less than five or greater than or equal to five times per day.

Absolute measures of exposure to outlets hypothesized to be less healthy were associated with FVI in the expected direction one out of ten times (10%) and relative measures of exposure representing the proportion of less healthy outlets were not associated with FVI in the lone study that tested this association (0%). Absolute measures of exposure to outlets hypothesized to be healthier were associated with FVI in the expected direction one out of seven times (14%) and relative measures

TABLE 2 (continued)
Associations between the food environment and diet quality scores

Author (year)/study/ population (*n*)	Outcome	Exposure operationalization	Findings (CI)	Covariates	Validity of food outlet database reported? *Author comments*
NON–FAST FOOD RESTAURANT EXPOSURE					
Absolute measures (0/2 results are associated with continuous diet quality scores)					
McInerney et al. (2016)[26] Pathways to Health, adults 20+ (*n = 446*)	Continuous diet quality score (HEI-C) (higher is better)	Presence of restaurants[b] (yes/no) within 400 m network buffer	β = −0.71 (−3.11, 1.68) *No conclusive association was identified between the presence of a restaurant and the diet quality score.*	Sex, age, ethnic origin, marital status, dependant at home, highest education, gross household income, smoking status, car available, dog ownership, self reported mental and physical health, hours spent sitting per day, hours spent in the neighbourhood during a typical week	Yes (done by a secondary study in Montréal). *"Montréal researchers found approximately a 77 % reliability (agreement between the database and ground audit for destination existence, name, and location)."*
Minaker et al. (2013)[32] NEWPATH, adults 19+ (*n = 1170*)	Continuous diet quality score (HEI-C) (higher is better)	Non–fast food restaurant count within 1 km of home	β = 0.03 (−0.03, 0.09)[a] *No conclusive association was identified between an additional non–fast food restaurant and the diet quality score.*	Age, education level, household income, household car ownership	No. *"Follow up direct observation was employed to ensure accuracy."*

Abbreviations: CI, confidence interval; CS, convenience store; FFR, fast food restaurant; FVS, fruit and vegetables store; GS, grocery store; HEI-C, Healthy Eating Index adapted for Canada; NEWPATH, Neighbourhood Environments in Waterloo Region: Patterns of Transportation and Health; RFEI, Retail Food Environment Index; S, supermarket; SF-36, 36-Item Short Form Health Survey.

Note: Bolded results are conclusive in the expected direction.

[a] Sex-stratified results were pooled.

[b] Authors combined FFR and non–FFR.

TABLE 3
Associations between the food environment and fruit and vegetable intake

Author (year)/study/ population (*n*)	Outcome	Exposure operationalization	Findings (CI)	Covariates	Validity of food outlet database reported? *Author comments*
LESS HEALTHY FOOD OUTLET EXPOSURE (fast food restaurant [FFR], convenience store [CS], "less healthy food retail")					
Absolute measures (1/10 results are associated with fruit and vegetable intake in the expected direction)					
Chum et al. (2015)[24] NEHW, adults 25–65 (*n = 2411*)	Odds of eating 5 or more fruits and vegetables servings per day	FFR count within 10 min walking distance network buffer	OR = 1.08 (0.73, 1.60) *No conclusive association was identified between a decrease from 3+ to 0 FFRs and the odds of eating 5 or more fruits and vegetables per day.*	Gender, age, education, self-rated health, marital status, visible minority status, family income	No.
		FFR count within 15 min walking distance network buffer	OR = 1.13 (0.67, 1.93) *No conclusive association was identified between a decrease from 3+ to 0 FFRs and the odds of eating 5 or more fruits and vegetables per day.*		
		Less healthy food outlet count within 10 min walking distance network buffer	OR = 1.05 (0.71, 1.54) *No conclusive association was identified between a decrease from 3+ to 0 less healthy food outlets and the odds of eating 5 or more fruits and vegetables per day.*		
		Less healthy food outlet count within 15 min walking distance network buffer	OR = 1.05 (0.71, 1.54) *No conclusive association was identified between a decrease from 3+ to 0 less healthy food outlets and the odds of eating 5 or more fruits and vegetables per day.*		

Continued on the following page

TABLE 3 (continued)
Associations between the food environment and fruit and vegetable intake

Author (year)/study/ population (*n*)	Outcome	Exposure operationalization	Findings (CI)	Covariates	Validity of food outlet database reported? *Author comments*
Clary et al. (2015)[18] 2007, 2008, 2009, 2010 CCHS 18+ (*n = 49 403*)	Fruit and vegetable (portions per day)	FFR kernel density linked with home postal code	**β = −0.04 (−0.06, −0.02)** *An additional FFR per km² was associated with a 0.04 decrease in the portions of fruits and vegetables consumed per day.*	Gender, age, education level, marital status, ethnic origin, household size adjusted income, CMA of residence, neighbourhood material and social deprivations, and overall outlet density	Yes (done by a secondary study in Montréal). *"Representativity of the dataset, that is, concordance between outlets present on the EPOI list and outlets observed on the field was 77.7% when relaxing on business names, small imprecisions in location (i.e. within the same census tract), and when compensating false negatives with false positives within the same outlet category and census tract."*
		Sum of less healthy outlets (FFR + CS) kernel density linked with home postal code	β = −0.01 (−0.03, 0.01) *No conclusive association was identified between an additional less healthy outlet per km² and the portions of fruits and vegetables consumed per day.*		
Van Hulst et al. (2012)[36] QUALITY, children Grades 2–5 (*n = 498*)	Odds of eating 5 or more fruits and vegetables per day	Distance (m) away from a FFR	OR = 1.39 (0.81, 2.40) *No conclusive association was identified between living the farthest vs. the shortest distance away from a FFR and the odds of eating 5 or more fruits and vegetables per day.*	Child's age and sex, mother's BMI, highest parental education attainment, total household income (adjusted for number of people in household)	Yes (done by a secondary study in Montréal). *"A validity study of food establishments from this list, verified by onsite field visits, showed good agreement (0.77), sensitivity (0.84) and positive predictive value (0.90)."*
		Distance (m) away from a CS	OR = 0.99 (0.57, 1.72) *No conclusive association was identified between living the farthest vs. the shortest distance away from a CS and the odds of eating 5 or more fruits and vegetables per day.*		
		Kernel FFR density within 1 km street buffer of home	OR = 1.22 (0.68, 2.22) *No conclusive association was identified between a decrease from the highest to the lowest tertile of FFR density and the odds of eating 5 or more fruits and vegetables per day.*		
		Kernel CS density within 1 km street buffer of home	OR = 1.02 (0.55, 1.91) *No conclusive association was identified between a decrease from the highest to the lowest tertile of CS density and the odds of eating 5 or more fruits and vegetables per day.*		
Relative measures (0/1 results are associated with fruit and vegetable intake in the expected direction)					
Van Hulst et al. (2012)[36] QUALITY, children Grades 2–5 (*n = 498*)	Odds of eating 5 or more fruits and vegetables per day	RFEI (FFR + CS / S + specialty food stores) within 1 km of home	OR = 0.90 (0.58, 1.42) *No conclusive association was identified between a RFEI score greater or equal to the approximate 75th percentile versus a RFEI score less than the approximate 75th percentile and the odds of eating 5 or more fruits and vegetables per day.*	Child's age and sex, mother's BMI, highest parental education attainment, total household income (adjusted for number of people in household)	Yes (done by a secondary study in Montréal). *"A validity study of food establishments from this list, verified by onsite field visits, showed good agreement (0.77), sensitivity (0.84) and positive predictive value (0.90)."*
HEALTHIER FOOD OUTLET EXPOSURE (grocery store [GS], supermarket [S], fruit & vegetable store [FVS], "healthier food outlet")					
Absolute measures (1/7 results are associated with fruit and vegetable intake in the expected direction)					
Chum et al. (2015)[24] NEHW, adults 25–65 (*n = 2411*)	Odds of eating 5 or more fruits and vegetables per day	Healthier outlet count within 10 min walking distance network buffer	OR = 1.25 (0.80, 1.96) *No conclusive association was identified between an increase from 0 to 3+ healthier outlets and the odds of eating 5 or more fruits and vegetables per day.*	Gender, age, education, self-rated health, marital status, visible minority status, family income	No.
		Healthier outlet count within 15 min walking distance network buffer	OR = 1.18 (0.94, 1.50) *No conclusive association was identified between an increase from 0 to 3+ healthier outlets and the odds of eating 5 or more fruits and vegetables per day.*		

Continued on the following page

TABLE 3 (continued)
Associations between the food environment and fruit and vegetable intake

Author (year)/study/ population (*n*)	Outcome	Exposure operationalization	Findings (CI)	Covariates	Validity of food outlet database reported? *Author comments*
Clary et al. (2015)[18] 2007, 2008, 2009, 2010 CCHS 18+ (*n = 49 403*)	Fruit and vegetable (servings per day)	S kernel density linked with home postal code	β = 0.12 (−0.01, 0.25) *The lower bound of the confidence interval is just below zero, so an additional S per km² may be associated with a 0.122 increase in servings of fruits and vegetables per day.*	Gender, age, education level, marital status, ethnic origin, household size adjusted income, CMA of residence, neighbourhood material and social deprivations, and overall outlet density	Yes (by a secondary study in Montréal). *"Representativity of the dataset, that is, concordance between outlets present on the EPOI list and outlets observed on the field was 77.7% when relaxing on business names, small imprecisions in location (i.e. within the same census tract), and when compensating false negatives with false positives within the same outlet category and census tract."*
		FVS kernel density linked with home postal code	**β = 0.03 (0.00, 0.05), *p* < .05** *An additional FVS per km² was associated with a 0.03 increase in servings of fruits and vegetables consumed per day.*		
		Sum of healthier outlets (S + FVS + GS + natural food store) kernel density linked with home postal code	β = 0.01 (0.00, 0.03) *No conclusive association was identified between an additional healthier outlet per km² and the servings of fruits and vegetables consumed per day.*		
Van Hulst et al. (2012)[36] QUALITY, children Grades 2–5 (*n = 498*)	Odds of eating 5 or more fruits and vegetables per day	Distance (m) away from a S	OR = 1.09 (0.62, 1.91) *No conclusive association was identified between living the farthest vs. the shortest distance away from a S and the odds of eating 5 or more fruits and vegetables per day.*	Child's age and sex, mother's BMI, highest parental education attainment, total household income (adjusted for number of people in household)	Yes (done by a secondary study in Montréal). *"A validity study of food establishments from this list, verified by onsite field visits, showed good agreement (0.77), sensitivity (0.84) and positive predictive value (0.90)."*
		Kernel S density within 1 km street buffer of home	OR = 1.11 (0.63, 1.93) *No conclusive association was identified between a decrease from the highest to the lowest tertile of S density and the odds of eating 5 or more fruits and vegetables per day.*		
Relative measures (1/1 results are associated with fruit and vegetable intake in the expected direction)					
Clary et al. (2015)[18] 2007, 2008, 2009, 2010 CCHS 18+ (*n = 49 403*)	Fruit and vegetable (portions per day)	Healthier/healthier + less healthy stores linked with home postal code	**β = 0.01 (0.00, 0.01), *p* < .001** *A unit increase in the proportion of healthy food stores is associated with a 0.01 increase in the portions of fruits and vegetables consumed per day.*	Gender, age, education level, marital status, ethnic origin, household size adjusted income, CMA of residence, neighbourhood material and social deprivations, and overall outlet density	Yes (done by a secondary study in Montréal). *"Representativity of the dataset, that is, concordance between outlets present on the EPOI list and outlets observed on the field was 77.7% when relaxing on business names, small imprecisions in location (i.e. within the same census tract), and when compensating false negatives with false positives within the same outlet category and census tract."*

Abbreviations: CCHS, Canadian Community Health Survey; CI, confidence interval; CMA, census metropolitan area; CS, convenience store; EPOI, Enhanced Points of Interest; FFR, fast food restaurant; FVS, fruit and vegetables store; GS, grocery store; NEHW, Neighbourhood Effects on Health and Well-being; OR, odds ratio; QUALITY, Quebec Adipose and Lifestyle Investigation in Youth; RFEI, Retail Food Environment Index; S, supermarket.

Note: Bolded results are conclusive in the expected direction.

of exposure representing the proportion of healthier outlets were associated with FVI in the expected direction in the lone study that assessed this association (100%). The results that were not associated with FVI outcomes in the expected direction were either inconclusive or close to being conclusive in the expected direction.

Fast food consumption

Studies that investigated associations between the food environment and fast food consumption are shown in Table 4. Participants in Paquet et al.[28] reported the number of times they had visited a fast food restaurant in their neighbourhood in the previous seven days, and results were dichotomized as one or more visits or no visits. Participants in Van Hulst et al.[36] reported if they had consumed delivery or take-out food in the previous week. Absolute measures of exposure to outlets hypothesized to be less healthy were not associated with fast food consumption in

TABLE 4
Associations between the food environment and fast food consumption

Author (year)/ study/ population (*n*)	Outcome	Exposure operationalization	Findings (CI)	Covariates	Validity of food outlet database reported? *Author comments*
LESS HEALTHY FOOD OUTLET EXPOSURE (fast food restaurant [FFR], convenience store [CS], "less healthy food retail")					
Absolute measures (0/5 results are associated with fast food consumption in the expected direction)					
Paquet et al. (2010)[28] MNSLH, adults 18–55 (*n = 415*)	Odds of having consumed fast food in the past 7 days (self-reported)	FFR count within 500 m circular buffer	OR = 0.92 (0.80, 1.05) *No conclusive association was identified between an additional FFR and the odds of having consumed fast food in the past 7 days.*	Age, sex, education, household income	Yes (done by a secondary study in Montréal). *"A validation study of this commercial database in the Montréal CMA showed that it was valid in terms of the likelihood that a listed establishment was present in the field (positive predictive value = 0.90) and that a food establishment present in the field was correctly listed in the database (sensitivity = 0.84)."*
Van Hulst et al. (2012)[36] QUALITY, children Grades 2–5 (*n = 506*)	Odds of eating delivery or takeout in the past week	Distance (m) away from a FFR	OR = 1.03 (0.61, 1.73) *No conclusive association was identified between living the farthest vs. the shortest distance away from a FFR and the odds of eating delivery or takeout in the past week.*	Child's age and sex, mother's BMI, highest parental education attainment, total household income (adjusted for number of people in household)	Yes (done by a secondary study in Montréal). *"A validity study of food establishments from this list, verified by onsite field visits, showed good agreement (0.77), sensitivity (0.84) and positive predictive value (0.90)."*
		Distance (m) away from a CS	OR = 0.93 (0.55, 1.56) *No conclusive association was identified between living the farthest vs. the shortest distance away from a CS and the odds of eating delivery or takeout in the past week.*		
		Kernel FFR density within 1 km street buffer of home	OR = 1.11 (0.63, 1.98) *No conclusive association was identified between a decrease from the highest to the lowest tertile of FFR density and the odds of eating delivery or takeout in the past week.*		
		Kernel CS density within 1 km street buffer of home	OR = 0.93 (0.51, 1.70) *No conclusive association was identified between a decrease from the highest to the lowest tertile of CS density and the odds of eating delivery or takeout in the past week.*		
Relative measures (0/1 results are associated with fast food consumption in the expected direction)					
Van Hulst et al. (2012)[36] QUALITY, children Grades 2–5 (*n = 506*)	Odds of eating delivery or takeout in the past week	RFEI (FFR + CS / S + specialty food stores) within 1 km of home	OR = 1.35 (0.89, 2.05) *No conclusive association was identified between a RFEI score greater or equal to the approximate 75th percentile vs. a RFEI score less than the approximate 75th percentile and the odds of eating delivery or takeout in the past week.*	Child's age and sex, mother's BMI, highest parental education attainment, total household income (adjusted for number of people in household)	Yes (done by a secondary study in Montréal). *"A validity study of food establishments from this list, verified by onsite field visits, showed good agreement (0.77), sensitivity (0.84) and positive predictive value (0.90)."*

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the five associations tested (0%) and relative measures of exposure representing the proportion of less healthy outlets were not associated with fast food consumption in the lone study that tested this association (0%). Absolute measures of exposure to outlets hypothesized to be healthier were not associated with fast food consumption in the two associations tested (0%). All of the results were inconclusive.

Body mass index (continuous and categorical overweight/obesity)

Studies that investigated associations between the food environment and body mass index are shown in Table 5. Eight studies assessed BMI using self reports and one study assessed BMI using non–self reported measurements. Absolute measures of exposure to outlets hypothesized to be less healthy were associated with BMI outcomes in the expected direction 3 of 17 times (18%) and in the

TABLE 4 (continued)
Associations between the food environment and fast food consumption

Author (year)/ study/ population (*n*)	Outcome	Exposure operationalization	Findings (CI)	Covariates	Validity of food outlet database reported? *Author comments*
HEALTHIER FOOD OUTLET EXPOSURE (grocery store [GS], supermarket [S], fruit and vegetable store [FVS], "healthier food outlet")					
Absolute measures (0/2 results are associated with fast food consumption in the expected direction)					
Van Hulst et al. (2012)[36] QUALITY, children Grades 2–5 (*n* = 506)	Odds of eating delivery or takeout in the past week	Distance (m) away from a S	OR = 0.96 (0.56, 1.65) *No conclusive association was identified between living the farthest vs. the shortest distance away from a S and the odds of eating delivery or takeout in the past week.*	Child's age and sex, mother's BMI, highest parental education attainment, total household income (adjusted for number of people in household)	Yes (done by a secondary study in Montréal). *"A validity study of food establishments from this list, verified by onsite field visits, showed good agreement (0.77), sensitivity (0.84) and positive predictive value (0.90)."*
		Kernel S density within 1 km street buffer of home	OR = 0.91 (0.53, 1.58) *No conclusive association was identified between a decrease from the highest to the lowest tertile of S density and the odds of eating delivery or takeout in the past week.*		

Abbreviations: BMI, body mass index; CI, confidence interval; CMA, census metropolitan area; CS, convenience store; FFR, fast food restaurant; GS, grocery store; FVS, fruit and vegetable store; MNSLH, Montreal Neighbourhood Survey of Lifestyle and Health; OR, odds ratio; QUALITY, Quebec Adipose and Lifestyle Investigation in Youth; RFEI, Retail Food Environment Index; S, supermarket.

unexpected direction 2 of 17 times (12%). Relative measures of exposure representing the proportion of unhealthy outlets were associated with BMI outcomes in the expected direction 4 of 6 times (67%). Absolute measures of exposure to outlets hypothesized to be healthier were associated with BMI outcomes in the expected direction 4 of 8 times (50%). Absolute measures of exposure to non–fast food restaurants were associated with more favourable BMI outcomes 6 out of 10 times (60%). The remaining results that were not associated with the BMI outcomes were mostly inconclusive or close to being conclusive in the expected direction.

Absolute versus relative measures of the retail food environment

For the diet outcomes, associations with absolute measures were found to be in the expected direction 12% of the time (4/34) and associations with relative measures were found to be in the expected direction 25% of the time (2/8). For the BMI outcomes, associations with absolute measures went in the expected direction 28% of the time (7/25) and associations with relative measures went in the expected direction 67% of the time (4/6). Across all of the outcomes, associations with absolute measures were found to be in the expected direction 19% of the time (11/59) and associations with relative measures were found to be in the expected direction 43% of the time (6/14).

Study quality

All of the studies were cross-sectional, which limited our ability to draw causal conclusions. The vast majority of studies[19,23,25,29-31,32,35] (89%) investigating BMI relied on self-reported heights and weights. Self-reporting of height and weight can be an efficient approach when large datasets are used and corrections for misreporting are taken into consideration.[38] Nine studies[24,25,27,29,30,31,32,33,34] (53%) did not report how well the retail food data represented actual food outlets present in the field. Of the eight studies reporting validation results, one study[35] performed street audits on a small subset of their dataset and determined 100% accuracy; six studies[18,21,23,26,28,36] referenced secondary validation studies and reported moderate to substantial validity, and one study[19] validated a subset of retail food outlets against a public health inspectors' list and determined a high level of agreement.

Discussion

This study was motivated by the desire to systematically examine the body of evidence on the role of food environments in diet quality and BMI-related outcomes for Canadians. Heterogeneity in the exposure measurement and the ascertainment of outcomes made comparing effect sizes difficult; we focussed on the general trends of the associations for what are thought to be less healthy retail outlets, healthier retail outlets and restaurants with diet quality and BMI-related outcomes. Overall, this body of literature is characterized by a large number of inconclusive results. We found limited evidence supporting the hypothesis that the food environment influences diet quality. The percent of associations that went in an expected direction were below 33% for all but one of the exposure categories and diet quality outcomes. The one association that tested the relationship between a relative measure (proportion of healthier outlets) and FVI went in the expected direction.

Absolute measures of exposure to outlets hypothesized to be healthier were associated with BMI in the expected direction 50% of the time, relative measures of exposure representing the proportion of unhealthy outlets were associated with BMI in the expected direction 67% of the time, and absolute measures of non–fast food restaurant exposure were associated with a more favourable BMI profile 60% of the time. The associations that were not in the expected direction were either inconclusive or close to being conclusive in an expected direction and do not preclude the possibility of an association. Given that some studies might have been able to make conclusive statements if they had had a larger sample size, the percentages of the associations that we tallied as conclusive in the expected direction may be conservative.

TABLE 5
Associations between the food environment and body mass index (continuous and categorical overweight/obesity)

Author (year)/ study/ population (*n*)	Outcome	Exposure operationalization	Findings (CI)	Covariates	Validity of food outlet database reported? *Author comments*
LESS HEALTHY FOOD OUTLET EXPOSURE (fast food restaurant [FFR], convenience store [CS], "less healthy food retail")					
Absolute measures (3/17 results are associated with BMI in the expected direction)					
Polsky et al., (2016)[19] 2005, 2007/08, 2009/10 CCHS, adults 18+ (*n = 10 199*)	Odds of obesity (BMI ≥ 30)	FFR density within 10 min walking buffer	OR = 1.03 (0.95, 1.12) *No conclusive association was identified between a one IQR increase (between 25th and 75th percentile) in FFR per km² and the odds of obesity.*	Age, marital status, cultural/ ethnic group, immigration status, educational attainment, city of residence, survey cycle, area material deprivation, walkability	Yes. *"We were also able to validate a subset of our final restaurant list for Toronto against a contemporaneous public health inspectors' list ... and results revealed a high level of agreement (all intra-class correlation coefficients > 0.80; data not shown)."*
	Continuous BMI		β = 0.11 (−0.02, 0.24) *The lower bound of the confidence interval is just below zero, so a one IQR increase (between 25th and 75th percentile) in FFR per km² may be associated with a 0.11 kg/m² higher BMI.*		
Larsen et al. (2015)[34] BEAT, Grade 5 and 6 students *(n = 1035)*	Odds of overweight or obesity	FFR density within 1 km network buffer	OR = 0.98 (0.95, 1.00) *No conclusive association was identified between an additional FFR per km² and the odds of overweight or obesity.*	Gender, age, median household income	No.
		Distance (km) from FFR	OR = 1.26 (0.87, 1.83) *No conclusive association was identified between an additional km away from a FFR and the odds of overweight or obesity.*		
		Density of "less healthy food retail" within 1 km network buffer	OR = 0.98 (0.96, 1.00) *No conclusive association was identified between an additional less healthy outlet per km² and the odds of overweight or obesity.*		
		Distance (km) from "less healthy food retail"	OR = 1.00 (1.00, 1.00) *No association was identified between an additional km away from a less healthy outlet and the odds of overweight or obesity.*		
Hollands et al. (2014)[25] 2007/08 CCHS, adults 18–65 (*n = 84 341*)	Continuous BMI	FFR density within forward sortation area	**β = 0.03 (0.02, 0.05)** *An additional FFR per 10 000 people is associated with a 0.03 kg/m² higher BMI.*	Smoking, alcohol use, physical activity, fruit and vegetable consumption, sedentary activity, immigration, ethnic origin, labour market, income, education, food security, sex, marital status, having children, urban region, province	No.

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TABLE 5 (continued)
Associations between the food environment and body mass index (continuous and categorical overweight/obesity)

Author (year)/ study/ population (*n*)	Outcome	Exposure operationalization	Findings (CI)	Covariates	Validity of food outlet database reported? *Author comments*
Minaker et al. (2013)[32] NEWPATH, adults 19+ (*n = 4102*)	Continuous BMI	Distance (km) from FFR	β = −0.74 (−1.48, 0.01)[a] *The upper bound of the confidence interval is just above zero, so an additional km away from a FFR may be associated with a 0.74kg/m² lower BMI.*	Age, education level, household income, household car ownership	No. *"Follow up direct observation was employed to ensure accuracy."*
		Distance (km) from CS	**β = −0.85 (−1.63, −0.07)[a]** *An additional km away from a CS is associated with a 0.85 kg/m²lower BMI.*		
Kestens et al. (2012)[23] 2003, 2005 CCHS, adults 18+ (*n = 5578*)	Odds of overweight or obesity (BMI ≥ 25)	Kernel FFR density with adaptive bandwidth	OR = 0.68 (0.58, 0.80)[b] *An increase from the lowest to the highest quartile of FFR density is associated with 32% lower odds of overweight or obesity.*	Age, gender, occupation, household type, household size, income, educational attainment	Yes (done by a secondary study in Montréal). *"An on-site ground truthing study showed good validity of the foodstore registry."*
		Kernel CS density with adaptive bandwidth	OR = 0.59 (0.49, 0.70)[b] *An increase from the lowest to the highest quartile of CS density is associated with 41% lower odds of overweight or obesity.*		
Prince et al. (2012)[30] 2000/01, 2003, 2005, 2007 CCHS, adults 18+ (*n = 4727*)	Odds of overweight or obesity (BMI ≥ 25)	FFR density within neighbourhood (most neighbourhoods ≥ 4000 people)	**OR = 1.31 (1.11, 1.52)[a]** *An additional FFR per 1000 people is associated with 31% higher odds of overweight or obesity.*	Age, education, household income, smoking status, season of data collection, leisure-time physical activity	No (some outlets verified but dataset not validated).
		CS density within neighbourhood (most neighbourhoods ≥ 4000 people)	OR = 1.03 (0.94, 1.12)[a] *No conclusive association was identified between an additional CS per 1000 people and the odds of overweight or obesity.*		
Gilliland et al. (2012)[35] Survey, students aged 10–14 (*n = 891*)	Age-specific BMI z-score	FFR count within 500 m network buffer around home	β = 0.01 (−0.23, 0.25) *No conclusive association was identified between an additional FFR and age specific BMI z-score.*	Age, sex	Yes. *"To 'ground truth' the database, trained research assistants performed on-site environmental audits within a 1000 m buffer around six of the sample schools during the same period as the surveys and confirmed 100% accuracy of the database."*
		CS count within 500 m network buffer around home	β = 0.19 (−0.05, 0.43) *The lower bound of the confidence interval is just below zero, so an additional CS may be associated with a 0.19kg/m² higher age-specific BMI z-score.*		

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In contrast, absolute measures of exposure to outlets thought to be less healthy were associated with BMI in the expected direction only 18% of the time and, counterintuitively, Kestens et al.[23] found higher absolute densities of fast food outlets and corner stores to be protective for BMI. This may be because areas with a high density of restaurants and retail are generally more walkable[19,39] and these areas may also have a higher density of healthier outlets, attenuating or outweighing potentially harmful effects of fast food and convenience outlets.

One interpretation of the predominately inconclusive relationship between food environment and exposure and diet is that no real association exists. Another is that associations may exist for some subpopulations, such as those with low income or limited mobility, but were diluted by looking at broader populations. We suspect that the inconclusive relationship is mainly a result of the difficulty in accurately ascertaining diet quality through self-reported dietary assessments. In studies

TABLE 5 (continued)
Associations between the food environment and body mass index (continuous and categorical overweight/obesity)

Author (year)/ study/ population (*n*)	Outcome	Exposure operationalization	Findings (CI)	Covariates	Validity of food outlet database reported? *Author comments*
Prince et al. (2011)[29] ONS, adults 18+ (*n = 5025*)	Odds of overweight or obesity (BMI ≥ 25)	FFR density within neighbourhood (most neighbourhoods > 4000 people)	OR = 1.09 (0.97, 1.23)[a] *The lower bound of the confidence interval is just below one, so an additional FFR per 1000 people may be associated with 9% higher odds of overweight or obesity.*	Age, education, household income, smoking status, season of collection	No (some outlets verified but dataset not validated).
		CS density within neighbourhood (most neighbourhoods > 4000 people)	OR = 1.17 (0.87, 1.57)[a] *No conclusive association was identified between an additional CS per 1000 people and the odds of overweight or obesity.*		
Relative measures (4/6 results are associated with BMI in the expected direction)					
Polsky et al. (2016)[19] 2005, 2007/08, 2009/10 CCHS, adults 18+ (*n = 10 199*)	Odds of obesity (BMI ≥ 30)	FFR/all restaurants within 10 min walking buffer	**OR = 1.15 (1.02, 1.29)** *A one IQR increase (between 25th and 75th percentile) in the proportion of FFRs of all restaurants is associated with 15% higher odds of obesity.*	Age, marital status, cultural/ ethnic group, immigration status, educational attainment, city of residence, survey cycle, area material deprivation, walkability	Yes. *"We were also able to validate a subset of our final restaurant list for Toronto against a contemporaneous public health inspectors' list ... and results revealed a high level of agreement (all intra-class correlation coefficients > 0.80; data not shown)."*
	Continuous BMI		**β = 0.21 (0.00, 0.41), $p < 0.05$** *A one IQR increase (between 25th and 75th percentile) in the proportion of FFRs of all restaurants is associated with a 0.21 kg/m² higher BMI.*		
Minaker et al. (2013)[32] NEWPATH, adults 19+ (*n = 4102*)	Continuous BMI	RFEI (FFR + CS / S + produce vendors) within 1 km of home	β = 0.06 (0.00, 0.11)[a] *The lower bound of the confidence interval is just below zero (before rounding), so an additional unit increase in RFEI may be associated with a 0.06 kg/m² higher BMI.*	Age, education level, household income, household car ownership	No. *"Follow up direct observation was employed to ensure accuracy."*
Kestens et al. (2012)[23] 2003, 2005 CCHS, adults 18+ (*n = 5578*)	Odds of overweight or obesity (BMI ≥ 25)	FFR/all restaurants with adaptive bandwidth	**OR = 1.44 (1.21, 1.73)[b]** *An increase from the lowest to the highest quartile of proportion of FFR is associated with 44% higher odds of overweight or obesity.*	Age, gender, occupation, household type, household size, income, educational attainment	Yes (done by a secondary study in Montréal). *"An on-site ground truthing study showed good validity of the foodstore registry."*
Spence et al. (2009)[31] PHS-2002, adults 18+ (*n = 2900*)	Odds of obesity (BMI ≥ 30)	RFEI (FFR + CS/GS) within 800 m buffer	**OR = 0.74 (0.59, 0.94)** *A RFEI score in the lowest category vs. the highest category is associated with 26% lower odds of obesity.*	Age, sex, education level, neighbourhood SES	No.
		RFEI (FFR + CS/GS) within 1600 m buffer	OR = 0.85 (0.66, 1.10) *No conclusive association was identified between the lowest category of RFEI score vs. the highest category and the odds of obesity.*		

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using self-reported instruments such as food records and food frequency questionnaires, the error in estimated dietary intake is often substantial and likely larger than other exposures and outcomes commonly investigated in epidemiological studies.[40] Errors can arise in different ways, including recall bias, social desirability bias, interviewer bias, day-to-day variability in diet and inaccurate translation of self-reported statements into specific nutrient amounts.[40,41] The implications of these errors are often an attenuation of the effect size, a loss of statistical power and false negative results.[40] A systematic review of dietary assessment in food environment research concluded that studies that used higher-quality instruments, such as 24-hour dietary recalls or food diaries, showed more consistent associations with food environment exposures in the expected direction than studies that used brief instruments, such as dietary screeners.[42] We are now in a new

TABLE 5 (continued)
Associations between the food environment and body mass index (continuous and categorical overweight/obesity)

Author (year)/ study/ population (*n*)	Outcome	Exposure operationalization	Findings (CI)	Covariates	Validity of food outlet database reported? *Author comments*
HEALTHIER FOOD OUTLET EXPOSURE (grocery store [GS], supermarket [S], fruit and vegetable store [FVS], "healthier food outlet")					
Absolute measures (4/8 results are associated with BMI in the expected direction)					
Larsen et al. (2015)[34] Project BEAT, Grade 5 and 6 students (*n = 1035*)	Odds of overweight or obesity	GS + S density within 1 km network buffer	OR = 1.05 (0.91, 1.12) *No conclusive association was identified between an additional GS or S per km² and the odds of overweight or obesity.*	Gender, age, median area household income	No.
		Distance (km) from GS + S	**OR = 1.48 (1.06, 2.06)** *An additional km away from an outlet is associated with 48% higher odds of overweight or obesity.*		
		Density of "healthier food outlets" within 1 km network buffer	**OR = 0.90 (0.85, 0.96)** *An additional healthier outlet per km² is associated with 10% lower odds of overweight or obesity.*		
		Distance (km) to nearest "healthier food outlet"	OR = 0.98 (0.74, 1.30) *No conclusive association was identified between an additional km away from a healthier outlet and the odds of overweight or obesity.*		
Minaker et al. (2013)[32] NEWPATH, adults 19+ (*n = 4102*)	Continuous BMI	Distance (km) from GS + S	**β = 0.39 (0.05, 0.73)**[a] *An additional km away from an outlet is associated with a 0.39 kg/m² increase in BMI.*	Age, education level, household income, household car ownership	No. *"Follow up direct observation was employed to ensure accuracy."*
Kestens et al. (2012)[23] 2003, 2005 CCHS, adults 18+ (*n = 5578*)	Odds of overweight or obesity (BMI ≥ 25)	Kernel FVS + S density with adaptive bandwidth	**OR = 0.68 (0.58, 0.79)**[b] *An increase from the lowest to the highest quartile of FVS or S density is associated with 32% lower odds of overweight or obesity.*	Age, gender, occupation, household type, household size, income, educational attainment	Yes (done by a secondary study in Montréal). *"An on-site ground truthing study showed good validity of the foodstore registry."*
Prince et al. (2012)[30] 2000/01, 2003, 2005, 2007 CCHS, adults 18+ (*n = 4727*)	Odds of overweight or obesity (BMI ≥ 25)	GS + S density within neighbourhood	OR = 1.00 (0.90, 1.11)[a] *No conclusive association was identified between an additional GS or S per 1000 people and odds of overweight or obesity.*	Age, education, household income, smoking status, season of data collection, leisure-time physical activity	No (some outlets verified but dataset not validated).
Prince et al. (2011)[29] ONS, adults 18+ (*n = 5025*)	Odds of overweight or obesity (BMI ≥ 25)	GS + S density within neighbourhood	OR = 1.29 (0.66, 2.54)[a] *No conclusive association was identified between an additional GS or S per 1000 people and odds of overweight or obesity.*	Age, education, household income, smoking status, season of collection	No (some outlets verified but dataset not validated).

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era when the digitization of food is possible through photographs and barcode scanning; creative new approaches to ascertaining diet quality are an interesting avenue for future research.

We identified stronger evidence for a food environment–BMI relationship. This finding may speak to a more accurate ascertainment of the outcome when compared against diet quality assessment. Even self-reported BMI, which suffers from reporting bias,[43] is relatively easy to understand, easy to measure, does not vary greatly day-to-day and is easier to remember than diet.

Relative measures of the food environment consistently outperformed absolute measures. The association between relative measures of the food environment, BMI and diet quality were found to be in the expected direction 43% of the time versus 19% of the time for absolute measures. Our findings align with a review from the United States that also found that relative food environment measures were more consistently associated with health-related outcomes than absolute measures of food outlets.[13] Relative measures may provide a

TABLE 5 (continued)
Associations between the food environment and body mass index (continuous and categorical overweight/obesity)

Author (year)/ study/ population (*n*)	Outcome	Exposure operationalization	Findings (CI)	Covariates	Validity of food outlet database reported? *Author comments*
NON–FAST FOOD RESTAURANT EXPOSURE					
Absolute measures (6/10 results are associated with a BMI outcome)					
Polsky et al. (2016)[19] 2005, 2007/08, 2009/10 CCHS, adults 18+ (*n = 10 199*)	Odds of obesity (BMI ≥ 30)	Density of full-service restaurants within 10 min walking buffer	OR = 0.97 (0.90, 1.04) *No conclusive association was identified between a one IQR increase (between 25th and 75th percentile) in full-service restaurant density and the odds of obesity.*	Age, marital status, cultural/ ethnic group, immigration status, educational attainment, city of residence, survey cycle, area material deprivation, walkability	Yes. *"We were also able to validate a subset of our final restaurant list for Toronto against a contemporaneous public health inspectors' list ... and results revealed a high level of agreement (all intra-class correlation coefficients > 0.80; data not shown)."*
	Continuous BMI		β = 0.01 (−0.12, 0.13) *No conclusive association was identified between a one IQR increase (between 25th and 75th percentile) in full-service restaurant density and BMI.*		
	Odds of obesity (BMI ≥ 30)	Density of other restaurants (e.g. café, coffee shop, snack shop) within 10 min walking buffer	OR = 0.97 (0.91, 1.05) *No conclusive association was identified between a one IQR increase (between 25th and 75th percentile) in other restaurant density and the odds of obesity.*		
	Continuous BMI		β = 0.02 (−0.10, 0.13) *No conclusive association was identified between a one IQR increase (between 25th and 75th percentile) in other restaurant density and the odds of obesity.*		
Hollands et al. (2014)[25] 2007/08 CCHS, adults 18–65 (*n = 84 341*)	Continuous BMI	Full-service restaurant density within forward sortation area	**β = −0.06 (−0.11, −0.01)** *An additional full-service chain restaurant per 10 000 people is associated with a 0.06 kg/m² decrease in BMI.*	Smoking, alcohol use, physical activity, fruit and vegetable consumption, sedentary activity, immigration, ethnic origin, labour market, income, education, food security, sex, marital status, having children, urban region, province	No.
		Other-service restaurant density within forward sortation area	**β = −0.01 (−0.02, −0.01)** *An additional other non-chain restaurant per 10 000 people is associated with a 0.01 kg/m² decrease in BMI.*		
Minaker et al. (2013)[32] NEWPATH, adults 19+ (*n = 4102*)	Continuous BMI	Restaurant count within 1 km circular buffer	**β = −0.03 (−0.05, −0.01)**[a] *An additional restaurant within a 1 km radius from home is associated with a 0.03 kg/m² decrease in BMI.*	Age, education level, household income, household car ownership	No. *"Follow up direct observation was employed to ensure accuracy."*
Kestens et al. (2012)[23] 2003, 2005 CCHS, adults 18+ (*n = 5578*)	Odds of overweight or obesity (BMI ≥ 25)	Kernel full-service restaurant density with adaptive bandwidth	**OR = 0.62 (0.53, 0.72)**[b] *An increase from the lowest to the highest quartile of full-service restaurant density is associated with 38% lower odds of overweight or obesity.*	Age, gender, occupation, household type, household size, income, educational attainment	Yes (done by a secondary study in Montréal). *"An on-site ground truthing study showed good validity of the foodstore registry."*

Continued on the following page

TABLE 5 (continued)
Associations between the food environment and body mass index (continuous and categorical overweight/obesity)

Author (year)/ study/ population (*n*)	Outcome	Exposure operationalization	Findings (CI)	Covariates	Validity of food outlet database reported? *Author comments*
Prince et al. (2012)[30] 2000/01, 2003, 2005, 2007 CCHS, adults 18+ (*n = 4727*)	Odds of overweight or obesity (BMI ≥ 25)	Full-service restaurant density within neighbourhood	**OR = 0.77 (0.61, 0.98)**[a] *An additional full-service restaurant per 1000 people is associated with 23% lower odds of overweight or obesity.*	Age, education, household income, smoking status, season of data collection, leisure-time physical activity	No (some outlets verified but dataset not validated).
Prince et al. (2011)[29] ONS, adults 18+ (*n = 5025*)	Odds of overweight or obesity (BMI ≥ 25)	Full-service restaurant density within neighbourhood	**OR = 0.74 (0.63, 0.88)**[a] *An additional full-service restaurant per 1000 people is associated with 26% lower odds of overweight or obesity.*	Age, education, household income, smoking status, season of collection	No (some outlets verified but dataset not validated).

Abbreviations: BEAT, Built Environment and Active Transport; BMI, body mass index; CCHS, Canadian Community Health Survey; CI, confidence interval; CS, convenience store; FFR, fast food restaurant; FVS, fruit and vegetables store; GS, grocery store; IQR, interquartile range; NEWPATH, Neighbourhood Environments in Waterloo Region: Patterns of Transportation and Health; ONS, Ottawa Neighbourhood Study; OR, odds ratio; PHS-2002, Population Health Survey 2002; RFEI, Retail Food Environment Index; S, supermarket; SES, socioeconomic status.

Note: Bolded findings are conclusive results in the expected direction (except for non–fast food restaurant exposure, where an expected direction was not identified).

[a] Sex-stratified results were pooled.

[b] Sex- and city-stratified results were pooled.

better conceptualization of the food environment because they consider the competitive food outlet choices that people face.[18] As an illustration, consider that two neighbourhoods may have the same absolute density of grocery stores; however, if one of the neighbourhoods is swamped with fast food outlets and the other has none, the food environment realities will be very different. A relative measure of the proportion of healthy outlets would capture the difference.[21]

All of the studies were cross-sectional, making causal inference difficult. Self-selection of healthy individuals into neighbourhoods with healthy food environments was not included in our quality filter because studies tend not to account for it. Past research in the built environment–health domain has shown that selection bias, when measured, is not a major driver of associations.[44] Most studies adjusted for SES at the individual level rather than at the area level, which reduces residual confounding. Twelve studies investigated the food environment within only one city. This can be an issue if the limited geographic regions under investigation lead to a lack of variability in the food environment exposure, which may in turn attenuate or mask true associations. While it was not informative to compare studies with self-reported height and weight to the one study with measured height and weight because the population was specific (grade school children) and methodologies differed, it is established in the literature that self-report introduces bias—men and women underestimate their corresponding BMI.[43] Underreporting without proper correction would bias the results towards the null.

More than half of the studies did not report the validity of the food outlet dataset that they used, and errors in databases may lead to inaccurate exposure ascertainment. There is no standard for validating food outlet datasets in the Canadian literature, which is an important issue given that the opening and closure of retail outlets can influence measures. Studies that included validation results used various techniques, and despite some evidence showing moderate to high validity, these studies were small and localized. One study performed a limited number of in-field audits; six studies referred to two secondary validation studies that took place within 12 census tracts in Montreal; and one validated a subsample of its dataset with a city's public health inspection list. The small sample sizes used for validation may not reflect the validity of the entire dataset and therefore results may not be generalizable to different places. There does not appear to be a consensus on which measures of validity to use. This lack of uniformity and the possible limited applicability, along with the paucity of studies reporting validation results mean that concerns about errors in food outlet datasets persist and a consensus "gold standard" dataset that can be used in different regions has not been identified. Larger validation studies with measures adapted to spatial exposures and food environment studies would provide better insight into which datasets are the least error prone. Representativity,[45] a novel measure that compensates false negatives with false positives within the same outlet category and geographic unit, may be a useful measure for this domain.

Most studies in our review operated under general ecological models that consider the multiple factors and contexts that are determinants of behaviour. Several of the studies incorporated the role of the food environment into these models to differing extents. Some studies appeared to be informed by established food environment models, but did not describe them in detail. One study referred to and described the conceptual model developed by Glanz et al.[9] in detail, outlining the dimensions of the food environment, and highlighting residents' perceptions of their food environment as a potential mediator of associations. Another incorporated Cohen and Farley's[37] work, identifying cues associated with palatable food in modern food environments as drivers of food consumption, with reward sensitivity as a potential important individual attribute for responding

to these cues. Generally, methodologies were similar across studies regardless of stated or unstated theoretical underpinnings. Authors that raised a particular attribute as important in their framework (e.g. residents' perceptions of their food environment, reward sensitivity, or time spent at home) did, however, tend to target it for investigation in their study.

Strengths and limitations

This is the first systematic review on the food environment and its relationship to diet quality or BMI in Canada. Strengths of this review include the synthesis of the literature by each association of interest; the calculation of 95% confidence intervals for studies that reported effect size with standard deviations or standard errors; the assessment of key quality issues identified a priori; and the comparison of absolute and relative measures of the retail food environment. The heterogeneity between the studies in exposure measurement, outcome ascertainment and study population made direct comparison between studies difficult and a meta-analysis unfeasible. To assess evidence of a relationship, we tallied the number of conclusive results for each outcome and exposure of interest; however, this does not take into account results that were almost conclusive nor does it account for the size of the effect. Additionally, certain subpopulations may experience differential effects of the neighbourhood food environment on diet or BMI; however, due to the numerous ways that analyses were stratified across the studies, we were not able to take these into account and synthesize the body of literature with clarity. Therefore, we only considered the pooled results. Finally, we cannot exclude the possibility of publication bias. Studies with conclusive relationships may be more likely to be published than studies with inconclusive or null results.

Conclusion

This systematic review looked at pooled results of 17 studies and found limited evidence supporting the hypothesis that the food environment influences diet quality. It may be difficult to show a food environment–diet relationship using commonly used self-reported dietary assessment tools because of problems with error and bias. The review identified stronger evidence for a relationship between the food environment and BMI. While there was wide heterogeneity in measurements used to characterize the food environment, it appears that relative measures perform better than absolute measures. Large-scale studies with wide geographic coverage using innovative diet assessment tools, measured BMI and other clinical markers of cardiometabolic health, together with GIS-based relative measures of the retail food environment and a gold standard dataset of food outlets, would advance our knowledge of the role of the food environment in shaping the health of Canadians.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Authors' contributions and statement

ACS, AB, KD, and NAR were all involved in the study design, the analysis and interpretation of the data, the drafting and revising of the paper and the approval of the final manuscript for submission. ACS and AB reviewed the titles and abstracts of articles identified in the systematic search.

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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At-a-glance

Canadian Chronic Disease Indicators, 2019 – Updating the data and taking into account mental health

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Abstract

The 2019 edition of the Canadian Chronic Disease Indicators (CCDI) provides recent estimates of the burden of chronic conditions and measures of general health and associated determinants in Canada. Using data from the CCDI and 2017 Canadian Community Health Survey, we explored the relationship between sociodemographic factors and self-reported mental health. Our findings suggest that sex (males vs females: adjusted odds ratio [aOR] = 1.22); age (65–79 vs 35–49 year age group: aOR = 1.48); education (postsecondary graduate vs less than high school: aOR = 1.68); household income adequacy (highest quintile [Q5] vs lowest [Q1]: aOR = 2.25); and immigrant status (recent immigrants vs nonimmigrants: aOR = 2.29) were significantly associated with higher self-reported mental health.

Keywords: *chronic conditions, mental health, public health, Canada, determinants of health, sociodemographic factors*

Highlights

- The Canadian Chronic Disease Indicators Quick Statistics table shows estimates of the burden of chronic conditions, measures of general health and associated determinants of health.
- In 2017, more than two-thirds (70.3%) of the population in Canada reported having "excellent" or "very good" mental health.
- Age, sex, province of residence, income quintile, education level and immigration status were sociodemographic factors significantly associated with self-reported mental health.

Introduction

The Canadian Chronic Disease Indicators (CCDI) is a resource produced by the Public Health Agency of Canada (PHAC) that captures the burden of chronic conditions, and measures of general health and associated determinants. The CCDI is updated annually and is made publicly available through the CCDI summary document, Quick Stats (Table 1), and in the interactive CCDI Data Tool (https://infobase.phac-aspc.gc.ca/ccdi-imcc/).

The CCDI comprises six domains: (1) social and environmental determinants; (2) maternal and child health risk and protective factors; (3) behavioural risk and protective factors; (4) risk conditions; (5) disease prevention practices; and (6) health outcomes/status. Self-reported mental health status is a measure within the general health indicator group of the health outcomes/status domain of the CCDI. This At-a-glance article presents the updated 2019 CCDI estimates and explores its mental health content to provide an in-depth look at the distribution of self-reported mental health in Canada.

Mental health is a key outcome reported in the CCDI as it is intrinsically linked to, and has a bidirectional relationship with, physical health, behavioural and emotional processes and social factors.[1-6] PHAC defines positive mental health as "a state of well-being that allows us to feel, think, and act in ways that enhance our ability to enjoy life and deal with the challenges we face."[7] Mental health promotion and mental illness prevention are key PHAC priorities.[8] Indicators of mental health, such as self-reported mental health, disaggregated by sociodemographic factors, included in the CCDI Data Tool, provide important data to support policies and programs. These data will also help to inform PHAC's collaborative work in mental health promotion as well as highlight areas for prevention of inequities among diverse populations.

PHAC and Statistics Canada identify self-reported mental health as a measure of the population's general mental health status.[9] Consistent with the PHAC Positive Mental Health Surveillance Indicator Framework (PMHSIF), the CCDI includes an estimate of the population in Canada who reported their mental health as "excellent" or "very good." The estimate was assessed using data from the 2017 Canadian Community Health Survey (CCHS) – Annual component. Respondents were asked, "In general, would you say your mental health is…?" Response options were as follows: "excellent," "very good," "good," "fair" or "poor." For this study, higher mental health includes respondents who reported their mental health as "excellent" or "very good."

This At-a-glance article includes estimates for self-reported mental health disaggregated

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by sociodemographic factors, including age group, sex, province, rural/urban residence, income quintile, education level, Indigenous status, immigration status and length of time since immigration. Estimates were weighted with the survey sampling weight, and variance was estimated using the bootstrap method to account for the complex survey design. An adjusted logistic regression model was used to examine the relationship between sociodemographic factors and self-reported mental health. Reference groups were chosen based on adjusted odds ratios (aORs), not on prevalence rates. The category with the lowest adjusted odds of higher mental health was chosen as the reference group for easy and consistent interpretation. All statistical analyses were executed using SAS Enterprise Guide version 5.1 (SAS Institute Inc., Cary, NC, USA).

Main findings

Table 1 displays the 2019 CCDI Quick Stats for all indicators. Data from the 2017 CCHS – Annual Component indicate that 70.3% of the population in Canada (n = 36 024) self-reported their mental health as "excellent" or "very good." The prevalence of higher mental health reported in previous CCDI Quick Stats ranges from 70.8% in 2016, to 72.5% in 2015 and 71.2% in 2014.[10-12]

Data breakdowns

Table 2 displays the descriptive characteristics of the population in Canada with higher ("excellent" or "very good") self-reported mental health, which can also be found in the CCDI Data Tool. We found that males aged 12 years or more had a prevalence of higher mental health of 72.7%, while females had a prevalence of 68.1%. The prevalence of higher mental health across all age groups ranged from 63.4% (80+ years) to 73.8% (65–79 years).

The rates of higher mental health also varied across provinces, between 65.9% (New Brunswick) and 73.1% (Quebec). Prevalence of higher mental health was similar for individuals living in rural areas (71.2%) and those living in urban areas (70.1%).

Rates of higher mental health tended to increase with increasing education level (from 57.2% for less than high school to 72.3% for postsecondary graduate) and increasing household income adequacy (from 61.6% at Q1 to 77.3% at Q5). The prevalence of higher mental health was 73.9% among Inuit, 62.8% among First Nations peoples and 60.3% among Métis people, whereas prevalence of higher mental health was 70.7% among non-Indigenous Canadians.

Nonimmigrants had a prevalence of higher mental health of 69.4%. Prevalence of higher mental health appeared to decrease with length of time in Canada, from 80.6% among recent immigrants (≤ 5 years in Canada) to 71.0% among those who had been in Canada for longer than 10 years.

The odds of higher self-reported mental health were 22% greater for males than for females (aOR = 1.22, 95% confidence interval [CI] = 1.14–1.30). Those aged 12–19 years (aOR = 1.28, 95% CI = 1.12–1.46) and 65–79 years (aOR = 1.48, 95% CI = 1.34–1.63) had greater odds of reporting higher mental health than 35–49 year olds. There were no significant differences in odds between the 20–34, 50–64, 80+ and the 35–49 year age groups.

Quebec was the only province with a statistically significant odds ratio, with odds of higher mental health 41% greater than for Nova Scotia (aOR = 1.41, 95% CI = 1.23–1.61).

Individuals who graduated from high school or from postsecondary institutions had odds of higher mental health that were 32% (aOR = 1.32, 95% CI = 1.16–1.49) and 68% (aOR = 1.68, 95% CI = 1.50–1.88) greater than those who did not graduate from high school. The odds of higher mental health increased in a significant, stepwise fashion with increasing income (aOR_{Q2} = 1.31, 95% CI = 1.19–1.44; aOR_{Q3} = 1.53, 95% CI = 1.38–1.69; aOR_{Q4} = 1.77, 95% CI = 1.58–1.97; and aOR_{Q5} = 2.25, 95% CI = 2.02–2.51).

No significant differences in odds of higher mental health were found by Indigenous status.

Immigrants had greater odds of higher mental health than nonimmigrants; however, the magnitude of this effect decreased with length of time in Canada (≤ 5 years: aOR = 2.29, 95% CI = 1.80–2.90; 6–10 years: aOR = 1.28, 95% CI = 0.99–1.66; > 10 years: aOR = 1.20, 95% CI = 1.08–1.33).

Conclusion

Self-reported mental health is one of the general health indicators included in the CCDI, a resource that presents information on the surveillance of chronic conditions in Canada. Based on the logistic regression results, females 12+ years old, individuals in the 35–49 age group, individuals with less than a high school education and/or those in the lowest income quintile group would benefit from targeted mental health promotion interventions.

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Conflicts of interest

The authors have no conflicts of interest.

Authors' contributions and statement

MB, EP, TL and MV drafted this At-a-glance article. MV analyzed the prevalence estimates for self-reported mental health and conducted the logistic regression model analysis. All authors interpreted the data, and reviewed and/or revised this At-a-glance article.

The content and views expressed in this At-a-glance article are those of the authors and do not necessarily reflect those of the Government of Canada.

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TABLE 1

CANADIAN CHRONIC DISEASE INDICATORS

QUICK STATS, 2019 EDITION

INDICATOR GROUP	INDICATOR MEASURE(S)	LATEST DATA[a]	DATA SOURCE (YEAR)
SOCIAL AND ENVIRONMENTAL DETERMINANTS			
Education	% of population that reports having less than a high school education, population aged 20+ years	11.1%	CCHS (2017)
Income	% of population living below low-income cut-offs, after tax, total population	7.8%	CIS (2017)
Childhood poverty	% of children living below low-income cut-offs, after tax, population aged <18 years[b]	6.3%	CIS (2017)
Employment	Average annual unemployment rate (% of labour force that was unemployed during reference period), population aged 15+ years	5.8%	LFS (2018)
Community belonging	% of population that reports a "very strong" or "somewhat strong" sense of belonging to their local community, population aged 12+ years	69.3%	CCHS (2017)
MATERNAL AND CHILD HEALTH RISK AND PROTECTIVE FACTORS			
Diabetes during pregnancy	Rate of pregnant women with diagnosed diabetes (pre-existing and gestational diabetes), women aged 15 to 54 years	99.1 per 1 000 total births[c]	DAD (2017)
Hypertension during pregnancy	Rate of pregnant women with diagnosed hypertension (pre-existing and gestational hypertension), women aged 15 to 54 years	69.6 per 1 000 total births[c]	DAD (2017)
Maternal weight during pregnancy	% of women who report gestational weight gain above recommended Health Canada guidelines, women aged 15 to 55 years	43.7%	CCHS (2017)
Preterm birth	% of live births with a gestational age at birth of less than 37 completed weeks	8.2 per 100 live births	DAD (2017)
Breastfeeding	% of women who report exclusive breastfeeding of their child for at least the first 6 months of life, women aged 15 to 55 years	32.2%	CCHS (2017)
Exposure to second-hand smoke	% of households with children aged < 15 years that report regular child exposure to environmental tobacco smoke at home	1.6%	CTADS (2017)
Family violence	% of population that reports experiencing before the age of 15 any type of physical or sexual abuse and/or exposure to violence by an adult (18+ years),[d] population aged 15+ years	34.1%	GSS (2014)
BEHAVIOURAL RISK AND PROTECTIVE FACTORS			
24-Hour movement	% of children and youth who meet the Canadian 24-Hour Movement Guidelines for Children and Youth, population aged 5 to 17 years	9.5%	CHMS (2014 to 2015)
Physical activity	% of children and youth who meet physical activity recommendations by accumulating at least 60 minutes of moderate-to-vigorous physical activity per day (measured data), population aged 5 to 17 years	39.2%	CHMS (2016 to 2017)
	% of adults who meet physical activity guidelines by accumulating at least 150 minutes of moderate-to-vigorous physical activity each week, in bouts of 10 minutes or more (measured data), population aged 18+ years	16.4%	CHMS (2016 to 2017)
Sedentary behaviour	% of children and youth who report meeting sedentary behaviour recommendations by spending 2 hours or less per day watching television, DVDs or videos or spending time on a computer, tablet or other hand-held electronic device during leisure-time,[e] population aged 5 to 17 years	53.9%	CHMS (2016 to 2017)
Sleep	% of population that reports obtaining the recommended amount of daily sleep, population aged 5+ years	65.5%	CHMS (2014 to 2015)
Nutrition	% of population that reports consuming fruit and vegetables at least 5 times/day, population aged 12+ years	28.7%	CCHS (2017)
	% of children and youth who report drinking sugar-sweetened beverages daily, population aged 5 to 17 years	11.6%	CHMS (2016 to 2017)
Chronic stress	% of population that reports life to be "quite a bit" or "extremely" stressful most days in the last 12 months, population aged 12+ years	21.7%	CCHS (2017)
Alcohol use	% of population that reports exceeding low risk alcohol drinking guidelines for chronic health effects, population aged 15+ years	16.1%	CTADS (2017)
Smoking	% of population that reports being current smokers (daily or occasional), population aged 15+ years	15.1%	CTADS (2017)
Drug use	% of population that reported using cannabis at least once a week in the last 3 months, population aged 15+ years	5.9%	CTADS (2017)
Main chronic disease risk factors prevalence	% of population that reports having at least one of four main chronic disease risk factors (tobacco smoking, physical inactivity, unhealthy eating and harmful use of alcohol),[e] population aged 20+ years	88.1%	CCHS (2017)
RISK CONDITIONS			
Obesity	% of children and youth who are obese (measured data), population aged 5 to 17 years	10.6%	CHMS (2016 to 2017)
	% of adults that are obese (measured data), population aged 18+ years	26.9%	CHMS (2016 to 2017)
Elevated blood glucose	% of population with elevated[f] blood glucose (measured data), population aged 18+ years	6.8%	CHMS (2016 to 2017)
Elevated blood cholesterol	% of population with elevated[f] blood cholesterol [TC:HDL-C ratio] (measured data), population aged 18+ years	15.1%	CHMS (2016 to 2017)
Hypertension	% of population with diagnosed hypertension, population aged 20+ years	25.5%	CCDSS (2016–17)

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INDICATOR GROUP	INDICATOR MEASURE(S)	LATEST DATA[a]	DATA SOURCE (YEAR)
DISEASE PREVENTION PRACTICES			
Contact with health care professional	% of population that reports having a regular health care provider, population aged 12+ years	84.6%	CCHS (2017)
	% of population that reported consulting a dentist, dental hygienist or orthodontist at least once in the past 12 months, population aged 12+ years	69.3%	CCHS (2016)
Disease screening	% of women who report having had a mammogram at least once in the past 5 years,[e] population aged 50 to 74 years	84.2%	CCHS (2017)
	% of women who report having had at least one Pap smear test in the past 3 years,[e] population aged 25 to 69 years	78.4%	CCHS (2017)
	% of population that reports having had at least one fecal occult blood test, colonoscopy and/or sigmoidoscopy in the recommended time period,[e] population aged 50 to 74 years	67.9%	CCHS (2017)
Vaccination (influenza)	% of population living with a chronic disease[g] that reported having a seasonal flu shot in the past 12 months, population aged 12+ years	48.4%	CCHS (2017)
HEALTH OUTCOMES/STATUS			
General health	% of population that reports their health is "very good" or "excellent," population aged 12+ years	61.1%	CCHS (2017)
	% of population that reports their mental health is "very good" or "excellent," population aged 12+ years	70.3%	CCHS (2017)
Morbidity – prevalence	% of population with diagnosed diabetes, population aged 1+ years	8.8%	CCDSS (2016–17)
	% of population that reports having diagnosed cardiovascular diseases (heart disease or stroke), population aged 20+ years	6.1%	CCHS (2017)
	% of population with diagnosed ischemic heart disease, population aged 20+ years	8.5%	CCDSS (2016–17)
	% of population with diagnosed heart failure, population aged 40+ years	3.7%	CCDSS (2016–17)
	% of population with diagnosed stroke, population aged 20+ years	2.9%	CCDSS (2016–17)
	% of population with diagnosed asthma, population aged 1+ years	11.6%	CCDSS (2016–17)
	% of population with diagnosed chronic obstructive pulmonary disease, population aged 35+ years	10.3%	CCDSS (2016–17)
	% of population that reports ever being diagnosed with cancer, population aged 12+ years	7.3%	CCHS (2017)
	% of population that reports ever having symptoms consistent with at least 1 of 6 mental or substance use disorders,[h] population aged 15+ years	33.3%	CCHS – MH (2012)
	% of population that reports having diagnosed mood and/or anxiety disorders, population aged 12+ years	13.4%	CCHS (2017)
	% of population with diagnosed dementia, including Alzheimer disease, population aged 65+ years	6.9%	CCDSS (2016–17)
	% of population with diagnosed osteoarthritis, population aged 20+ years	13.6%	CCDSS (2016–17)
	% of population with diagnosed osteoporosis, population aged 40+ years	11.9%	CCDSS (2016–17)
	% of population that reports having been diagnosed with at least 1 of the 5 major chronic diseases,[i] population aged 20+ years	34.2%	CCHS (2017)
Multimorbidity	% of population that reports having been diagnosed with at least 1 of the 10 common chronic diseases,[j] population aged 20+ years	43.7%	CCHS (2017)
	% of population that reports having been diagnosed with at least 2 of the 5 major chronic diseases,[i] population aged 20+ years	8.9%	CCHS (2017)
	% of population that reports having been diagnosed with at least 2 of the 10 common chronic diseases,[j] population aged 20+ years	18.4%	CCHS (2017)
Morbidity – incidence	Rate of newly diagnosed diabetes cases, population aged 1+ years	603.5 per 100 000	CCDSS (2016–17)
	Rate of newly diagnosed ischemic heart disease cases, population aged 20+ years	598.5 per 100 000	CCDSS (2016–17)
	Rate of newly diagnosed acute myocardial infarction cases, population aged 20+ years	222.2 per 100 000	CCDSS (2016–17)
	Rate of newly diagnosed heart failure cases, population aged 40+ years	535.6 per 100 000	CCDSS (2016–17)
	Rate of newly diagnosed asthma cases, population aged 1+ years	448.8 per 100 000	CCDSS (2016–17)
	Rate of newly diagnosed chronic obstructive pulmonary disease cases, population aged 35+ years	823.2 per 100 000	CCDSS (2016–17)
	Rate of all newly diagnosed cancer cases,[k] total population	563.6 per 100 000	CCR/NCIRS (2017)
	Rate of newly diagnosed dementia cases, including Alzheimer disease, population aged 65+ years	1 350.9 per 100 000	CCDSS (2016–17)
	Rate of newly diagnosed osteoarthritis cases, population aged 20+ years	872.0 per 100 000	CCDSS (2016–17)
	Rate of newly diagnosed hip fractures, population aged 40+ years	149.8 per 100 000	CCDSS (2016–17)
Disability	% of population that reports being limited in their activities "sometimes" or "often" due to disease/illness, population aged 12+ years	32.7%	CCHS (2014)

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INDICATOR GROUP	INDICATOR MEASURE(S)	LATEST DATA[a]	DATA SOURCE (YEAR)
Mortality	Death rate due to a major chronic disease (diabetes, cancer, cardiovascular diseases, chronic respiratory diseases), total population	475.7 per 100 000	CVSD (2016)
	Death rate due to diabetes, total population	18.9 per 100 000	CVSD (2016)
	Death rate due to cardiovascular diseases, total population	192.9 per 100 000	CVSD (2016)
	Death rate due to chronic respiratory diseases, total population	45.9 per 100 000	CVSD (2016)
	Death rate due to cancer, total population	218.1 per 100 000	CVSD (2016)
	Death rate due to suicide, total population	11.0 per 100 000	CVSD (2016)
	Death rate due to dementia, including Alzheimer disease, total population	69.4 per 100 000	CVSD (2016)
	Death rate within one year of hip fracture, population aged 40+ years that had a hip fracture	215.1 per 1 000	CCDSS (2015–16)
Premature mortality	Probability of dying between ages 30 and 69 years from one of the major chronic diseases (cardiovascular diseases, cancer, chronic respiratory diseases, diabetes)	10.0%	CVSD (2016)
	Probability of dying between ages 30 and 69 years from cardiovascular disease	3.0%	CVSD (2016)
	Probability of dying between ages 30 and 69 years from cancer	6.0%	CVSD (2016)
	Probability of dying between ages 30 and 69 years from chronic respiratory disease	0.7%	CVSD (2016)
	Probability of dying between ages 30 and 69 years from diabetes	0.4%	CVSD (2016)

Abbreviations: CCDSS, Canadian Chronic Disease Surveillance System; CCHS, Canadian Community Health Survey; CCHS-MH, Canadian Community Health Survey – Mental Health; CCR, Canadian Cancer Registry; CHMS, Canadian Health Measures Survey; CIS, Canadian Income Survey; CTADS, Canadian Tobacco, Alcohol and Drugs Survey; CVSD, Canadian Vital Statistics–Death Database; DAD, Discharge Abstract Database; GSS, General Social Survey; HDL-C, high-density lipoprotein cholesterol; LFS, Labour Force Survey; NCIRS, National Cancer Incidence Reporting System; TC, total cholesterol.

Note: Indicators/measures identified as data gaps are prenatal smoking; prenatal alcohol drinking; developmental disorders (including autism spectrum disorder [ASD] and fetal alcohol spectrum disorder [FASD]); social support; resilience; discrimination and stigma; and built environment.

[a] All rates in this table are crude and based on actual data, unless otherwise stated.

[b] Includes all children aged 0 to 17 years both living in and not living in economic families.

[c] Total births include live births and stillbirths.

[d] Physical abuse includes being slapped/hit/pushed/grabbed/shoved/thrown at/physically attacked at least once by an adult (18+ years); sexual abuse includes forced/attempted forced sexual activity/touching at least once by an adult (18+ years); and exposure to violence includes having seen/heard parents or guardians hit each other or another adult (18+ years). The definition for this indicator changed; estimates are not directly comparable to previously reported estimates.

[e] The methodology has changed for this indicator; estimates are not directly comparable to previously reported estimates.

[f] This indicator captures individuals (excluding pregnant women) found to have elevated levels of the risk condition measured in a single fasting sample regardless of diagnosis status.

[g] Chronic diseases include cancer (ever had); diabetes; cardiovascular diseases (heart disease and/or stroke); and chronic respiratory diseases (asthma and/or chronic obstructive pulmonary disease).

[h] The six mental or substance use disorders include major depressive episode; bipolar disorder; generalized anxiety disorder; and abuse of/dependence on alcohol, cannabis or other drugs.

[i] The five major groups of chronic diseases include cancer (ever had); diabetes; cardiovascular diseases (heart disease and/or stroke); chronic respiratory diseases (asthma and/or chronic obstructive pulmonary disease); and mood and/or anxiety disorders.

[j] The 10 common chronic diseases include heart disease; stroke; cancer (ever had); asthma; chronic obstructive pulmonary disease; diabetes; arthritis; Alzheimer disease or other dementia; mood disorders; and anxiety disorders.

[k] These numbers are projected estimates for 2017 that are based on the August 2015 CCR tabulation master file (1992–2013) and the NCIRS (1969–1991).

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For questions or comments, please contact us at: phac.infobase.aspc@canada.ca.

Visit the Canadian Chronic Disease Indicators "online tool" to view additional data breakdowns (e.g. by sex, trends over time, etc.): https://health-infobase.canada.ca/ccdi/.

TABLE 2
Descriptive characteristics and adjusted odds ratio of population with higher self-reported mental health, age ≥12 years, Canada excluding territories

Variable	Percentage of population with self-reported "very good" or "excellent" mental health, weighted, % (95% CI)	aOR (95% CI)
Sex		
Females	68.1 (67.2–68.9)	(Ref.)
Males	72.7 (71.8–73.6)	1.22 (1.14–1.30*)
Age		
12–19	73.1 (71.2–75.0)	1.28 (1.12–1.46*)
20–34	68.8 (67.3–70.3)	0.99 (0.89–1.10)
35–49	69.8 (68.5–71.2)	(Ref.)
50–64	69.9 (68.6–71.2)	1.05 (0.96–1.15)
65–79	73.8 (72.6–75.1)	1.48 (1.34–1.63*)
80+	63.4 (60.6–66.3)	1.06 (0.90–1.24)
Province, age-standardized		
British Columbia	67.0 (65.2–68.7)	0.98 (0.85–1.13)
Alberta	69.3 (67.6–71.0)	1.01 (0.88–1.17)
Saskatchewan	67.0 (64.0–70.1)	1.02 (0.85–1.22)
Manitoba	68.1 (65.3–71.0)	1.10 (0.92–1.32)
Ontario	69.7 (68.4–71.0)	1.03 (0.90–1.18)
Quebec	73.1 (71.8–74.4)	1.41 (1.23–1.61*)
New Brunswick	65.9 (62.4–69.4)	1.03 (0.85–1.24)
Nova Scotia	66.1 (63.2–69.1)	(Ref.)
Prince Edward Island	68.9 (64.9–72.8)	1.02 (0.83–1.26)
Newfoundland and Labrador	69.3 (65.8–72.8)	1.19 (0.98–1.43)
Urban/Rural status		
Rural	71.2 (70.1–72.3)	1.01 (0.94–1.09)
Urban	70.1 (69.4–70.8)	(Ref.)
Highest level of education household		
Less than high school	57.2 (54.9–59.4)	(Ref.)
High school graduate	64.2 (62.5–65.9)	1.32 (1.16–1.49*)
Post-secondary graduate	72.3 (71.6–73.1)	1.68 (1.50–1.88*)
Household income adequacy		
Q1 (lowest)	61.6 (60.1–63.1)	(Ref.)
Q2	67.7 (66.2–69.1)	1.31 (1.19–1.44*)
Q3	70.9 (69.5–72.4)	1.53 (1.38–1.69*)
Q4	73.7 (72.3–75.0)	1.77 (1.58–1.97*)
Q5 (highest)	77.3 (76.0–78.6)	2.25 (2.02–2.51*)
Indigenous status		
Non-Indigenous	70.7 (70.0–71.3)	(Ref.)
First Nations	62.8 (58.5–67.1)	0.89 (0.73–1.09)
Métis	60.3 (56.2–64.4)	0.73 (0.61–0.88)
Inuit	73.9 (55.8–92.0)	1.37 (0.51–3.63)
Multiple Indigenous status	39.5[D] (15.0–64.1)	0.29 (0.07–1.23)

Continued on the following page

TABLE 2 (continued)
Descriptive characteristics and adjusted odds ratio of population with higher self-reported mental health, age ≥12 years, Canada excluding territories

Variable	Percentage of population with self-reported "very good" or "excellent" mental health, weighted, % (95% CI)	aOR (95% CI)
Immigrant status		
Nonimmigrant	69.4 (68.7–70.1)	(Ref.)
≤5 years in Canada	80.6 (77.0–84.1)	2.29 (1.80–2.90*)
6–10 years in Canada	71.8 (67.2–76.5)	1.28 (0.99–1.66)
>10 years in Canada	71.0 (69.1–72.9)	1.20 (1.08–1.33*)

Abbreviations: aOR, adjusted odds ratio; CI, confidence interval; Ref., reference group.

Note: Logistic model adjusted for sex, age, province, urban/rural residence, education, household income, Indigenous status and immigrant status.

*$p < 0.05$.

[D] As per the CCHS sampling variability guidelines, prevalence estimates should be interpreted with caution, as the coefficient of variation is between 25.1% and 35.0%.

Other PHAC publications

Researchers from the Public Health Agency of Canada also contribute to work published in other journals. Look for the following articles published in 2019:

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Tiwari A, Andrews K, Casey R, Liu A, **Tonmyr L**, Gonzalez A. Associations among child maltreatment, mental health, and police contact in adulthood: findings from a national Canadian sample. J Interpers Violence. 2019. doi: 10.1177/0886260519851789.

Yu X, Nassar N, Mastroiacovo P, […], **Leon JA, Luo W**, **Rouleau J**, et al. Hypospadias prevalence and trends in international birth defect surveillance systems, 1980–2010. Eur Urol. 2019. doi: 10.1016/j.eururo.2019.06.027.