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Consumption of ultra-processed food and its association with obesity in Canada

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Résumé

Introduction: La prévalence de l'obésité a augmenté à l'échelle mondiale. Parallèlement, les régimes alimentaires traditionnels basés sur des préparations culinaires faites maison à partir de produits frais sont remplacés par des aliments transformés et prêts à manger.

Objectifs: Cette étude vise à évaluer l'association entre la consommation d'aliments ultra-transformés et l'obésité au Canada. L'objectif secondaire consiste à étudier les déterminants associés à la consommation de ces aliments.

Méthode: Étude transversale comprenant les adultes âgés de 18 ans ou plus qui ont participé à l'Enquête sur la santé dans les collectivités canadiennes, 2004, cycle 2.2. L'obésité est déterminée en utilisant l'indice de masse corporelle. La consommation d'aliments ultra-transformés est estimé en utilisant l'apport énergétique relatif provenant des aliments ultra-transformés du rappel alimentaire de 24 heures. La régression linéaire multivariée a été réalisée pour étudier les déterminants associés à la consommation d'aliments ultra-transformé, et la régression logistique multivariée a été réalisée pour évaluer l'association entre la consommation de ces aliments et l'obésité.

Résultats: Les aliments ultra-transformés sont largement consommés au Canada. La consommation de ces aliments est plus élevée chez les hommes, les jeunes adultes, les personnes avec moins d'années d'études, les fumeurs, les personnes physiquement inactives, et celles nées au Canada. La consommation d'aliments ultra-transformés est associée à l'obésité. Une augmentation de dix points de pourcentage de l'apport énergétique relatif des aliments ultra-transformés augmente le risque d'obésité de 6%, après ajustement pour les facteurs de confusion potentiels (RC= 1,06; IC 95%= 1,02-1,10).

Conclusion: Les Canadiens pourraient bénéficier d'une réduction de la consommation d'aliments ultra-transformés.

Mots-clés: aliments ultra-transformés, transformation alimentaire, obésité, qualité de l'alimentation.

Abstract

Background: The prevalence of obesity has increased worldwide. Meanwhile, traditional dietary patterns based on homemade culinary preparations from fresh foods are being replaced by processed and ready-to-consume foods.

Objectives: This study aims to assess the association between consumption of ultra-processed foods and obesity in the Canadian population. A secondary objective consists in investigating potential determinants associated with ultra-processed food consumption.

Methods: Cross-sectional study including adults aged 18 years or more from the 2004 Canadian Community Health Survey, cycle 2.2. Obesity is determined using body mass index. Ultra-processed food intake is estimated using daily relative energy intake of ultra-processed food (% of total energy intake) from 24-hour food recall. Multivariate linear regression is performed to investigate potential determinants of ultra-processed food consumption, and multivariate logistic regression is performed to verify the association between ultra-processed food consumption and obesity.

Results: Ultra-processed foods are largely consumed in Canada, almost half (44.7%) of Canadians daily calories comes from these foods. Consumption of ultra-processed foods is higher amongst men, younger adults, with fewer years of formal education, smokers, physically inactive, and Canadian-born individuals. Ultra-processed food consumption is positively associated with obesity. A ten-percentage point increase in the relative energy intake of ultra-processed foods increases the odds of having obesity by 6%, after adjustment for potential confounding factors (OR = 1.06, 95% CI = 1.02-1.10).

Conclusion: Canadians willing to improve their health and diet would benefit in reducing consumption of ultra-processed foods and increasing consumption of freshly prepared dishes made from unprocessed and minimally processed foods.

Keywords: ultra-processed food, food processing, obesity, diet quality.

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List of acronyms

BMI: body mass index

CCHS 2.2: Canadian Community Health Survey, cycle 2.2.

CI: confidence interval

EER: estimated energy requirement

EI: energy intake

FAO: Food and Agriculture Organization of the United Nations

FID: Food and ingredient details

HR: hazard ratio

INFORMAS: International Network for Food and Obesity/non-communicable diseases Research, Monitoring and Action Support.

MET: metabolic equivalents

OR: odds ratio

PAc: physical activity coefficient

PAHO: Pan American Health Organization

PAI: physical activity index

PAL: physical activity level

WHO: World Health Organization

À minha mãe, Izilda - a minha estrela mais brilhante.

Acknowledgements

Introduction

The prevalence of obesity has increased all over the world, nearly doubling between the years of 1980 and 2014 (WHO, 2014). In 2014, 39% of adults were overweight, and 15% of women and 11% of men were obese (WHO, 2014). Globally, chronic diseases are the leading cause of death - they represented 68% of the world's death in 2014, where the majority (75%) was in low- and middle-income countries (WHO, 2014). Several physical, psychological, and social consequences can arise due to obesity. It increases the risk of type-2 diabetes, cardiovascular diseases, hypertension, certain types of cancer, negative social stigma, and reduced psychological well-being (PHAC, 2011; Prospective Studies Collaboration et al., 2009; WHO, 2014). Obesity, with its 18 associated comorbidities, represents an increasing threat not only to populations' overall health, but also to healthcare systems (Anis et al., 2010). Obese individuals have medical costs approximately 30% higher than normal weight individuals (Withrow & Alter, 2011). If the global trends in the prevalence of obesity continue, it is estimated that 21% of women and 18% of men will be obese by the year of 2025 (NCD-RisC, 2016).

In Canada, one in four adults (25%) is now obese – almost twice the prevalence observed in 1978 when 14% of the adult population was obese (PHAC, 2011). The annual costs associated with obesity in Canada are estimated to be up to 7.1 billion Canadian dollars when accounting direct and indirect costs such as health care expenses and loss of productivity (Ogilvie & Eggleton, 2016).

It is well documented that the current epidemic of obesity is more likely a consequence of non-genetic risk factors, such as behavioral and environmental factors (Hill & Peters, 1998).

Behaviors that protect against obesity, such as regular physical activity and consumption of a healthy diet, are difficult to adopt in an environment that promotes low energy expenditure and high energy intake (Hill & Peters, 1998). Our food environment is now characterized by an increasing availability and accessibility of very convenient, hyper-palatable and energy-dense foods (Hill & Peters, 1998; Scrinis, 2016). As a consequence, traditional dietary patterns based on homemade culinary preparations from fresh local foods are being replaced by modern diets mainly composed of packaged and processed foods (Crino, Sacks, Vandevijvere, Swinburn, & Neal, 2015; Zobel, Hansen, Rossing, & von Scholten, 2016). Food processing is now argued to be the main shaping force of the global food system and an important determinant of the nature of diets and related states of health and well-being (Monteiro, 2009; Monteiro, Cannon, et al., 2017).

The global food supply has changed significantly during the nineteenth and twentieth century; in particular, industrialization of the food supply has allowed processed food to be more available, affordable and mass-produced (Popkin, 2001; Tillotson, 2004). Fast food outlets, large-chain supermarkets and convenience stores have replaced local fresh food markets as major sources of foods, at first in high-income industrialized countries, and then in lower-income countries (Monteiro, Moubarac, Cannon, Ng, & Popkin, 2013; Ogilvie & Eggleton, 2016; Stuckler & Nestle, 2012; Zobel et al., 2016). With growth of urban centers and changes in lifestyle, consumption of foods produced by others and away from home has increased (Zobel et al., 2016). Concomitantly, we observe that traditional food cultures based on family gatherings and homemade meals prepared from scratch are being replaced by very convenient, ready-to-consume and processed foods (Ogilvie & Eggleton, 2016; Popkin, 2001).

It is only relatively recent that food processing has been emphasized as an important aspect on the study of dietary quality and health (Fardet et al., 2015; Monteiro, 2009). Due to globalization and advances in technology and science, methods used on food processing have rapidly evolved and impacted the quality and properties of foods (Moubarac, Parra, Cannon, & Monteiro, 2014). It is important to note that food processing is of fundamental importance, it has allowed the development of very safe and convenient food products (Crino et al., 2015; Popkin, 2006). However, commonly used methods - such as removal of water, addition of salt, sugars, fats, and additives - often result in energy-dense and nutritionally imbalanced foods (Fardet, 2016; Moubarac, Batal, Louzada, Martinez, & Monteiro, 2016). Studies have shown that extensive food processing can fractionate or even destroy the food structure which is known to play an important role, along with chemical components, in the health potential of foods (Fardet, 2016; Jacobs & Steffen, 2003).

Research in the field of nutrition has traditionally examined adequacy of isolated nutrients or foods to establish links between diet and health outcomes (Tucker, 2010). Such studies are essential to elucidate biological mechanisms of nutrients; however, they often result in paradoxical nutritional recommendations (Mozaffarian, 2016). This is because people do not eat nutrients but meals composed by different combinations of foods (Hu, 2002; Tucker, 2010). Instead, analyses of dietary patterns have been increasingly appreciated since they allow the assessment of overall quality of diets (Hu, 2002). They are particularly effective when several dietary components are associated with the risk of a disease - such as obesity (Hu, 2002; Michels & Schulze, 2005). Today, holistic approaches that consider dietary patterns and the impacts of food processing are argued to be key to understand the links between diet quality and complex chronic diseases (Fardet et al., 2015; Monteiro et al., 2017; Moubarac et al., 2014; Scrinis,

2016). Despite that, food processing has been largely ignored in nutrition and epidemiological science, and most food classifications used in official dietary guidelines overlook food processing (Fardet et al., 2015; Moubarac, Parra, et al., 2014).

Only few tools have allowed the study of dietary patterns in the perspective of food processing. A systematic review assessed five food classifications based on food processing and concluded that the NOVA system is the most systematic, specific, and coherent (Moubarac, Parra, et al., 2014). This classification has been extensively used to predict overall diet quality of individuals since it identifies all foods with low nutritional quality rather than just a certain food type or nutrient (Mendonça, Pimenta, et al., 2016; Monteiro et al., 2016; Vandevijvere et al., 2013).

According to NOVA, food processing is defined as all physical, biological, and chemical methods and techniques applied to whole fresh foods to turn them into food products (Monteiro et al., 2016). It involves all industrial processes undertaken after the separation of food from nature and before its consumption or culinary preparation (Monteiro et al., 2016). In this sense, there are four groups of foods: (1) unprocessed and minimally processed foods, (2) processed culinary ingredients, (3) processed foods, and (4) ultra-processed foods (Monteiro et al., 2017).

Particularly important for this study, ultra-processed foods are industrial formulations made up from refined substances extracted or derived from food and additives not commonly used in culinary preparations (Monteiro et al., 2017). These products contain small or any proportion of whole foods, and they are typically energy-dense and nutritionally imbalanced (Louzada et al., 2017; Monteiro et al., 2017; Moubarac et al., 2016). Examples of ultra-processed foods are breakfast cereals, sugar-sweetened beverages such as soft drinks, sugary milk and fruit drinks, packaged snacks such as chips and cookies, flavored yogurts, instant

dishes such as soups and noodles, reconstituted meat products such as sausages and bacon, and most types of fast foods such as burgers and pizzas (Monteiro et al., 2016).

Globally, ecological studies have revealed that ultra-processed foods are dominating food supplies - sales of ultra-processed foods increased by almost 45% between the years of 2000 and 2013 (PAHO, 2015). High-income countries present the highest sales of ultra-processed foods, but sales of these products are now increasing faster in middle- and low-income countries (Monteiro et al., 2013; PAHO, 2015). After the United States of America (USA), Canada is the second country with the highest annual sales of ultra-processed foods in the world (PAHO, 2015). It was estimated that, on average, Canadians consumed approximately 230 kilos per person of ultra-processed foods in 2013 (PAHO, 2015). Analysis of the 2004 national food consumption data reveals that, on average, almost half of the Canadians daily calories comes from ultra-processed foods (Moubarac et al., 2016). The most consumed ultra-processed foods in Canada are sugar-sweetened beverages, packaged breads, confectionary, and fast food dishes (Moubarac et al., 2016).

Several social, economic, and behavioral determinants have been associated with ultra-processed food consumption. In Canada, consumption of ultra-processed foods is higher amongst men, younger individuals, and people with less years of formal education (Moubarac et al., 2016). In other high-income countries, behavioral habits such as smoking and not practicing physical activity are linked to increased ultra-processed food consumption (Julia et al., 2017; Mendonça, Pimenta, et al., 2016). Further, skills related to home food preparation are associated with diets less based on ultra-processed foods (Lam & Adams, 2017).

Empirical studies have consistently shown that overall diet quality deteriorates as intake of ultra-processed food increases (Adams & White, 2015; Batal et al., 2017; Cediel et al., 2017;

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Crovetto, Uauy, Martins, Moubarac, & Monteiro, 2014; Louzada et al., 2017; Moubarac & Batal, 2016; Moubarac et al., 2016; Steele, Popkin, Swinburn, & Monteiro, 2017). In essence, diets based on ultra-processed foods are energy-dense, high in free and added sugars, saturated and trans fats; and low in most micronutrients, fiber and protein – the last two closely linked to the satiety and glycemic potential of diets (Fardet, Méjean, Labouré, Andreeva, & Feron, 2017; Louzada et al., 2017; Moubarac et al., 2016; Steele et al., 2017). A study performed in Canada exploring the impact of ultra-processed food consumption on overall diet quality concluded that "lowering the dietary share of ultra-processed food and raising consumption of hand-made meals from unprocessed or minimally processed food would substantially improve the diet quality of Canadians" (Moubarac et al., 2016, p. 512). Based on all these evidences, the dietary share of ultra-processed food to overall intake has been proposed as an indicator of overall diet quality (Moubarac et al., 2016; Vandevijvere et al., 2013).

There is an increasing number of studies suggesting that consumption of ultra-processed foods increases the risk of several diet-related chronic diseases (Canella et al., 2014; Julia et al., 2017; Louzada, Baraldi, et al., 2015; Mendonça, Lopes, et al., 2016; Mendonça, Pimenta, et al., 2016; Rauber, Campagnolo, Hoffman, & Vitolo, 2015; Tavares, Fonseca, Garcia Rosa, & Yokoo, 2012). Longitudinal studies performed in Spain show that ultra-processed food consumption increases the risk of overweight, obesity and hypertension (Mendonça, Lopes, et al., 2016; Mendonça, Pimenta, et al., 2016). Cross-sectional analyses in Brazil indicate a link between ultra-processed foods and metabolic syndrome and dyslipidemias (Rauber et al., 2015; Tavares et al., 2012). Further, in Quebec, a study among First Nation adults found a positive association between ultra-processed food consumption and metabolic syndrome (Lavigne-Robichaud et al., 2017). Global ecological studies have demonstrated a strong correlation

between ultra-processed food consumption and rates of obesity (Juul & Hemmingsson, 2015; Monteiro, Moubarac, et al., 2017; PAHO, 2015).

Countries such as Brazil and Uruguay have incorporated in their dietary guidelines recommendations based on food processing (Brazilian Ministry of Health, 2014; FAO, 2016). The Brazilian Dietary Guide focuses on disseminating messages such as "make natural or minimally processed foods the basis of your diet", "limit consumption of processed foods" and "avoid consumption of ultra-processed foods" (Brazilian Ministry of Health, 2014, pp. 125–128). Similar recommendations were made by the Heart and Stroke Foundation of Canada (Heart and Stroke Foundation of Canada, 2014). In 2016, the Standing Senate Committee on Social Affairs, Science, and Technology of Canada published a report pointing out the necessity of an updated Food Guide for the Canadian population since the current version overlooks food processing (Ogilvie & Eggleton, 2016). In addition, the report calls for an awareness campaign aimed at limiting consumption of ultra-processed food and emphasizing its links with chronic diseases (Ogilvie & Eggleton, 2016). Despite that, to date, there are no studies performed in Canada linking consumption of ultra-processed food with diet-related chronic diseases.

In order to contribute to a better understanding in this field, the main objective of this study is to assess the relationship between consumption of ultra-processed foods and obesity in the Canadian population. A secondary objective consists in investigating potential social, economic and cultural determinants associated with ultra-processed food consumption. The results of the present study will support the development of new public health policies and improved nutritional recommendations to promote healthy eating and to address the problem of obesity and associated chronic diseases.

Chapter 1 - Literature Review

This literature review is organized in four main sections. The first part summarizes key aspects on the study of diet and health outcomes, such as the importance of considering dietary patterns and food processing. The second part describes methods commonly used on epidemiological studies to estimate dietary intake and obesity. The third part presents the NOVA classification, a system used to classify foods based on the nature and extent of food processing. The last part summarizes studies using the NOVA classification to assess links between ultra-processed food consumption and diet quality/health.

1.1 Study of diet and chronic diseases

Dietary patterns have shifted worldwide towards an increasing consumption of packaged and processed foods (Crino et al., 2015; Zobel et al., 2016). Meanwhile, nutrition science has advanced and some key aspects have emerged in the study of diets and chronic diseases (Mozaffarian, 2016). Two main aspects are discussed in this section. First, the importance of considering overall dietary patterns, rather than specific nutrients or foods (Mozaffarian, 2016). And second, the importance of considering food processing when assessing dietary quality, rather than relying on traditional food groups based on food origin or type (Monteiro, Cannon, et al., 2017; Mozaffarian, 2016).

1.1.1 Study of dietary patterns

Research in the field of nutrition has traditionally examined isolated nutrients with the purpose of establishing links between diet and health (Jacobs & Tapsell, 2013; Tucker, 2010).

Such studies are essential to elucidate biological mechanisms of nutrients and are very effective in a context where diet-related diseases are mostly caused by deficiency of specific nutrients (Jacobs & Tapsell, 2013; Monteiro et al., 2012). For instance, scurvy is caused by vitamin C deficiency which can be prevented or cured by providing this micronutrient in isolation (Jacobs & Tapsell, 2013). This single-nutrient approach, however, appears to have limited ability to express the complexity of foods and diets and their association with multifactorial chronic diseases (Hu, 2002; Jacobs & Tapsell, 2013; Mozaffarian, 2016).

Food cannot be resumed to its nutrients. There are many naturally occurring food components other than nutrients acting synergistically on foods (Jacobs & Steffen, 2003). This concept is called food matrix, which is the "nutrient and non-nutrient components of foods and their molecular relationships, i.e. chemical bonds, to each other" (USDA, 2016). Even small changes in a food molecule can have huge effects on health (Jacobs & Tapsell, 2013). An example is the omega-9, a fatty acid found in olive oil and nuts, which is known to have beneficial effects on health (Jacobs & Tapsell, 2013). The trans version (which has simply the double bound in the opposite side of the molecule), however, has adverse effects on health (Jacobs & Tapsell, 2013). The perspective of food synergy states that food matrix must be taken into account when studying diets in association with chronic diseases (Jacobs & Steffen, 2003). This can be done by looking at whole foods rather than at single food components (Jacobs & Steffen, 2003).

In addition, studies focusing on isolated nutrients or foods can lead to paradoxical policy recommendations and confusing dietary choices (Mozaffarian, 2016). To illustrate, in 2012, the US National School Lunch Program, with the goal of reducing total and saturated fat content in schools, banned unflavored whole-fat milk, but allowed flavored fat-free milk (Food and

Nutrition Service, USDA, 2012). By focusing on a single nutrient (fat), they banned a minimally processed food (unflavored whole milk) and replaced it by an ultra-processed food (flavored fat-free milk) high in free sugars and additives (Monteiro, Cannon, et al., 2017). In this sense, diet-based approaches such as analyses of dietary patterns have been increasingly appreciated (Hu, 2002; Mozaffarian, 2016). They are believed to be more relevant to public health in the context of chronic diseases since they are closer to the "real world" and facilitate public guidance (Mozaffarian, 2016), especially because people do not eat nutrients but meals composed by different combinations of foods (Hu, 2002).

Analyses of dietary patterns consist of the study of diets by assessing the overall combination of food groups consumed by individuals or groups (Hu, 2002; Jacobs & Tapsell, 2007; Mozaffarian, 2016). It allows the evaluation of overall quality of diets, rather than the adequacy of single nutrients or foods (Hu, 2002). This approach is particularly effective when several dietary components are associated with the risk of a disease, since controlling for all potential confounders of one's diet can be complicated and may not remove all the confounding effect (Hu, 2002; Michels & Schulze, 2005). In the case of obesity, several foods are known to be independently associated with obesity risk, and they all may be potential confounders in a study of the relationship between consumption of a certain food, such as soft drinks, and obesity (Hu, 2002). For this reason, study of dietary patterns is believed to be more predictive of diet quality in association with complex health outcomes (Hu, 2002; Michels & Schulze, 2005).

The reductionist focus of dietary quality based on specific nutrients or foods has deviated the attention from important aspects that affect diet quality, such as the impact of extensive industrial processing (Scrinis, 2016). Evidences have shown that beneficial dietary patterns often share some characteristics (Mozaffarian, 2016). They include more fresh and whole foods,

for example, fruits, vegetables, legumes, and nuts; and fewer processed foods such as refined grains, processed meats, and foods with added sugars (Mozaffarian, 2016).

1.1.2 Food processing and diet quality

It is only relatively recent that food processing has been emphasized as an important aspect on the study of dietary quality (Fardet et al., 2015; Monteiro, 2009). In nutrition and epidemiological science, it is customary to use food classifications that discriminate food by its origin or type (Fardet et al., 2015). For instance, vegetal or animal source; or group of fruits, vegetables, proteins, grains, dairy, etc. At the time these traditional food classifications were created, dietary patterns were mostly based on homemade meals prepared from fresh and local foods (Crino et al., 2015; Fardet et al., 2015; Zobel et al., 2016). However, with globalization and industrialization, most food systems are now characterized by an increasing participation of processed and ready-to-consume foods (Monteiro et al., 2012). In addition, food processing methods and techniques have rapidly evolved impacting the quality and properties of foods (Moubarac, Parra, et al., 2014). Thus, it seems to be crucial to consider food processing when assessing quality of foods and diets nowadays (Fardet et al., 2015; Monteiro et al., 2012).

It is important to note that food processing is of fundamental importance, it has provided safety, availability, variety, and convenience of food supplies (Fardet et al., 2015; Mozaffarian, 2016). However, it is known that the more food is processed, the more its matrix structure is fractionated or destroyed (Fardet et al., 2015). Along with nutrient components, food matrix characteristics can affect nutrient bioavailability and density, food texture and hardness, satiety and glycemic potential of foods (Fardet et al., 2015, 2017). With the goal of increasing shelf-life or reducing costs of production and transportation, methods such as hydrogenation, removal

of water, addition of salt, sugars, fats and additives are often undertaken by food industries (Fardet et al., 2015). Yet these methods commonly result in energy-dense, nutrient-depleted, hyper-palatable, low-satiating and hyper-glycemic food products (Fardet, 2016; Fardet et al., 2015; Moubarac et al., 2016).

Most food classifications used in official dietary guidelines overlook food processing (Monteiro, Cannon, et al., 2017). As a consequence, a large diversity of foods are encountered in the same group, even foods with different levels of processing, and therefore, different impacts on health (Fardet et al., 2015). To illustrate, in the Canadian Food Guide, brown rice and sugary breakfast cereal are considered similar and are categorized into the group of "cereals" (Canadian Ministry of Health, 2011). These foods, however, are extremely different. The first is a whole-grain food, naturally rich in complex carbohydrates and dietary fibers, while the second is a refined and processed product, high in added free sugars and energy-dense. Traditional food classifications are becoming outdated because hundreds of new food products have been developed since their conception (Fardet et al., 2015; Monteiro, Cannon, et al., 2017; Moubarac, Parra, et al., 2014). The lack of information about industrial food processing makes it difficult to elaborate solid nutritional recommendations to address the problem of obesity and other chronic diseases (Fardet et al., 2015; Monteiro, Cannon, et al., 2017; Moubarac, Parra, et al., 2014).

The level and type of processing is now questioned as an important determinant of diet quality (Fardet et al., 2015; Monteiro, 2009; Mozaffarian, 2016; Scrinis & Monteiro, 2017). Assessing dietary quality in the perspective of food processing provides an important advantage. It discriminates foods with their natural characteristics and structure to foods that have passed

through a multitude of processes to arrive in a final product that contains little or any whole foods (Monteiro, Cannon, et al., 2017).

1.2 Assessment of obesity and dietary intake

1.2.1 Obesity assessment

In epidemiological studies, commonly methods used to assess obesity are based on anthropometric measurements because of their simplicity and low cost (Hu, 2008). Examples are skinfold thicknesses, waist circumference, and body mass index (BMI) (Hu, 2008). The first method measures the thickness of a skinfold with a special caliper in predetermined sites, such as biceps, triceps and abdomen, in order to estimate body-fat distribution (Hu, 2008). The second method, waist circumference, consists in estimating abdominal obesity by using a measuring tape at the natural waist or at the umbilicus level (Hu, 2008). The third method, BMI, consists in estimating overall body adiposity by using measured or self-reported values of height (m) and weight (kg) (BMI=weight/height^2) (Hu, 2008). Standardized cutoff points of BMI are provided to classify adults as underweight (BMI < 18.5), healthy weight ($18.5 \leq$ BMI < 25.0), overweight ($25.0 \leq$ BMI < 30.0), and obese (BMI $\geq$ 30.0) (Health Canada, 2006).

It is common in large epidemiological studies to use self-reported values of height and weight to estimate BMI, since measured data can be expensive (Gorber, Shields, Tremblay, & McDowell, 2008; Hu, 2008). Self-reported values are subjected to potential systematic bias since there is a tendency to underestimate weight and overestimate height, resulting in an underestimation of the obesity prevalence (Gorber et al., 2008). Although measured data provides the most accurate estimates of the obesity prevalence, it is possible to establish

correction factors in order to approximate self-reported estimates to measured values (Gorber et al., 2008). In a subsample of individuals with both measured and self-reported values, correction equations can be generated improving significantly self-reported data (Gorber et al., 2008).

Anthropometric methods to assess obesity are relatively simple to obtain and fairly inexpensive (Hu, 2008). However, they are an indirect and imperfect measure of body fat, comparing to reference methods such as underwater weighing (densitometry), dual-energy x-ray and magnetic resonance imaging (MRI) (Hu, 2008). Among the indirect methods, BMI seems to be the most valid predictor of obesity since measurements of weight and height are subjected to less technical errors (Hu, 2008; Marks, Habicht, & Mueller, 1989). The validity of BMI is well-established in different age, sex and racial groups (Health Canada, 2006; Hu, 2008). Limitations concerning the use of BMI at the individual level are linked to certain groups, such as adults older than 65 years old, pregnant women, and adults with very lean body mass (Health Canada, 2006). But, at a population level, BMI is the most useful indicator in studies of weight-related risks (Health Canada, 2006).

In the present study, obesity is assessed throught BMI using measured weight and height for the marjority of the population. When measured values are not available, adjusted self-reported values are used (Gorber et al., 2008).

1.2.2 Dietary intake assessment

In epidemiological studies, largely used methods to assess dietary intake are food frequency questionnaires (FFQs) and 24-hour food recalls (Hu, 2008). Food frequency questionnaires consist of a list of specific foods where respondents need to indicate their usual frequency and amount of consumption (Hu, 2008). The 24-hour food recall involves the

collection of data on all foods and drinks consumed in the previous 24 hours of the interview (Hu, 2008). Both methods are easy and quick to apply offering a low burden to respondents and interviewers, they have fairly low costs and reasonable accuracy (Hu, 2008).

Food frequency questionnaires allow the assessment of usual consumption of foods in a certain period of time (e.g. last 12 months) (Thompson & Subar, 2017). However, little information is provided about other food characteristics such as cooking methods and food brands (Thompson & Subar, 2017). In addition, FFQs rely on a limited list of foods that might not always contemplate all foods consumed by the respondents (Thompson & Subar, 2017). Another source of inaccuracy comes from the fact that respondents are asked to estimate their usual portion size, which may be challenging since food intake can vary importantly across eating occasions and periods of time (Thompson & Subar, 2017).

In 24-hour food recalls, respondents are asked to provide detailed information of all foods and drinks consumed, including quantity, food brand, preparation methods, occasion, time, and place of consumption (Health Canada, 2006). The use of 24-hour food recalls is particularly useful in culturally diverse populations, as in Canada, since it permits to assess any food or food combination reported by the subjects (Willett, 1998). Food recalls have considerable flexibility in terms of analysis, it is possible to analyze the same dataset by nutrients, individual foods, or different food groups (Willett, 1998). The 24-hour food recall is considered the least biased instrument to asses self-reported dietary intake (Thompson & Subar, 2017). In order to minimize errors and maximize respondents' recall of foods eaten in the previous day, data collection can be performed by well-trained interviewers, and it can be assisted by computer and the automated multiple-pass method (Thompson & Subar, 2017).

The automated multiple-pass method consists of five steps (Health Canada, 2006). First, respondents are asked to give a quick list of all foods consumed in the previous day (Health Canada, 2006). Second, questions are asked in order to increase recall of commonly forgotten foods such as beverages and snacks (Health Canada, 2006). The third step consists of collecting information about the time and occasion that foods were eaten (Health Canada, 2006). In the fourth step, details about each food are collected including preparation methods and amounts consumed (Health Canada, 2006). The last step consists of a final review of all information collected and a last opportunity to recall any missed foods or details (Health Canada, 2006).

Dietary assessment methods often rely on the respondents' answers (Health Canada, 2006). Self-reported food intake is often subjected to systematic misreporting (Garriguet, 2008a; Jessri, Lou, & L'Abbé, 2016). For instance, under-reporting is more frequent among obese adults and across foods perceived as less healthful (Health Canada, 2006; Jessri et al., 2016). In contrast, foods perceived as healthy are often over-reported (Health Canada, 2006; Jessri et al., 2016). As a consequence, associations between food consumption and chronic diseases might be attenuated or even susceptible to reverse causation (differential bias). Several methods are available in the literature in order to identify implausible dietary assessments (Garriguet, 2008a; Jessri et al., 2016). A study systematically compared seven procedures to handle inaccurate 24-hour food recalls when examining associations between dietary intake and obesity (Jessri et al., 2016). Among the methods tested, adjusting the analyses by reporting group (under-reporter, plausible reporter, and over-reporter) was considered the best procedure since it generated more consistent results than the other methods while maintaining statistical power (Jessri et al., 2016).

All methods of dietary assessment have strengths and limitations, and the best one should be chosen depending of the research question and study design (Thompson & Subar, 2017). In

order to obtain information regarding food processing, 24-hour food recall seems to be the most appropriate method. Different from Food Frequency Questionnaires, food recalls have open-ended questions which allows collecting any level of detail needed (Willett, 1998). Information about food processing method, food preparation, recipe ingredients, and food brands can be obtained (Willett, 1998) – supporting the process of differentiating domestic from industrial food processing, for instance. It is important to note that misclassification of foods may occur, resulting in either under- or over-estimation of food groups. It is crucial to have well-trained interviewers in order to ensure that respondents provide the necessary level of detail about all food and drink items consumed (Willett, 1998). Also, the use of the automated multiple-pass method can reduce errors at data collection (Thompson & Subar, 2017). Another advantage of the use of food recall is that it permits data to be analyzed by any food grouping desired (Willett, 1998), such as by the level of food processing. In the present study, 24-hour food recall is used to estimate daily dietary intake of respondents.

Dietary quality assessment and food processing

From dietary assessment data, it is possible to assess overall diet quality of respondents (Hu, 2008). A variety of indices have been developed for this purpose, such as the Health Eating Index (Chiuve et al., 2012), and the Food Quality Score (Fung et al., 2016). The Health Eating Index attributes a score based on a certain combination of foods or nutrients such as fruits, vegetables, whole grains, sodium, long chain fatty acids, among others (Chiuve et al., 2012). The Food Quality Score is based on the frequency of consumption of fourteen foods, for example, yogurts, potatoes, fried foods, nuts, and processed meat (Fung et al., 2016). Although

these indices have been extensively used, they present important limitations since they do not discriminate foods with different levels of processing.

Only few tools have allowed the study of diet quality in the perspective of food processing. A systematic literature review analyzed and assessed the quality and relevance of several food classification systems based on food processing (Moubarac, Parra, et al., 2014). Among them, the following three classifications received the highest scores (from lower to higher): (1) the European classification developed by the International Agency for Research on Cancer (Chajès et al., 2011), (2) the Mexican classification created by researchers from the National Institute of Public Health in Mexico (González-Castell, González-Cossío, Barquera, & Rivera, 2007), and (3) The NOVA food classification developed in Brazil by researchers from the Center of Epidemiological Studies in Public Health and Nutrition at the University of São Paulo (Monteiro, Cannon, et al., 2017; Moubarac, Parra, et al., 2014).

The European classification groups food into three main categories: non-processed foods, modestly and moderately processed foods, and processed foods (Chajès et al., 2011; Moubarac, Parra, et al., 2014). The Mexican system classifies food into three groups as well: industrialized modern foods, industrialized traditional foods, and non-industrialized foods (González-Castell et al., 2007; Moubarac, Parra, et al., 2014). Finally, the NOVA system groups food into four categories: unprocessed and minimally processed foods, processed culinary ingredients, processed foods, and ultra-processed foods (Monteiro, Cannon, et al., 2017; Moubarac, Parra, et al., 2014).

With the exception of the NOVA system, most of the food classifications lacked specific definitions of food processing and distinctions between industrial and artisanal-domestic

processing (Moubarac, Parra, et al., 2014). In addition, their application was judged to be limited to the country and settings of elaboration (Moubarac, Parra, et al., 2014).

The NOVA classification provides a clear definition of food processing, it discriminates industrial and domestic food processing, and classifies food by the nature, purpose, and level of processing (Moubarac, Parra, et al., 2014). NOVA is evaluated to be the most systematic, specific and coherent food classification based on food processing (Moubarac, Parra, et al., 2014). It has been largely used worldwide and it is recognized by international organizations such as the World Health Organization (WHO), Pan American Health Organization (PAHO), and Food and Agriculture Organization of the United Nations (FAO) (FAO, 2015; PAHO, 2015).

The NOVA classification allows the assessment of relative daily intake of ultra-processed foods (Monteiro, Cannon, et al., 2017). Ultra-processed foods are defined as industrial formulations made of refined substances extracted or derived from food and additives not commonly used in culinary preparations (Monteiro et al., 2017). In the literature, two ways are proposed to calculate the relative daily intake of ultra-processed foods. First, by calculating the relative weight share from ultra-processed foods (% of grams from ultra-processed foods) (Mendonça, Pimenta, et al., 2016). Or second, by calculating the relative caloric share from ultra-processed foods (% kcal from ultra-processed foods) (Moubarac et al., 2016). The first method allows to account for ultra-processed foods with no calories, such as soft drinks added of artificial sweeteners, however, the second method is the most frequent in the literature, allowing comparison among studies.

The dietary share of ultra-processed foods has been demonstrated as a good predictor of overall diet quality (Louzada et al., 2017; Moubarac et al., 2016; Steele et al., 2017;

Vandevijvere et al., 2013). As well, indicators based on food processing may have more predictive power than indices such as the Health Eating Index and the Food Quality Score (Lavigne-Robichaud et al., 2017).

In this study, all foods and drinks reported in the 24-hour food recall are classified according to the NOVA food classification in order to calculate the relative caloric share from ultra-processed foods (% kcal from ultra-processed foods).

1.3 The NOVA food classification

According to NOVA, food processing is all physical, biological, and chemical methods and techniques applied to whole fresh foods to turn them into food products (Monteiro, Cannon, et al., 2017). It involves all industrial processes undertaken after the separation of food from nature and before its consumption or culinary preparation (Monteiro, Cannon, et al., 2017). According to the level, type and purpose of industrial processing, there are four groups of foods: (1) unprocessed and minimally processed foods; (2) processed culinary ingredients; (3) processed foods; and (4) ultra-processed foods (Monteiro, Cannon, et al., 2017). Information about each food group are summarized below, but for a detailed definition and more examples see Boxes 1-4 in Appendix 1.

1.3.1 Group 1 - unprocessed and minimally processed food

Unprocessed foods are all natural foods from edible parts of plants or animals, as well as fungi, algae, and water (Monteiro, Cannon, et al., 2017). Examples are fruits, roots, seeds, nuts, leaves and stems, and animal sources such as muscles, offal, eggs and milk (Monteiro, Cannon, et al., 2017).

Minimally processed foods are whole foods submitted to some processes that do not substantially alter their nutritional properties (Monteiro, Cannon, et al., 2017). Processes such as removal of inedible parts, washing, drying, non-alcoholic fermentation, and freezing are undertaken in order to make them safer and edible for consumption, to facilitate storage, and to diversify preparation (Monteiro, Cannon, et al., 2017). Examples of minimally processed foods are pasteurized milk, plain yogurt, dried fruits, washed and vacuum-packaged vegetables, fresh or frozen meats and fish, flours, dried grains such as rice and beans, pasta (made only with flours, flakes or grits and water, with no added salt or oil), spices and herbs, coffee and tea (Monteiro et al., 2016).

1.3.2 Group 2 - processed culinary ingredients

Processed culinary ingredients are substances extracted directly from unprocessed and minimally processed food by processes such as drying, pressing, and refining (Monteiro, Cannon, et al., 2017). Examples of processed culinary ingredients are vegetable oils, fats, butter, vinegar, salt, sugar, honey, and maple syrup (Monteiro, Cannon, et al., 2017).

These ingredients are used to prepare, season, and cook unprocessed and minimally processed food, and to make dishes and meals more palatable, diverse and enjoyable (Monteiro, Cannon, et al., 2017). Thus, processed culinary ingredients are not meant to be consumed by themselves (Monteiro, Cannon, et al., 2017).

1.3.3 Group 3 - processed food

Processed foods are made by the combination of unprocessed and minimally processed foods with culinary ingredients (Monteiro et al., 2016). Processes such as smoking, curing, and fermentation are used to create relatively simple food products with two or three ingredients

(Monteiro et al., 2016). The purpose of the processes here is to increase durability or modify/enhance sensory qualities of foods (Monteiro, Cannon, et al., 2017). Processed foods are considered modified versions of group 1 foods of unprocessed and minimally processed foods (Monteiro, Cannon, et al., 2017). Examples of processed foods are cheeses, freshly made breads, canned vegetables, legumes and fish, smoked meats, salted or sugared nuts, and fruits in syrup (Monteiro, Cannon, et al., 2017).

1.3.4 Group 4 - ultra-processed food

Ultra-processed foods are industrial formulations containing small or any proportion of whole foods, they are mostly made from substances derived from foods and additives (Monteiro, Cannon, et al., 2017). They are typically composed by five or more ingredients, including sugars, oils, fats and salt, but also other ingredients not commonly used in culinary preparations such as casein, whey, gluten, hydrogenated oils, hydrolyzed proteins, fructose corn syrup, maltodextrin, and so on (Monteiro et al., 2016).

They contain additives used "to imitate or enhance sensory qualities of foods or to disguise unpalatable aspects of the final product" (Monteiro, Cannon, et al., 2017, p. 6). Examples of additives used only on ultra-processed foods are dyes, color stabilizers, flavors enhancers, non-sugar sweeteners, emulsifiers, among others (Monteiro, Cannon, et al., 2017). Numerous processes - such as hydrogenation, hydrolyzation, extrusion and moulding - are used to combine the many ingredients of ultra-processed foods, in order to arrive in a final product that is durable, ready-to-consume, attractive, hyper-palatable and viable of displacing homemade meals and dishes (Monteiro, Cannon, et al., 2017).

Examples of ultra-processed products are soft drinks, industrial packaged breads, reconstituted meats such as bacon, burgers and sausages, breakfast cereals, pre-prepared frozen dishes, sugary and salty packaged snacks such as chips and cookies, cake mixes, margarines and spreads, among others (Monteiro et al., 2016).

1.4 Consumption of ultra-processed food

This section of the literature review aims to assess the extent and nature of the research on ultra-processed foods using the NOVA food classification. The results of this section are synthetized in a narrative form. First, trends in consumption of ultra-processed foods are presented. Second, determinants of ultra-processed food consumption are identified. Third, studies assessing the relationship between ultra-processed food consumption and diet quality/health are presented. Last, some methodological considerations and potential gaps in the literature are discussed.

1.4.1 Trends in consumption of ultra-processed food

Studies of global trends have documented an increasing consumption of ultra-processed foods in parallel with a decreasing consumption of unprocessed, minimally processed foods, and culinary ingredients (Monteiro et al., 2013; PAHO, 2015). In Canada, between the years of 1938 and 2001, calories from store purchases of ultra-processed food rose from 24% to 55% (Moubarac, Batal, et al., 2014). At the same period, calories from unprocessed and minimally processed food fell from 42% to 29%, and calories from culinary ingredients fell from 30% to 10% - confirming a shift in behavior towards eating more ready-to-consume products and cooking less (Moubarac, Batal, et al., 2014). In 2013, it was estimated that, on average,

Canadians consumed approximately 230 kilos per person of ultra-processed foods when accounting for carbonated drinks, breakfast cereals, biscuits, fruit and vegetable juices, sports and energy drinks, spreads and sauces, ready-to-consume meals, and foods purchased at fast food outlets (PAHO, 2015).

Studies in Asia (Baker & Friel, 2016), Sweden (Juul & Hemmingsson, 2015), Norway (Solberg, Terragni, & Granheim, 2016), and Australia (Venn, Banwell, & Dixon, 2016) have documented similar trends. In essence, high-income countries present the highest sales and consumption of ultra-processed products, but sales of these products are now increasing faster in middle- and low-income countries (Monteiro, Levy, Claro, de Castro, & Cannon, 2011; Monteiro et al., 2013; PAHO, 2015). To illustrate, sales of ultra-processed products in North America (Canada and United States) were much higher than Latin American sales in 2013 (approximately 105,000 vs. 79,000 kilotons) (PAHO, 2015). However, between the years of 2000 and 2013, sales of these products increased by 2% in North America and by 48% in Latin America (PAHO, 2015).

A cross-sectional ecological study estimated household relative energy availability of ultra-processed foods in nineteen European countries from budget surveys performed between the years of 1991 and 2008 (Monteiro, Moubarac, et al., 2017). Portugal, Italy, Greece and France have the lowest household availability of ultra-processed foods in Europe (10%, 13%, 14%, 14%, respectively), and the UK, Germany, and Ireland have the highest (51%, 46%, 46%, respectively) (Monteiro, Moubarac, et al., 2017).

Today, dietary patterns in most North American countries are based on ultra-processed foods. Canadians consume on average 48% of their daily calories from ultra-processed foods (Moubarac et al., 2016). The most consumed ultra-processed foods in Canada are sugary drinks,

accounting for 8% of daily calories, followed by industrial packaged breads, confectionary, and fast food dishes (Moubarac et al., 2016). In the USA, 58% of total daily calories are from ultra-processed foods (Steele et al., 2017). In contrast, in Latin America, diets are still based on unprocessed and minimally processed foods. In Brazil and Chile, less than a third of total daily calories are from ultra-processed foods (20% and 29%, respectively) (Cediel et al., 2017; Louzada et al., 2017).

1.4.2 Determinants of ultra-processed food consumption

Sociodemographic factors

The literature demonstrates an association between consuming ultra-processed foods and certain sociodemographic factors such as sex, age, education and income. However, the results differ according to countries and different contexts. In Canada, men consume more ultra-processed food than women (49% vs. 47%) (Moubarac et al., 2016), as in other high-income countries such as Norway, the UK, Spain and France (Adams & White, 2015; Djupegot et al., 2017; Julia et al., 2017; Mendonça, Pimenta, et al., 2016).

Regarding age, in essence, it was observed that consumption of ultra-processed foods decreases with age. In Canada, children, adolescents, and young adults (under 19 years) are the major consumers of ultra-processed foods (Moubarac & Batal, 2016; Moubarac et al., 2016). On average, 55% of their total daily calories come from these foods (Moubarac et al., 2016). The elderly population consumes the least calories from ultra-processed foods (Fardet et al., 2017; Moubarac & Batal, 2016; Moubarac et al., 2016). Even so, elder adults consume around 40% of their daily calories from ultra-processed foods in Canada (Moubarac & Batal, 2016; Moubarac et al., 2016). Similar associations between ultra-processed food consumption and age

are observed in other countries (Adams & White, 2015; Crovetto et al., 2014; Julia et al., 2017; Mendonça, Pimenta, et al., 2016).

Several studies in the literature have linked consumption of ultra-processed foods with education. In Canada, Norway, and France, people with less years of formal education tend to consume more ultra-processed foods than people with higher degrees of education (Djupegot et al., 2017; Julia et al., 2017; Moubarac et al., 2016). However, in lower-income countries such as Brazil, individuals with higher levels of education are the major consumers of ultra-processed foods (Bielemann, Motta, Minten, Horta, & Gigante, 2015; Louzada, Baraldi, et al., 2015).

The influence of income on ultra-processed food consumption varies across countries as well. In some high-income countries, such as Canada and the UK, consumption of ultra-processed foods does not vary across different household revenue levels (Adams & White, 2015; Moubarac et al., 2016). However, in France, lower-income individuals tend to consume more ultra-processed foods than those with higher incomes (Julia et al., 2017). This inverse association is also seen in most low- and middle-income countries. In Brazil and Chile, the caloric contribution of ultra-processed foods doubles or triples as household income increases (Crovetto et al., 2014; Louzada, Baraldi, et al., 2015; Monteiro et al., 2010).

A limited number of studies have assessed the association of social factors - such as marital status and number of children in the household - with ultra-processed food consumption. In France and Spain, marital status does not predict consumption of ultra-processed foods (Julia et al., 2017; Mendonça, Pimenta, et al., 2016). A study in Norway exploring the influence of number of children in the household on consumption of ultra-processed foods found no association as well (Djupegot et al., 2017).

Lifestyle and dietary habits

Some studies have investigated the influence of lifestyle and dietary habits on consumption of ultra-processed foods. Habits such as smoking, drinking alcohol, practicing physical activity, snacking between meals, cooking, and watching TV have been explored.

In Spain and France, consumption of ultra-processed foods is higher among smokers (Julia et al., 2017; Mendonça, Lopes, et al., 2016), whereas in Brazil it is higher among non-smokers (Louzada, Baraldi, et al., 2015). Alcohol drinkers tend to consume more ultra-processed foods in Spain than non-alcohol-drinkers (Mendonça, Lopes, et al., 2016).

The association between physical activity habits and ultra-processed food consumption is still unclear. In Spain, major consumers of ultra-processed foods are less likely to practice physical activity (Mendonça, Lopes, et al., 2016). In France, the association between physical activity and ultra-processed food consumption is not significant (Julia et al., 2017). On the other hand, in Brazil, physically active individuals consume more ultra-processed foods than inactive individuals (Louzada, Baraldi, et al., 2015).

The habit of snacking between meals and watching television are associated with increased consumption of ultra-processed foods in Spain and Norway (Djupegot et al., 2017; Mendonça, Pimenta, et al., 2016). A study in the UK revealed that adults with the habit and skills for cooking have diets less based on ultra-processed foods (Lam & Adams, 2017).

Cultural factors

There is a scarcity of studies in the literature analyzing the association between cultural background and ultra-processed food consumption. In Norway, individuals with Norwegian ethnicity consume more ultra-processed foods than non-ethnic Norwegians (Djupegot et al.,

2017). According to the authors, these findings are somehow unexpected because ultra-processed foods are less expensive than non-ultra-processed foods in Norway, and non-ethnic Norwegians often belong to lower-income groups (Djupegot et al., 2017). In Brazil, African-descendants – who often live under disadvantaged socioeconomic circumstances - have higher intakes of ultra-processed foods than white individuals (Louzada, Baraldi, et al., 2015). In contrast to Norway and other high-income countries, ultra-processed foods in Brazil are more expensive than fresh and minimally processed foods (Claro, Maia, Costa, & Diniz, 2016; Moubarac, Claro, et al., 2013).

When comparing Canada and France – countries with similar socioeconomic status -, it is observed that ultra-processed food intake accounts for almost half (48%) of daily calories in Canada but only approximately a third of daily calories (36%) in France (Julia et al., 2017; Moubarac et al., 2016). France still holds a strong and traditional dietary culture, based on homemade cooking meals and family gatherings, which may be a protective factor for ultra-processed food consumption (Julia et al., 2017). These results may support the hypothesis that culture influences ultra-processed food consumption regardless of socioeconomic status, however, more studies are needed to confirm it.

Environmental factors

Environmental factors such as zone of residence (rural/urban), availability, affordability, convenience and food marketing have been studied in association with ultra-processed food consumption.

Analyses of residential zone as a determinant of ultra-processed food consumption are inconclusive. In Canada, individuals living in rural areas consume more ultra-processed foods

than individuals in urban areas (50% vs. 47%) (Moubarac et al., 2016). Although significant, this is a very small difference. In France, no difference in consumption is seen between rural and urban areas (Julia et al., 2017). In lower income countries, such as Brazil and Chile, consumption of ultra-processed foods is higher in urban than rural areas (Cediel et al., 2017; Louzada, Baraldi, et al., 2015). An ecological study of global tendencies shows that countries with higher degree of urbanization have higher sales of ultra-processed foods (PAHO, 2015). It is known that people from more industrialized countries tend to buy more of their food from establishments such as supermarkets, convenience stores, and fast food restaurants (PAHO, 2015; Zobel et al., 2016). These food shops typically have higher offer of ultra-processed foods than non-ultra-processed foods (Luiten, Steenhuis, Eyles, Ni Mhurchu, & Waterlander, 2016).

Consumption of ultra-processed foods might be associated with availability and accessibility of ultra-processed food in the environment (Leite et al., 2017; Luiten et al., 2016; Machado, Claro, Canella, Sarti, & Levy, 2017). In New Zealand, a study found that ultra-processed food accounts for around 85% of all packaged foods in the supermarkets (Luiten et al., 2016). In Brazil, in-store availability of ultra-processed foods has shown to increase children's consumption of these products and decrease consumption of other healthier foods such as unprocessed and minimally processed foods (Leite et al., 2017). Low prices of ultra-processed foods in supermarkets in Brazil are associated with increased purchases of these foods as well as calorie acquisition (Machado et al., 2017). In Norway, individuals that experience lack of time are more likely to consume ultra-processed foods (Djupegot et al., 2017). Time scarcity might influence food choices because homemade meals require more time to be prepared, and ultra-processed foods are probably used as a strategy to save time (Djupegot et al., 2017).

Marketing and advertising are hypothesized to be determinants of ultra-processed food consumption. Ultra-processed foods are heavily advertised (Maia et al., 2017), and it is known that foods that are heavily advertised are often overconsumed (French, Story, & Jeffery, 2001). Ultra-processed food marketing campaigns and packaging often link these products to nutrition and health claims which may induce consumption. In Australia, 56% of ultra-processed food packages contain nutrition claims and 25% have health claims (Pulker, Scott, & Pollard, 2017).

1.4.3 Consumption of ultra-processed food and diet quality

There is considerable evidence indicating that overall diet quality deteriorates as intake of ultra-processed foods increases (Batal et al., 2017; Cediel et al., 2017; Cornwell et al., 2017; Fardet et al., 2017; Julia et al., 2017; Louzada et al., 2017; Moubarac & Batal, 2016; Moubarac et al., 2016; Steele et al., 2017). As consumption of ultra-processed foods increases, the intake of all other food groups decreases, including fruits and vegetables (Julia et al., 2017; Louzada, Martins, et al., 2015b; Mendonça, Pimenta, et al., 2016; Moubarac et al., 2016; Steele et al., 2017).

Diets based on ultra-processed foods are higher in energy, free and added sugars, carbohydrates, and total and saturated fats than diets based on non-ultra-processed foods (Louzada, Martins, et al., 2015b; Louzada et al., 2017; Moubarac et al., 2016; Steele, Baraldi, Louzada, Moubarac, & Mozaffarian, 2015). Moreover, diets rich in ultra-processed foods are depleted in protein, fiber, most micronutrients, and other bioactive compounds (Louzada, Martins, et al., 2015b, 2015a; Mendonça, Pimenta, et al., 2016; Moubarac et al., 2016; Steele et al., 2017; Steele & Monteiro, 2017).

Concerning sodium content, some studies demonstrate a positive association between ultra-processed food consumption and sodium intake (Adams & White, 2015; Bielemann et al., 2015; O'Halloran, Grimes, Lacy, Nowson, & Campbell, 2016). Nevertheless, studies in Canada and the USA found no association (Moubarac & Batal, 2016; Moubarac et al., 2016; Steele et al., 2017). These results might indicate that non-ultra-processed foods such as cheeses, freshly made breads, and homemade food preparations are also significant sources of salt (Moubarac & Batal, 2016; Moubarac et al., 2016). In Canada and Quebec, both diets based or not on ultra-processed foods are rich in sodium and both exceed the recommendation of 2,400 mg of sodium per day (Moubarac & Batal, 2016; Moubarac et al., 2016).

Overall, studies have concluded that "reducing ultra-processed food consumption is a natural way to promote healthy eating" (Louzada, Martins, et al., 2015b, p. 8), and that the dietary share of ultra-processed foods is a good predictor of overall diet quality (Lavigne-Robichaud et al., 2017; Mendonça, Pimenta, et al., 2016; Moubarac & Batal, 2016; Moubarac et al., 2016; Vandevijvere et al., 2013). This has been endorsed by the INFORMAS (International network for food and obesity/non-communicable diseases research, monitoring and action support) research network and other international organizations such as the WHO, FAO and PAHO (FAO, 2015; PAHO, 2015; Vandevijvere et al., 2013).

1.4.4 Consumption of ultra-processed food and health

Using NOVA, studies have demonstrated an association between consuming ultra-processed foods and several negative health outcomes such as obesity, hypertension, metabolic syndrome, dyslipidemias and cardiovascular disease (Louzada, Baraldi, et al., 2015; Mendonça,

Lopes, et al., 2016; Mendonça, Pimenta, et al., 2016; Moreira et al., 2015; Rauber et al., 2015; Tavares et al., 2012).

Prospective cohort studies performed in Spain reveal that consumption of ultra-processed food increases the risk of overweight, obesity and hypertension (Mendonça, Lopes, et al., 2016; Mendonça, Pimenta, et al., 2016). Spanish university graduates with high consumption of ultra-processed foods have a risk 26% higher of developing overweight or obesity (HR = 1.26; 95% CI = 1.10, 1.45) (Mendonça, Pimenta, et al., 2016), and a risk 21% higher of having hypertension (HR = 1.21; 95% CI = 1.06, 1.37) than individuals with lower consumption of these foods (Mendonça, Lopes, et al., 2016).

Several cross-sectional studies have shown a positive association between ultra-processed food consumption and overweight, obesity, dyslipidemias and metabolic syndrome (Canella et al., 2014; Louzada, Baraldi, et al., 2015; Rauber et al., 2015; Tavares et al., 2012). In Brazil, adolescents and adults whose diets are based on ultra-processed food are 1.98 times more likely of being obese (OR = 1.98; 95% CI = 1.26, 3.12) than those who consume less ultra-processed foods (Louzada, Baraldi, et al., 2015). In addition, their body mass index (BMI) is on average 0.94 kg/m^2 higher (95% CI = 0.42, 1.47) (Louzada, Baraldi, et al., 2015). In the UK, greater intake of minimally processed foods and culinary ingredients combined are associated with lower likelihood of being overweight and obese (Adams & White, 2015).

In Quebec, a cross-sectional study shows that consumption of ultra-processed foods is associated with metabolic syndrome among in-reserve indigenous adults (Lavigne-Robichaud et al., 2017). In this population, those with diets based on ultra-processed foods have almost twice the odds of developing metabolic syndrome (OR = 1.90; 95% CI = 1.14; 3.17) than those with diets based on unprocessed and minimally processed foods (Lavigne-Robichaud et al.,

2017). In addition, the same study evaluated the association between two other dietary quality indexes (Food Quality Score and Healthy Eating Index) and metabolic syndrome in the Indigenous context (Lavigne-Robichaud et al., 2017). The study concludes that the dietary energy share from ultra-processed foods provided the strongest relationship with metabolic syndrome, indicating that this is a meaningful predictive indicator of overall dietary quality (Lavigne-Robichaud et al., 2017).

Ecological studies have pointed that ultra-processed food consumption is increasing in parallel with rates of obesity worldwide. The increased prevalence of obesity has mirrored the rise in consumption of ultra-processed foodstuffs in the period between 1960 and 2010 in Sweden (Juul & Hemmingsson, 2015). A cross-sectional ecological study performed in 19 countries in Europe demonstrates that each percentage point increase in the household availability of energy from ultra-processed foods is associated with 0.25 points increase in the prevalence of obesity (Monteiro, Moubarac, et al., 2017). Cross-sectional time-series analyses demonstrate that changes in ultra-processed food sales are associated with changes in body weight in 12 Latin American and two North American (USA and Canada) countries between the years of 2000 and 2013 (PAHO, 2015). An increase of 20 units in average annual sales per capita of ultra-processed foods was correlated with an increase of $0.28\ kg/m^2$ in age-standardized BMI scores (PAHO, 2015).

1.5 Summary and methodological considerations

This literature review has explored four main points. First, the importance of considering overall dietary patterns and the impacts of food processing in the study of diet and health outcomes. Second, it shows that only few methods have allowed the study of dietary patterns in

the perspective of food processing in the context of epidemiological studies. Among them, the NOVA food classification is the most specific, systematic and coherent. Finally, the literature reveals that NOVA has been largely used to describe food supplies, dietary patterns, and the impacts of ultra-processed food on diet quality and health.

Worldwide, there is an increasing number of studies using NOVA, which has enabled comparisons within and between countries. Studies of global trends have documented an increasing consumption of ultra-processed food in parallel with a decreasing consumption of fresh and minimally processed foods, confirming a shift towards eating more ready-to-consume foods and cooking less. According to this literature review, consumption of ultra-processed foods is associated with several sociodemographic factors, such as sex, age, education level, and income. Lifestyle and dietary habits (such as smoking, drinking alcohol, practicing physical activity, cooking, snacking, and watching TV) and environmental factors (residential area, availability, affordability, convenience, and food marketing) seem to influence ultra-processed food consumption. There is considerable evidence of an inverse association between consumption of ultra-processed food and quality of diets and foods. Moreover, studies have shown that consumption of ultra-processed foods increases the risk of overweight, obesity, hypertension, and other diet-related chronic diseases.

Some methodological considerations should be pointed out about the existing literature. First, most of the studies retrieved used nationally representative samples and controlled for relevant socioeconomic and demographic variables. Moreover, most studies exploring the association between ultra-processed food consumption and chronic diseases additionally controlled for dietary aspects (such as total dietary energy intake and consumption of fruits and vegetables). These studies have demonstrated that the adverse effects of ultra-processed food

consumption may not be entirely explained by the increased caloric intake and reduced intake of fruits and vegetables.

Second, household expenditure is largely used as a proxy of ultra-processed food consumption using data from household budget surveys. Limitations of these studies are: not measuring directly the consumption of ultra-processed foods, not recording whether the household purchases were actually consumed, and not taking into account foods consumed away from home or food wastage (Canella et al., 2014). Third, there is a scarcity of studies analyzing the potential determinants of ultra-processed food consumption. In Canada, the effects of physical activity, smoking habits and cultural background on ultra-processed food consumption are still unknown. Last, the links between consumption of ultra-processed food and obesity have not been extensively studied and, to our knowledge, there are no studies performed in Canada.

Our study aims to examine potential determinants of ultra-processed food consumption, as well as the influence of ultra-processed food consumption on obesity in a nationally representative sample of the Canadian population. Precisely, we aim to assess the influence of several sociodemographic, lifestyle, and cultural factors on daily relative energy intake (% of total energy) of ultra-processed food. In addition, we aim to verify the association between consumption of ultra-processed foods and obesity, adjusting for potential confounding factors.

Based on the existing literature, a schema was elaborated to illustrate the main objectives of this study (Figure 1). The blue-shadow boxes represent the potential association between ultra-processed food consumption – a proxy for overall diet quality - and obesity. The white boxes represent potential determinants of ultra-processed food consumption, and also potential confounding factors in the association between ultra-processed food consumption and obesity. The box entitled "sociodemographic factors" is composed by sex, age, income and education.

The "lifestyle habits" box includes physical activity and smoking habits. The box "cultural background" is represented by immigrant status (non-immigrant/immigrant). Finally, the box "environment" makes reference to residential area (rural/urban). We believe there is an independent association between overall diet quality and obesity, after taking into account the covariates represented by the white boxes. We hypothesize that ultra-processed foods are commonly overconsumed contributing to excessive energy intake and weight gain, which increases the risk of obesity.
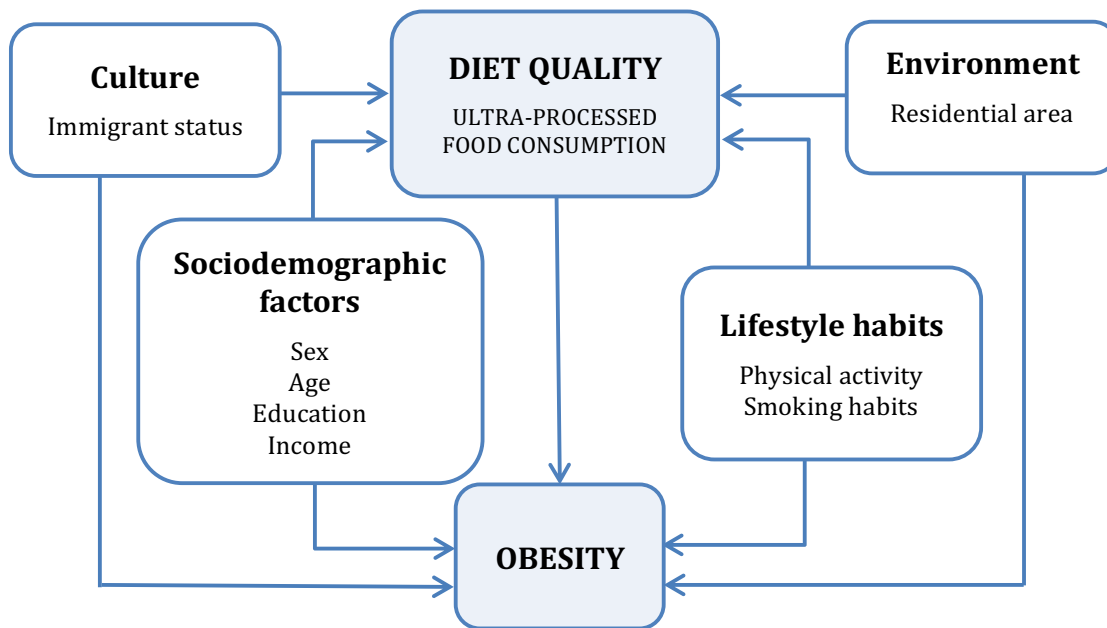
Figure 1. Schema of the potential association between consumption of ultra-processed food and obesity and the potential determinants of ultra-processed food consumption.

Chapter 2 - Methodology

In order to achieve our study objectives, we used data from the 2004 Canadian Community Health Survey, cycle 2.2 nutrition (CCHS 2.2) (Health Canada, 2006). The CCHS 2.2 is a national cross-sectional nutrition survey performed by Health Canada, Canadian Institute for Health Information, and Statistics Canada (Health Canada, 2006). At the moment of the present study, the 2004 CCHS 2.2 was the most recent data available providing information on food intake and physical measurements at a national level (Health Canada, 2006).

This study is part of a larger project conducted by Dr. Batal and Dr. Moubarac (13-SSH-MTL-3475). Data access to the CCHS 2.2 was granted by Statistics Canada under contract and data analyses were done at the Quebec Interuniversity Centers for Social Statistics (CIQSS) in Montreal. This study respects current research ethics standards and it was approved by the Health Research Ethics Board of the University of Montreal (17-017-CERES-D). See Appendix 2.

2.1 Specific contribution of this study

Food items from 24-hour food recall were already classified according to the NOVA groups by the researchers cited above (Dr. Batal and Dr. Moubarac) with the goal of describing dietary patterns in Canada and Quebec according to food processing, as well as investigating the association between nutrient profile of diets and ultra-processed food consumption (Moubarac & Batal, 2016; Moubarac et al., 2016). In the present study, we used this food consumption data (already classified according to the NOVA food groups) in order to further

investigate potential determinants of ultra-processed food consumption among the Canadian adult population. We further extend previous works by including in our analyses determinants not previously explored, such as physical activity, smoking habits and cultural background. As well, different from previous studies, this study aims to verify how sociodemographic factors, lifestyle habits, cultural background, and zone of residence independently influence consumption of ultra-processed foods, by performing a multivariate linear regression. In addition, this study aims to verify the association between consumption of ultra-processed foods and obesity, analysis never performed in the dataset.

2.2 Study context and design

The main objective of the CCHS 2.2 is to provide information about dietary intake and its key determinants (Health Canada, 2006). Specifically, it provides data on food consumption through 24-hour food recall, measured height and weight, and several sociodemographic characteristics of respondents (Health Canada, 2006).

Data collection of the 2004 CCHS 2.2 was performed between January 2004 and January 2005 (Health Canada, 2006). The target population of the survey is individuals of all age groups living in private dwellings in the ten provinces of Canada, which represents about 98% of the Canadian population (Health Canada, 2006). The survey has a high overall response rate of about 77%, and an approximate total number of respondents of 35,000 (Health Canada, 2006). Adjustment for non-response was applied to the survey weights considering the effect of several socioeconomic variables (Health Canada, 2006).

The sampling strategy of the CCHS 2.2 is a multistage stratified cluster used to ensure representativeness of the Canadian population in terms of sex, age, residential area, and

sociodemographic status (Health Canada, 2006). Dwellings were the sampling unit (Health Canada, 2006). Trained interviewers contacted the dwellings selected to participate in the survey by mail and subsequently by phone or personal visit (Health Canada, 2006). After collecting basic demographic information, one person from each dwelling was randomly selected to participate in the complete survey (Health Canada, 2006). Interviews were computer-assisted and most of them conducted in person in the participants' residences (Health Canada, 2006).

The questionnaire used in the interviews contains two components: (1) general health, with information concerning measured height and weight, physical activity, smoking habits, sociodemographic characteristics, among others; and (2) 24-hour food recall containing data on all food consumed in the previous 24 hours of the interview day (Health Canada, 2006).

A subsample (10%) of respondents aged 18 years or more was asked to self-report their weight and height before being measured (Health Canada, 2006). As well, due to several reasons - refusal, problems with equipment, physical inability of participants, among others – around 37% of the survey's respondents were not measured, but they agreed to report their missing values instead (Health Canada, 2006).

In order to increase accuracy of the 24-hour food recall, data collection was assisted by the Automated Multiple-Pass Method, a system used to maximize respondents' recall of foods eaten in the previous 24 hours (Health Canada, 2006).

More details regarding the design and sample procedures of the 2004 CCHS 2.2 have been published elsewhere (Health Canada, 2006).

2.3 Study population

For the present study, we retained all individuals aged 18 years or above (n=21,160). We excluded pregnant and breastfeeding women (n=257), respondents with invalid 24-hour food recall due to technical problems or due to missing information, and those who reported not having eaten on the previous day of the survey (n=44). The portion of individuals with very low body weight (body mass index < 18.5 kg/m^2) was very small ($<1\%$ of the sample size) and irrelevant to our study and therefore, they were excluded in order to avoid having small cell sizes in some subgroups. All respondents with complete data on physical activity and with measured or self-reported height and weight were included (n=19,571). Further, missing values for any other covariate used in our analyses were additionally removed (n=450), apart from the variable income. An increased number of adults (approximately 9% of the sample) did not state their income. In order to avoid excluding these individuals and losing representativeness of our sample, we created a category "not stated" for this variable.

A total of 19,121 individuals were retained for our analyses, which represents 54.6% of the total number of participants of the 2004 CCHS 2.2 (approximately 35,000 respondents).

2.4 Study variables

2.4.1 Obesity and overweight indicators

Body mass index (BMI) was calculated by Statistics Canada from values of weight (kg) and height (m) (BMI= weight / height^2) (Health Canada, 2006). We grouped BMI into three categories: healthy weight ($18.5 \leq$ BMI < 25.0), overweight ($25.0 \leq$ BMI < 30.0), and obesity (BMI ≥ 30.0) (Health Canada, 2006).

Trained interviewers collected height and weight values of respondents following procedures to ensure accuracy and consistency of measurements (Government of Canada & Statistics Canada, 2007). Weight and height were estimated using a high quality calibrated digital balance (ProFit UC-321 made by Lifesource) and a measuring tape attached to the wall (Gorber et al., 2008). In the absence of measured height and weight, we used self-reported values.

Adjustment of self-reported height and weight

Self-reported values are subjected to potential bias since there is a tendency to underestimate weight and overestimate height (Gorber et al., 2008). In order to approximate self-reported estimates to measured values, we established correction factors following procedures described elsewhere (Gorber et al., 2008).

Briefly, in a subsample of individuals with both measured and self-reported values (~10% of the sample), we performed linear regressions to generate correction equations. Here, measured values were the dependent variables and self-reported values were the independent variables. We fitted separate models for BMI, weight and height. Analyses were done for men and women separately. Table 1 shows the final equations. We used Model 1 for individuals with both height and weight self-reported. Models 2 and 3 were used when only one of the estimates (height or weight) was self-reported.

Table 1. Correction equations to adjust self-reported BMI (kg/m^2), weight (kg), and height (m) by sex for individuals aged 18 years or more.

Sex	Model	Equation				
Men	(1)	BMI $_{measured}$	=	-0.74	+	1.05 * BMI $_{self-reported}$
	(2)	Weight $_{measured}$	=	-1.84	+	1.04 * Weight $_{self-reported}$
	(3)	Height $_{measured}$	=	0.12	+	0.93 * Height $_{self-reported}$
Women	(1)	BMI $_{measured}$	=	0.32	+	1.02 * BMI $_{self-reported}$
	(2)	Weight $_{measured}$	=	0.21	+	1.02 * Weight $_{self-reported}$
	(3)	Height $_{measured}$	=	0.14	+	0.91 * Height $_{self-reported}$

2.4.2 Ultra-processed food consumption

We used information from a 24-hour food recall available for all respondents in order to estimate daily mean dietary intake. Data information included detailed description of all food and drink consumed, brand, quantity, preparation and cooking methods, occasion and time of consumption, and place of purchase, preparation and consumption (Health Canada, 2006).

Food items were previously classified according to the NOVA food system by other researchers in the context of the larger project in which this study is a part (Moubarac et al., 2016). Foods were classified into four groups: (1) unprocessed and minimally processed foods, (2) processed culinary ingredients, (3) processed foods, and (4) ultra-processed foods (Monteiro, Cannon, et al., 2017). Dishes consumed at home or at a restaurant with table service were broken down and each ingredient was classified in one of the four NOVA groups (Moubarac et al., 2016). For instance, a chicken wrap is broken down into tortillas, chicken, lettuce, and spices. Dishes consumed or purchased at fast food restaurants, such as hamburgers, fries, and pizzas were classified as single food items as ultra-processed foods, with exception of salads with no dressing, milk, and egg preparations (Moubarac et al., 2016). After classification, food items

were converted into kilocalories using the Food and Ingredient Details (FID) file which contains nutritional profile of foods already calculated by Statistics Canada (Moubarac et al., 2016). The FID file is based on the Nutrient File of Health Canada and recipe databases (Health Canada, 2006; Moubarac et al., 2016). More details of this classification procedure performed previously have been published elsewhere (Moubarac et al., 2016).

Misreporting in 24-hour food recalls

Self-reported food intake is often subjected to systematic misreporting (Garriguet, 2008a; Jessri et al., 2016). For instance, under-reporting is more frequent among obese adults and across foods perceived as less healthful (Health Canada, 2006; Jessri et al., 2016). In contrast, foods perceived as healthy are often over-reported (Health Canada, 2006; Jessri et al., 2016). As a consequence, associations between food consumption and obesity might be attenuated or even susceptible to reverse causation (differential bias). To handle misreporting, we followed procedures described in details elsewhere (Garriguet, 2008a, 2008b; Jessri et al., 2016).

Briefly, we compared the reported energy intake (EI) with the estimated energy requirement (EER) of respondents to identify plausible and implausible reporters (under- or over-reporters). We calculated an EI:EER ratio for each subject and we used cut-off points proposed by Jessri and colleagues to identify implausible reporters (Jessri et al., 2016). Individuals whose EI:EER ratio were below 0.70 were classified as under-reporters and individuals whose ratio were above 1.42 were classified as over-reporters (Jessri et al., 2016). While energy intake (EI) expressed in kilocalories is readily available in the CCHS 2.2, the estimated energy requirement (EER) demanded some calculations, described as follows.

We used equations from the Institute of Medicine in order to estimate energy requirement (IOM, 2005). These equations are based on respondent's sex, age (years), BMI (kg/m^2), weight (kg), height (m) and Physical Activity Coefficient (PA$_C$) (IOM, 2005). See Box 5, Appendix 3 for the equations. The PA$_C$ is derived from the Physical Activity Level (PAL). The physical activity data available in the CCHS 2.2 is expressed in Metabolic Equivalents (MET). It is possible to convert MET to change in Physical Activity Level (ΔPAL) using formulas proposed by the Institute of Medicine (IOM, 2005). These formulas are presented in the Box 6, Appendix 3. They are based on MET values of physical activity (Statistics Canada, 2008b, p. 22), number of times (N times) the same activity was practiced in the last 3 months, and its average duration (13, 23, 45 or 60 minutes) (Garriguet, 2008a). We calculated ΔPAL for each activity declared by the respondents and then we divided it by 90 days to express the daily energy expenditure from physical activity (Garriguet, 2008a). The final PAL was obtained by summing all ΔPAL with 1.39 which represents a base PAL for all individuals (Garriguet, 2008a). Afterwards, we converted the final PAL into Physical Activity Coefficient (PA$_C$) based on a conversion table from the Institute of Medicine (see Box 7, Appendix 3) (IOM, 2005).

2.4.3 Covariates

Several covariates are considered in our analyses. For the sociodemographic characteristics, four variables are taken into account: sex (men/women), age, education and income level. For the descriptive analyses, we grouped age into four categories: 18-34, 35-44, 45-64, and 65 or above. For the multiple regression models, age was kept as a continuous variable.

Education was assessed through the highest level of formal education completed, and we subsequently grouped into two categories (less than post-secondary graduation vs. post-secondary graduation) (Health Canada, 2006).

Income was assessed through the question: "What is your best estimate of the total income, before taxes and deductions, of all household members from all sources in the past 12 months?" (Statistics Canada, 2005, p. 63). Statistics Canada calculated a variable entitled "income adequacy" which is based on the total household income and the number of people living in the household (Statistics Canada, 2008b, p. 98). Income was grouped into five categories: lowest income, lower-middle income, upper-middle income, highest income (Statistics Canada, 2008b, p. 98), and not stated.

Two lifestyle habits are explored in our analyses: physical activity and smoking status. Physical activity is estimated by the Physical Activity Index (PAI), which considers the intensity, frequency, and duration of leisure-time physical activity expressed in Metabolic Equivalents (MET) (Health Canada, 2006). We grouped individuals into two categories: inactive (PAI < 1.5 kcal/kg/d) or active (moderately active and active; ≥ 1.5 kcal/kg/d) (Health Canada, 2006).

Smoking status is self-identified by the following question: "At the present time, do you smoke cigarettes daily, occasionally or not at all?" (Statistics Canada, 2005, p. 43). We classified participants as smokers (occasionally and daily smokers) and non-smokers (Garriguet, 2008b).

Cultural background is expressed by immigrant status (non-immigrant/immigrant) which was assessed through two questions: "In what country were you born?" and "Were you born a Canadian citizen?" (Statistics Canada, 2005, p. 51). In the survey, those who answered

not being born in Canada and not being born a Canadian citizens were considered immigrants (Tremblay, Pérez, Ardern, Bryan, & Katzmarzyk, 2005).

Residential area was classified by Statistics Canada into urban or rural according to the number of dwellings in the region of residence (Health Canada, 2006).

Additionally, in order to assess the association between ultra-processed foods and obesity, we considered two dietary aspects in our analyses as covariates: total daily energy intake (total kcal/day) and daily consumption of fruits and vegetables (Statistics Canada, 2008b). The variable of daily consumption of fruits and vegetables expresses the total number of times per day respondents eat fruits and vegetables (Statistics Canada, 2008b, p. 70). Both variables were kept as continuous.

2.5   Statistical analyses

2.5.1 Descriptive analyses

For the descriptive analyses, we first calculated the relative consumption (% of total daily energy intake) of each NOVA food groups and subgroups (see Table 4 for the NOVA subgroups). We also calculated the mean relative intake of each NOVA food group across quintiles of ultra-processed food consumption.

Second, we estimated the mean relative consumption of ultra-processed foods by the following respondents' characteristics: sex, age group, education and income level, physical activity, smoking status, immigrant status, zone of residence, reporting group (plausible reporters, under-reporters, and over-reporters), and weight categories (healthy weight, overweight, and obesity).

We performed bivariate linear regressions to assess differences in consumption of ultra-processed foods across the respondents' characteristics. Here, relative consumption of ultra-processed foods (% of total energy intake, continuous) is the outcome variable. We assessed normality of variables graphically using histograms.

2.5.2 Analyses of determinants of ultra-processed food consumption

With the goal of studying how sociodemographic factors, lifestyle habits, cultural background, and zone of residence independently influence consumption of ultra-processed foods, we performed a multivariate linear regression.

Here, relative consumption of ultra-processed foods (% of total energy intake, continuous) is the outcome variable. A hierarchical procedure was fitted to allow specifying a fixed sequential order of entry of the explanatory variables (Victora, Huttly, Fuchs, & Olinto, 1997). The choice and order of factors included in the model are based on the schema presented in Figure 1.

The first block "sociodemographic factors" includes the following variables: sex (men/women), age (continuous), education level (less than post-secondary graduation/post-secondary graduation), and income level (lowest, lower-middle, upper-middle, highest, not stated). The second block "lifestyle habits" is composed by physical activity (inactive/active) and smoking status (non-smoker/smoker). The third block "culture" contains immigrant status (non-immigrant/immigrant). Finally, the last block "environment" includes residential area (rural/urban).

2.5.3 Analyses of ultra-processed food consumption and obesity

We performed a multivariate logistic regression to assess the association between ultra-processed food consumption and obesity, independently of the effects of other predictors.

Here, obesity status (non-obese [BMI < 30 kg/m^2] / obese [BMI ≥ 30 kg/m^2]) is the outcome variable. Relative intake of ultra-processed foods (% of total energy intake, continuous) is the independent variable of interest. In order to facilitate interpretation, results are reported in a ten-percentage point increase (instead of a one-percentage point increase). To do so, we transformed the variable relative consumption of ultra-processed foods by dividing it by ten. Likewise, we compare risks of obesity across quintiles of ultra-processed food consumption by multiplying the β exponential coefficient (e^β) by the appropriate values.

The entry of covariates followed a similar hierarchical procedure as described earlier, with the exception that two more blocks were added. The blocks are as follows. Block (1) sociodemographic: sex, age, education and income level; (2) lifestyle habits: physical activity and smoking status; (3) culture: immigrant status; (4) environment: residential area; (5) reporting group (plausible reporters, under-reporters, and over-reporters); (6) dietary characteristics: total daily energy intake (kcal/day, continuous), and frequency of consumption of fruits and vegetables (continuous).

Multiplicative interactions between the exposure variable (relative intake of ultra-processed foods) and all covariates (sex, age, education, income, physical activity, smoking status, immigrant status, residential area, reporting group, total energy intake, and fruit and vegetable consumption) were tested. No significant interaction was found (data not shown). We performed exploratory analyses with overweight status (overweight + obesity) as the outcome variable (non-overweight [BMI < 25 kg/m^2] / overweight [BMI ≥ 25 kg/m^2]).

Descriptive estimates were weighted using standardized survey weights. This procedure is done in order to produce estimates representative of the Canadian population and not only the sample itself (Statistics Canada, 2008a). All regression analyses were weighted and bootstrapped to account for the complex design of the survey, following procedures recommended by Statistics Canada (Statistics Canada, 2008a).

Data manipulation and descriptive analyses were done using SPSS version 24. Regression analyses were performed using SAS version 9.4 with the assistance of the Bootvar program version 3.2 developed by Statistics Canada in order to facilitate the bootstrap procedure (Statistics Canada, 2008a). Alpha is set at the 0.05 level.

Chapter 3 – Results

3.1   Descriptive results

A total of 19,121 individuals were included in our analyses. The mean age of respondents is 46.0 years (SE: 0.12), and their mean BMI is 27.0 kg/m^2 (SE: 0.03). Canadians aged 18 years or over consume on average 2,547.4 kcal per day (SE: 10.39), 44.7% of which from ultra-processed foods (1,158.6 kcal/day), 41.9% from unprocessed or minimally processed foods (1,040.3 kcal/day), 7.0% from processed foods (182.1 kcal/day), and 6.4% from culinary ingredients (166.3 kcal/day). The average daily consumption of fruits and vegetables by Canadians is 4.2 times a day (SE: 0.01).

In our sample, 40.8% of subjects have a healthy weight, 37.0% are overweight, and 22.1% are obese. Concerning reporting group, 55.4% of individuals are classified as plausible reporters, 35.6% as under-reporters, and 9.0% as over-reporters. The main characteristics of participants and the mean daily dietary share of ultra-processed foods (% of total daily energy) by the respondents' characteristics are presented in Table 2, as well as the results of the bivariate linear regressions.

Table 2. Mean dietary share of ultra-processed food by characteristics of respondents. Canadian adults $\geq$ 18 years (n=19,121), 2004.

Variables	Distribution [a] %	Dietary share of ultra-processed foods Mean % (SE)
Sex		
Men	51.1	45.0 (0.2)
Women	48.9	43.2 (0.2)*
Age		
18 to 34 years	28.4	49.2 (0.3)
35 to 44 years	20.6	42.9 (0.3)*
45 to 64 years	35.0	41.7 (0.2)*
65 years or more	16.0	41.9 (0.3)*
Education		
< Post-secondary graduation	28.4	45.8 (0.3)
Post-secondary graduation	71.6	43.4 (0.2)*
Income		
Lowest	8.2	44.2 (0.5)
Lower-Middle	18.6	44.2 (0.3)
Upper-Middle	32.9	44.6 (0.3)
Highest	31.8	43.6 (0.2)
Not stated	8.5	44.1 (0.1)
Physical activity		
Inactive	56.6	44.8 (0.2)
Active	43.4	43.3 (0.2)*
Smoking status		
Non-smoker	75.3	42.8 (0.2)
Smoker	24.7	48.2 (0.3)*
Immigration status		
Non-immigrant	76.4	46.7 (0.1)
Immigrant	23.6	35.8 (0.3)*
Residential area		
Rural	17.7	46.5 (0.3)
Urban	82.3	43.6 (0.2)*
Weight status		
Healthy weight	40.8	43.1 (0.2)
Overweight	37.0	44.0 (0.2)
Obese	22.1	46.1 (0.3)*
Reporting group		
Plausible reporter	55.4	44.8 (0.2)
Under-reporter	35.6	43.1 (0.2)*
Over-reporter	9.0	44.0 (0.4)

a. Weighted distribution (standardized weight).
*p<0.05 based on bivariate linear regressions (the category of reference is the first listed).
Data source: Statistic Canada, CCHS 2.2, Nutrition (2004).

Table 2 shows that men seem to consume more ultra-processed foods than women (45.0% vs. 43.2%). Younger adults (18-34 years) have the highest intake of ultra-processed foods, and adults aged between 45-64 years have the lowest (49.2% vs. 41.7%). Individuals with post-secondary graduation seem to consume fewer calories from ultra-processed foods than those with less than post-secondary graduation (43.4% vs. 45.8%). Mean consumption of ultra-processed foods seems not to vary when comparing individuals across income groups. Physically inactive individuals consume more calories from ultra-processed foods than physically active individuals (44.8% vs. 43.3%). Non-smokers consume less energy from ultra-processed foods than smokers (42.8% vs. 48.2%). Canadian-born individuals consume more ultra-processed foods than immigrants (46.7% vs. 35.8%). Residents of rural areas consume more of these products than residents of urban areas (46.5% vs. 43.6%). However, in the multivariate linear regression, zone of residence was not a significant predictor of ultra-processed food consumption (data shown in 3.2 section). On average, healthy weight individuals consume less ultra-processed foods than obese individuals (43.1% vs. 46.1%).

In summary, we observe that consumption of ultra-processed foods does not vary across income level. As well, although significant in the univariate analyses, the difference in consumption of ultra-processed foods according to sex, education level, physical activity and residential area seems not be large. In contrast, age group, smoking status and immigrant status seem to be the most important determinants of ultra-processed food consumption.

The distribution of total daily energy intake according to NOVA groups and subgroups is presented in Table 3. The most consumed ultra-processed foods in Canada by adults are: industrial packaged breads (8.4% of total daily energy intake), followed by sugary drinks (6.6%), fast food dishes (5.2%), and confectionary (4.8%).

Table 3. Distribution of total daily energy intake (% of total energy intake) according to NOVA food groups and subgroups. Canadian adults ≥ 18 years (n=19,121), 2004.

NOVA food groups and subgroups	Daily relative intake (%) Mean (SE)
Unprocessed or minimally processed foods	**41.9 (0.1)**
Meat and poultry	10.3 (0.1)
Grains and flours	7.9 (0.1)
Milk and plain yogurt	5.3 (0.1)
Fruits	4.9 (0.0)
Pasta	3.3 (0.1)
Roots and tubers	3.1 (0.0)
Vegetables	2.2 (0.0)
Eggs	1.9 (0.0)
Nuts	1.0 (0.0)
Fish	0.8 (0.0)
Legumes	0.5 (0.0)
Other [a]	0.8 (0.0)
Culinary ingredients	**6.4 (0.1)**
Sugars [b]	2.8 (0.0)
Plaint oils	2.2 (0.0)
Animal fats	1.0 (0.0)
Other [c]	0.4 (0.0)
Processed foods	**7.0 (0.1)**
Cheese	3.4 (0.0)
Canned or preserved foods [d]	1.3 (0.0)
Other [e]	2.3 (0.0)
Ultra-processed foods	**44.7 (0.1)**
Industrial packaged breads	8.4 (0.1)
Soft drinks, fruits drinks and fruit juices	6.6 (0.1)
Fast food dishes [f]	5.2 (0.1)
Confectionary	4.8 (0.1)
Sauces and spreads	4.5 (0.0)
Margarine	4.0 (0.0)
Breakfast cereals	2.6 (0.0)
Chips, crackers, and other salty snacks	2.3 (0.0)
Milk-based products [g]	2.3 (0.0)
Reconstituted meat products [h]	2.0 (0.0)
Other ultra-processed foods [i]	2.0 (0.0)
Total	**100.0**

a. Sea foods, spices and herbs, yeast, coffee, tea, un-disaggregated home-made dishes.
b. White and brown sugar, iced sugar, molasses, honey, and maple syrup.
c. Vinegar, coconut milk, unsweetened cocoa powder, cornstarch.
d. Fruits, vegetables or pulses preserved in oil, salt or sugar, cured, smoked or pickled meat and fish.
e. Salted, sweetened or oil roasted nuts or seeds, almond paste, prepared tofu, condensed milk, peanut butter, pita breads, bannock, and dumpling.
f. Hamburgers, hot dogs, fries, pizzas, sandwiches and other products bought in fast-food outlets.
g. Ice cream, chocolate milk, flavored yogurt, milkshakes, malted milk.
h. Sausages, luncheon meats, meat spreads, bacon, corned beef, beef jerky, fish sticks and simulated meats.
i. Canned soups, canned mixed dishes, cheese products, frozen and prepared French fries and onion rings, fish or seafood imitations, meal replacements, sweeteners, protein shake powder, egg substitutes, coffee whitener, veggie slice, sausages, vanilla extract, malt extract, whey protein, added calcium and soy protein.
Data source: Statistic Canada, CCHS 2.2, Nutrition (2004).

Figure 2 shows the mean relative daily energy intake of each NOVA food group across quintiles of ultra-processed food consumption. NOVA 1 represents the group of unprocessed and minimally processed foods, NOVA 2 the group of culinary ingredients, NOVA 3 the group of processed foods, and NOVA 4 the group of ultra-processed foods. The mean dietary share of ultra-processed foods is 18.2% in the first quintile, 33.4% in the second, 43.2% in the third, 53.9% in the fourth, and 72.1% in the last quintile. We observe that as we increase consumption of ultra-processed foods (NOVA 4), the consumption of unprocessed and minimally processed foods decreases (NOVA 1).
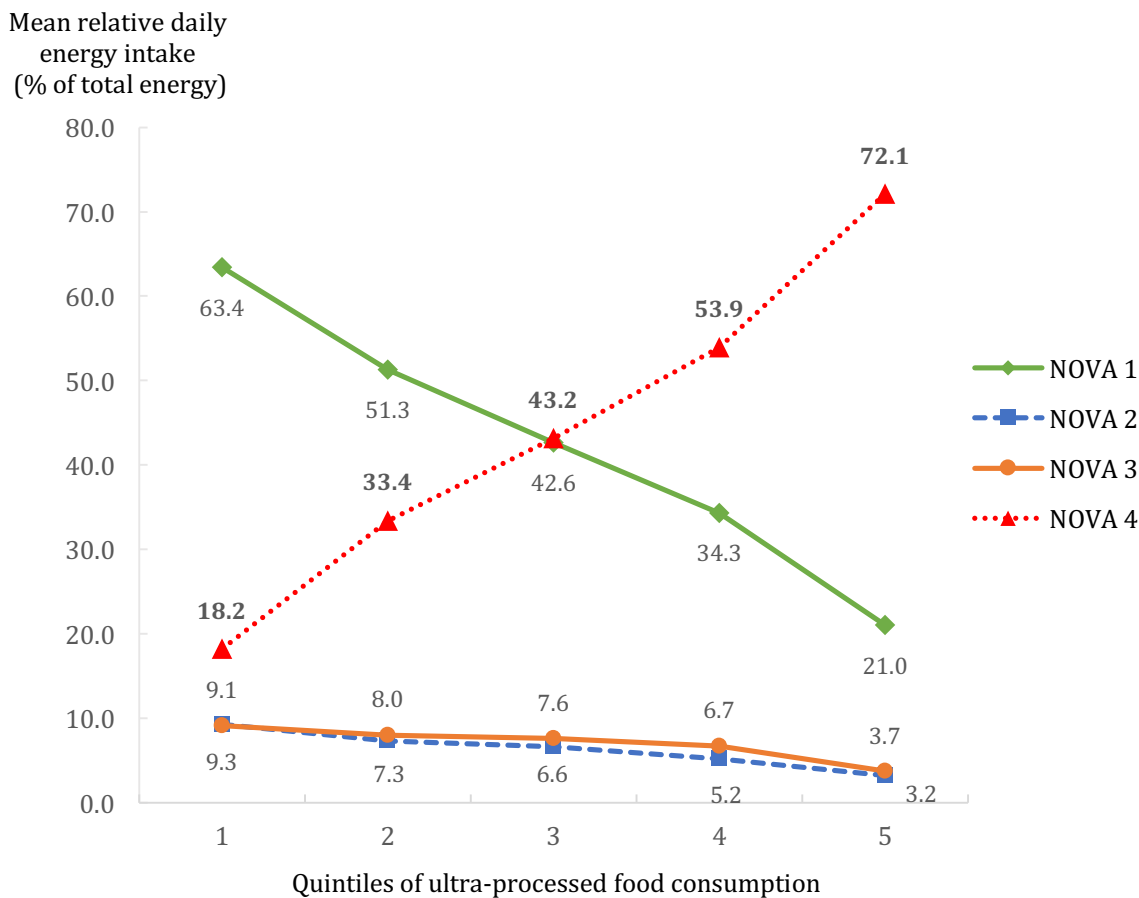
Figure 2.   Mean relative daily energy intake of NOVA food groups (% of total energy intake) across quintiles of ultra-processed food consumption.

Data source: Statistic Canada, CCHS 2.2, Nutrition (2004).

3.2   Determinants of ultra-processed food consumption

Results from the multivariate linear regression models are shown in Table 4. For each model, we present the *p*-value, standardized coefficients (β) and goodness-of-fit (R^2).

In the first model, the strongest predictors of ultra-processed food consumption are age (standardized β = -0.16) and education (standardized β = -0.09). After adding the block of lifestyle variables (physical activity and smoking status), age is still the main predictor of ultra-processed food consumption (standardized β = -0.15), followed now by smoking status (standardized β = 0.09). In the third model, immigrant status becomes the strongest predictor of ultra-processed food consumption (standardized β = -0.23), and the contribution of almost all other variables decreases (with exception of age which remains constant in all models).

In the final model, we observe a significant negative association between ultra-processed food consumption and sex, age, education level, physical activity and immigrant status. A significant positive association is observed between ultra-processed food consumption and smoking status. The strongest predictors of ultra-processed food consumption in the last model are immigrant status (standardized β = -0.23) and age (standardized β = -0.14).

We observe that income is not a significant predictor in all four models. As well, residential area seems not to be a meaningful addition to the last model. The goodness-of-fit (R^2) of the models increases as we add new variables, with exception of the last model that remains constant.

Table 4. Analyses of determinants of ultra-processed food consumption. Results from multivariate linear regressions. Canadian adults ≥ 18 years (n=19,121), 2004.

Variables	Model 1 Sociodemographic ($R^2 = 0.03$)		Model 2 Lifestyle ($R^2 = 0.04$)		Model 3 Culture ($R^2 = 0.09$)		Model 4 Environment ($R^2 = 0.09$)	
	p-value	β	*p*-value	β	*p*-value	β	*p*-value	β
Sex								
Men	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Women	0.004	**-0.04**	0.014	**-0.04**	0.002	**-0.04**	0.002	**-0.04**
Age								
Continuous	<0.001	**-0.16**	<0.001	**-0.15**	<0.001	**-0.14**	<0.001	**-0.14**
Education								
< Post-secondary grad.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Post-secondary grad.	<0.001	**-0.09**	<0.001	**-0.07**	<0.001	**-0.06**	<0.001	**-0.06**
Income								
Lowest	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Lower-middle	0.737	0.01	0.609	0.01	0.490	0.01	0.509	0.01
Upper-middle	0.500	0.02	0.274	0.03	0.745	0.01	0.758	0.01
Highest	0.858	-0.01	0.670	0.01	0.344	-0.02	0.348	-0.02
Not stated	0.715	0.01	0.449	0.01	0.647	0.01	0.653	0.01
Physical activity								
Inactive	-	-	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Active	-	-	0.002	**-0.04**	<0.001	**-0.05**	<0.001	**-0.05**
Smoking status								
Non-smoker	-	-	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Smoker	-	-	<0.001	**0.09**	<0.001	**0.07**	<0.001	**0.07**
Immigrant status								
Non-immigrant	-	-	-	-	Ref.	Ref.	Ref.	Ref.
Immigrant	-	-	-	-	<0.001	**-0.23**	<0.001	**-0.23**
Residential area								
Rural	-	-	-	-	-	-	Ref.	Ref.
Urban	-	-	-	-	-	-	0.166	-0.02

Ref. = reference.
Grad. = graduation.
Data source: Statistic Canada, CCHS 2.2, Nutrition (2004).

3.3 Consumption of ultra-processed food and obesity

Results of the multivariate logistic models are shown in Table 5. Results are expressed in a ten-percentage point increase in the relative consumption of ultra-processed foods.

In the crude model, there is a significant positive association between relative energy intake from ultra-processed foods and obesity (OR=1.07, 95% CI=1.03-1.11) and overweight (OR=1.05, 95% CI=1.02-1.08).

Table 5. Association between ultra-processed food consumption and obesity and overweight. Results from the multivariate logistic regression models. Canadian adults ≥ 18 years (n=19,121), 2004.

Outcome	Models		Odds Ratio*	95% Confidence Interval	*p*-value
Obesity (BMI ≥ 30)	Model 1	Crude [a]	1.07	1.03 - 1.11	<0.001
	Model 2	Sociodemographic [b]	1.08	1.05 - 1.12	<0.001
	Model 3	Lifestyle [c]	1.08	1.04 - 1.12	<0.001
	Model 4	Culture [d]	1.06	1.02 - 1.10	0.002
	Model 5	Environment [e]	1.06	1.02 - 1.10	0.002
	Model 6	Reporting group [f]	1.06	1.02 - 1.10	0.001
	Model 7	Diet characteristics [g]	1.06	1.02 - 1.10	0.005
Overweight (BMI ≥ 25)	Model 1	Crude [a]	1.05	1.02 - 1.09	0.005
	Model 2	Sociodemographic [b]	1.07	1.04 - 1.11	<0.001
	Model 3	Lifestyle [c]	1.07	1.04 - 1.11	<0.001
	Model 4	Culture [d]	1.05	1.02 - 1.09	0.002
	Model 5	Environment [e]	1.05	1.02 - 1.09	0.002
	Model 6	Reporting group [f]	1.06	1.02 - 1.09	<0.001
	Model 7	Diet characteristics [g]	1.06	1.02 - 1.09	<0.001

*Odds Ratio of a 10% increase in relative intake of ultra-processed foods (% of total energy intake).

a. Model 1: crude.
b. Model 2: Model 1 + Sociodemographic characteristics (sex, age, education and income).
c. Model 3: Model 2 + Lifestyle habits (physical activity and smoking status).
d. Model 4: Model 3 + Cultural background (immigrant status).
e. Model 5: Model 4 + Environment (residential area).
f. Model 6: Model 5 + Reporting group (reporting group: under-reporter, plausible reporter, over-reporter).
g. Model 7: Model 6 + Diet characteristics (total energy intake and fruit and vegetables intake).

Data source: Statistic Canada, CCHS 2.2, Nutrition (2004).

In the final model, after adjustment for all covariates, a ten-percentage point increase in the relative energy intake from ultra-processed foods increases the likelihood of obesity by 6% (OR = 1.06, 95% CI=1.02-1.10). Similar results were found for overweight (OR= 1.06, 95% CI=1.02-1.09).

As presented earlier, the mean dietary share of ultra-processed foods is 18% in the first quintile, 33% in the second, 43% in the third, 54% in the fourth, and 72% in the last quintile. There is an increase of 15 percentage points between the first and the second quintile of ultra-processed food consumption, an increase of 25 percentage points between the first and the third quintile, an increase of 36 percentage points between the first and the fourth quintile, and finally, an increase of 54 percentage points between the first and the fifth quintile of ultra-processed food consumption. If we multiply the b exponential coefficient for a one-percentage point increase in the relative consumption of ultra-processed foods (e^b, where b=0.006) by the values cited above (15, 25, 36 and 54), we obtain the odds of having obesity across quintiles of ultra-processed food consumption.

To illustrate, if we compare individuals in the first quintile of ultra-processed food consumption with individuals in the second quintile ($e^{0.006 \times 15} = 1.09$), those in the second quintile are 1.09 time more likely of having obesity than those in the first quintile (OR=1.09; 95% CI=1.03-1.16). Likewise, if we compare individuals in the first quintile of ultra-processed food consumption with individuals in the fifth quintile, those in the fifth quintile are 1.38 times more likely of having obesity ($e^{0.006 \times 54} = 1.38$) than those in the lowest quintile (OR=1.38; 95% CI=1.11-1.72). In other words, individuals in the upper quintile of ultra-processed food consumption have a 38% higher odds of having obesity than individuals in the lowest quintile. Similar results were found for overweight (OR=1.38; 95% CI=1.11-1.63).

Figure 3 shows the adjusted Odds Ratio (OR) and 95% Confident Interval (CI) of having obesity across quintiles of ultra-processed food consumption.
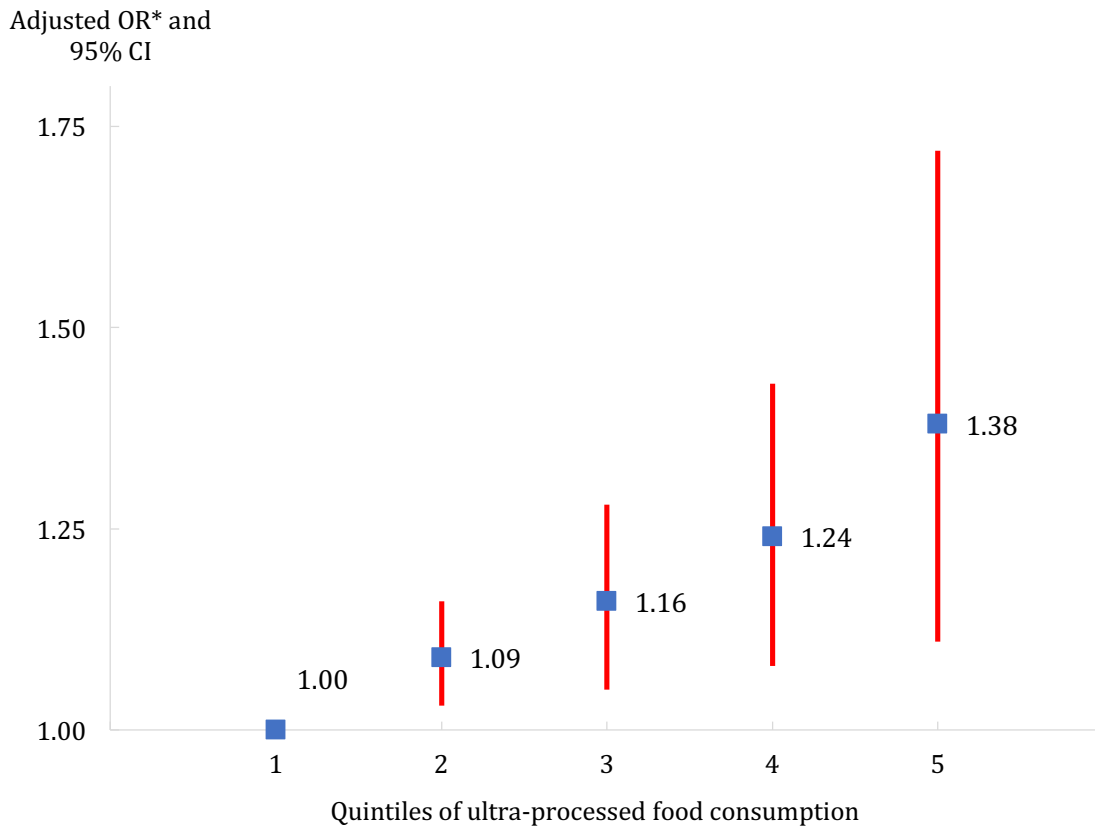

Figure 3. Adjusted Odds Ratio (OR) and 95% Confident Interval (CI) of having obesity across quintiles of ultra-processed food consumption.

*Adjustment for: age, sex, income, education, physical activity, smoking, immigrant status and residential area.

Data source: Statistic Canada, CCHS 2.2, Nutrition (2004).

Chapter 4 – Discussion

The main objective of this study was to verify the relationship between consumption of ultra-processed foods and obesity in the Canadian population. A secondary objective consisted in investigating determinants associated with ultra-processed food consumption.

Our results suggest that ultra-processed foods are largely consumed in Canada; on average, adults consume almost half (44.7%) of their daily calories from ultra-processed foods. Similar results were found in previous studies performed in Canada and Quebec (Moubarac & Batal, 2016; Moubarac et al., 2016).

As consumption of ultra-processed foods increases, the consumption of unprocessed and minimally processed food decreases, including fruits and vegetables. Fruits and vegetables have been previously demonstrated as protective factors of obesity (Newby et al., 2003; USDA, 2015).

Our study indicates that sociodemographic factors (sex, age, and education level), lifestyle habits (smoking and physical activity habits), and cultural background (immigrant status) are determinants of ultra-processed food consumption. Moreover, our findings suggest that consumption of ultra-processed foods is associated with obesity among Canadian adults.

4.1 Determinants of ultra-processed food consumption

We found a statistically significant association between consumption of ultra-processed foods and sex, age, education level, smoking status, physical activity habits, and immigrant status (Canadian-born/immigrant). The strongest predictors of ultra-processed food consumption are the fact of being immigrant or not, and age.

Both in our study and in most published articles, men tend to consume more ultra-processed foods than women (Adams & White, 2015; Djupegot et al., 2017; Mendonça, Pimenta, et al., 2016; Moubarac et al., 2016). Our findings also demonstrate that consumption of ultra-processed foods decreases with age. This inverse association is sustained by the literature (Adams & White, 2015; Fardet et al., 2017; Mendonça, Pimenta, et al., 2016; Moubarac & Batal, 2016; Moubarac et al., 2016).

A previous study performed in Canada indicates that men are less likely than women to choose or avoid foods due to their content and health impacts (Ree, Riediger, & Moghadasian, 2008). Another study shows that Canadian elderly adults, and especially elderly women, are the most likely to only eat food prepared at home, and the least likely of eating out at fast food outlets (Garriguet, 2007). Elder adults are from a generation where diets were still mainly based on homemade preparations from unprocessed and minimally processed foods, and ultra-processed foods were not very present (Moubarac, Batal, et al., 2014). In addition, culinary skills were customarily passed to women who were often responsible for household meal preparation (Flagg, Sen, Kilgore, & Locher, 2014). It is known that the habit of cooking is associated with better diet quality (Wolfson & Bleich, 2015), and with decreased ultra-processed food consumption in the UK (Lam & Adams, 2017). This might partially explain the differences in consumption across sex and age groups. It would be interesting to explore in the future whether or not these differences in consumption are maintained.

In our study, respondents with higher levels of formal education consume fewer calories from ultra-processed foods than those with lower levels of education. Similar results are found in studies performed in Canada and Norway (Djupegot et al., 2017; Moubarac & Batal, 2016; Moubarac et al., 2016). We extrapolate that education might be an indicator of increased

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nutrition knowledge (Hiza, Casavale, Guenther, & Davis, 2013). Although education and nutrition knowledge do not always result in healthy eating habits, they are indeed prerequisites for making better food choices in a food environment where a multitude of healthy and unhealthy food options are available (McEntee, 2009).

According to our analyses, income level is not a significant determinant of ultra-processed food consumption in Canada. Previous studies performed in Canada and Quebec show similar results (Moubarac & Batal, 2016; Moubarac et al., 2016), as well as in the UK (Adams & White, 2015). In contrast, in most low- and middle-income countries, it is observed an inverse association between ultra-processed food consumption and income (Crovetto et al., 2014; Louzada, Baraldi, et al., 2015; Monteiro et al., 2010). In these countries, it is still more economical to prepare meals from unprocessed and minimally processed foods (Claro et al., 2016; Luiten et al., 2016; Moubarac, Claro, et al., 2013).

Our results suggest that unhealthy lifestyle habits such as smoking and physical inactivity are associated with increased consumption of ultra-processed foods. The association of health-related behaviors and poor dietary habits have been previously explored in the literature (Gillman et al., 2001; Kvaavik, Andersen, & Klepp, 2005; Palaniappan, Starkey, O'Loughlin, & Gray-Donald, 2001; Pearson & Biddle, 2011). We hypothesize that individuals that adopt healthy lifestyle habits, such as not smoking and practicing physical activity, are more concerned about their health and diet, and might be less likely to consume ultra-processed foods.

The present study shows that immigrants consume significantly less ultra-processed foods than native-born Canadians. The literature demonstrates that immigrants usually have better health when they first arrive in Canada than non-immigrants, a consequence of immigrant selection (Chen, Ng, & Wilkins, 1996; Gee, Kobayashi, & Prus, 2004; Newbold, 2005). After

settlement in the host country, immigrants tend to have their health deteriorated due to acculturation (Gilbert & Khokhar, 2008; Pérez-Escamilla & Putnik, 2007; Tremblay et al., 2005). Acculturation is "the process by which immigrants adopt the attitudes, values, customs, beliefs, and behaviors of a new culture" (Abraido-Lanza, White, & Vasques, 2004, p. 534), including dietary habits. The impacts of acculturation on immigrants' health and diet depend on, among other factors, the extent to which they maintain or change their traditional practices (Pérez-Escamilla & Putnik, 2007). A literature review shows that although acculturation commonly occurs after long periods in the host country, certain immigrant groups in Canada tend to maintain some traditional dietary habits, which are believed to be healthier than typical Western diets (Sanou et al., 2014). We argue that maintenance of traditional food culture and habits such as preparing traditional home-cooked meals and family gatherings may be protective factors of ultra-processed food consumption.

We found that individuals living in rural areas consume more ultra-processed foods than those living in urban areas. Previous studies in Canada and Quebec found similar results (Moubarac & Batal, 2016; Moubarac et al., 2016). However, this difference is only significant in the univariate linear regression, but not in the multivariate linear regression. It is likely that the effect of residential area might have been attenuated by the presence of other covariates in the model. As well, rural and urban populations may be quite different for several characteristics beyond the region of residence. In France, no difference in consumption is seen between rural and urban areas (Julia et al., 2017). We believe that consumption of ultra-processed foods is systemic in Canada and in most high-income countries since global food supplies are dominated by these foods (Zobel et al., 2016).

4.2 Consumption of ultra-processed food and obesity

The findings of this study suggest an association between consuming ultra-processed foods and obesity in Canada. In essence, we found that individuals whose diets are based on ultra-processed foods (average intake of ultra-processed foods: ~72% of total daily energy intake) have a 38% higher odds of having obesity than individuals whose diets are not based on ultra-processed foods (average intake: ~18% of total daily energy intake).

Existing evidence has consistently shown a link between food processing and obesity. A cohort study performed in Spain reveals that adults in the upper quartile of ultra-processed food consumption have a risk 26% higher of having obesity than individuals in the lowest quartile (Mendonça, Pimenta, et al., 2016).

Cross-sectional studies have presented results in the same direction. A cross-sectional study performed in the UK shows that greater intake of unprocessed, minimally processed foods, and culinary ingredients combined are associated with lower odds of being overweight and obese (Adams & White, 2015). In Brazil, results from a cross-sectional study show that adolescents and adults in the upper quintile of ultra-processed food consumption have a 98% higher odds of having obesity than subjects in the lowest quintile (Louzada, Baraldi, et al., 2015). It is likely that in middle-income countries such as Brazil, the penetration rate of ultra-processed foods as well as the rates of obesity are increasing faster than in high-income countries (PAHO, 2015; WHO, 2014).

Finally, ecological studies have suggested a correlation between ultra-processed food sales and rates of obesity worldwide (Juul & Hemmingsson, 2015; Monteiro, Moubarac, et al., 2017; PAHO, 2015).

We observe that most studies in the literature linking consumption of ultra-processed foods and obesity have a cross-sectional design, and only one has a longitudinal design. Despite that, results are consistent across studies which points to a causal association between ultra-processed food consumption and obesity.

Although a limited number of studies have assessed the association between ultra-processed foods as a group and obesity, the links between certain ultra-processed foods and diet-related chronic diseases are well established in the literature. For instance, prospective studies have demonstrated an association between consumption of fast food with obesity and type-2 diabetes (Pereira et al., 2005); sugary beverages with obesity, type-2 diabetes, and coronary heart disease (Fung et al., 2009; Hu & Malik, 2010); potato chips with long-term weight gain (Mozaffarian, Hao, Rimm, Willett, & Hu, 2011); and white bread, processed meat, and margarine with increased abdominal adiposity (Romaguera et al., 2011).

The association between ultra-processed food consumption and obesity seems to be only partially explained by reduced consumption of fruits and vegetables, and increased total energy intake. This is because after controlling for these two dietary aspects, the association between ultra-processed food and obesity remained significant. Our results suggest that other factors associated with industrial food processing - such as the impacts on the matrix structure of foods, the use of additives, and the amount of free sugars - might contribute to the effects of ultra-processed food consumption on obesity. It is known that the more food is processed, the more its matrix structure is fractionated or destroyed, affecting not only nutrient bioavailability and density, but also texture, hardness, satiety, and glycemic potential of foods (Fardet et al., 2015). However, more studies are needed in order to better understand the impacts of ultra-processing

methods and techniques on food nutrient and non-nutrient components and their molecular relationship.

In essence, Canadian evidence has demonstrated that, in order to meet WHO recommendations (WHO & FAO, 2003) to prevent and manage obesity and other chronic diseases, ultra-processed foods should contribute less than one-third of total daily intake (Moubarac, Martins, et al., 2013; Moubarac et al., 2016). This might only be achieved with diets mainly based on meals prepared from fresh and whole foods (Moubarac, Martins, et al., 2013). Our results are in accordance with these recommendations.

4.2.1 Potential mechanisms for ultra-processed food association with obesity

We believe that ultra-processed foods are often overconsumed, contributing to overall poor diet quality and excessive energy intake, and therefore, weight gain and metabolic disorders. Several attributes of ultra-processed foods are argued to induce overconsumption.

First, the nutritional profile of ultra-processed foods. These foods are typically energy-dense, hyper-palatable, and low-satiating (Fardet, 2016; Moubarac et al., 2016). These attributes have been linked to overeating in the literature (Fardet et al., 2017; Ledikwe et al., 2006; Rogers & Brunstrom, 2016). Our results show that on average almost half (44.7%) of Canadians daily energy intake comes from ultra-processed foods. Foods such as industrial packaged breads, sugary drinks, fast food dishes, confectionary and sauces and spreads represent a large portion of daily energy intake in Canada. Even ultra-processed foods with no calories - with added artificial sweeteners - might be associated with long-term weight gain and obesity (Azad et al., 2017). In addition, ultra-processed foods are often high in added or free sugars, saturated and trans-fats; and depleted in fiber, protein, and most micronutrients (Louzada et al., 2017;

Moubarac, Martins, et al., 2013; Steele et al., 2015). In Canada and the USA, previous studies have shown that ultra-processed foods contribute to nearly 75% to 90% of all added sugars in diets (Moubarac, Martins, et al., 2013; Steele et al., 2015). High intake of added sugars increases the risk of weight gain and obesity (Heart and Stroke Foundation of Canada, 2014; USDA, 2015).

Second, ultra-processed foods are increasingly available in our food environment – and often sold in large portion sizes -, making them very convenient to buy and consume (Djupegot et al., 2017; Duran, Lock, Latorre, & Jaime, 2015; Lam & Adams, 2017; Machado et al., 2017; Solberg et al., 2016; Zimmerman, 2011). They can be bought in handy places such as vending machines, convenience stores, and fast food drive-through (Seiders & Petty, 2004). It is known that greater convenience and visibility of foods can lead to excessive intake by either conscious and unconscious mechanisms (French et al., 2001; Painter, Wansink, & Hieggelke, 2002; Zimmerman, 2011). Moreover, a number of studies have linked large portion sizes with increases in energy intake (Ello-Martin, Ledikwe, & Rolls, 2005). This might partially explain the high consumption of ultra-processed foods in our study.

Third, ultra-processed foods require little or any cooking preparation before consumption, and they can be consumed anytime and anywhere (Monteiro et al., 2016). The habit of cooking is known to be associated with better diet quality and is argued to be a protective factor of obesity (Wolfson & Bleich, 2015). Because ultra-processed foods are often presented as ready-to-consume snacks, they can be consumed while doing other things such as watching TV or working (French et al., 2001; Zobel et al., 2016). It is hypothesized that eating while watching TV may induce overconsumption since individuals may be less aware of the amount

and types of foods consumed (Blass et al., 2006; French et al., 2001; Temple, Giacomelli, Kent, Roemmich, & Epstein, 2007).

Fourth, ultra-processed foods are abusively marketed and advertised (Maia et al., 2017; Pulker et al., 2017; Zimmerman, 2011). It is known that foods that are heavily advertised - such as soft drinks, snacks, and breakfast cereals – are often overconsumed (French et al., 2001). Moreover, ultra-processed food advertising campaigns often link these products to nutrition and health claims – such as "source of vitamins", "zero sugar", or "reduces cholesterol" – which may mislead people into thinking these nutritionally imbalanced products are healthy (Monteiro et al., 2016; Pulker, Scott, & Pollard, 2017; Scrinis, 2008). Other marketing strategies, such as attractive packages and linking these products to "deals" may also favor consumption (Ello-Martin, Ledikwe, & Rolls, 2005; Monteiro et al., 2016; Nielsen & Popkin, 2003; Zimmerman, 2011). Most fast food restaurants offer "value meals" and bigger sizes for reduced prices (French et al., 2001; Zimmerman, 2011). These strategies are hypothesized to trick people to overconsume by the idea of "economy" (French et al., 2001; Zimmerman, 2011).

All these attributes of ultra-processed foods are argued to induce unhealthy dietary behaviors and favor consumption. However, more studies are needed to confirm these hypotheses.

4.3   Weaknesses and strengths of this study

Because of the cross-sectional design, the results of this study may not provide strong information about cause-and-effect relationship. Despite that, this study shows some first evidence of the association between ultra-processed food consumption and obesity in Canada. Future longitudinal studies will be necessary to confirm our results.

Item nonresponse, occurring when a participant does not provide answers on certain items of a questionnaire, is a current problem in analytical cross-sectional studies. The relationship between an exposure and a disease observed among those who accepted to participate in the study and were included in the analyses might be different for those who would have been eligible to participate but were not retained in the study due to rejection or missing data. The crucial issue in studying item nonresponse is to establish whether the mechanism generating missing observations is random or, conversely, it appears in ways that may be related to the exposure and the outcome under investigation. It would have been useful to compare individuals with complete data and those with incomplete data in order to discuss potential selection bias and its effect on our results. However, less than 5% of our sample were excluded due to missing values in our dependent variables (consumption of ultra-processed foods and weight status), and missing values on other covariates were minimal (most of them were less than 1%).

Another limitation of this study concerns the fact that, at the time of this study, the most recent data available in Canada with detailed information on food intake and measurements of weight and height was the 2004 Canadian Community Health Survey, cycle 2.2 (CCHS 2.2). Thus, our results may not account for changes in dietary habits and in the food environment in the last few years. However, an ecological study shows that ultra-processed food consumption in Canada remained relatively stable between the years of 2000 and 2013 (PAHO, 2015).

In this study, it is likely that consumption of ultra-processed foods was underestimated, resulting in information bias. This is because mixed dishes, such as lasagna, were already broken down into ingredients in the FID file by Statistics Canada (Moubarac et al., 2016). Some ultra-processed dishes not consumed in a fast food place (such as frozen lasagna) might not have been

treated as ultra-processed foods, but instead as culinary preparations (Moubarac et al., 2016). In addition, ultra-processed foods with no calories, such as beverages with added artificial sweeteners, are not taken into account. As a consequence, the association between ultra-processed food consumption and obesity might have been attenuated in this study. Another limitation concerns day-to-day variation linked to 24-hour dietary recalls. With a single 24-hour food recall, it is not possible to infer the proportion of the population that meets nutrition recommendations; however, it is adequate to estimate daily food intake of a group (Health Canada, 2006).

This study has several limitations linked to its covariates, which might have resulted in misclassification and residual confounding. For instance, physical activity is estimated using only leisure-time physical activity. Individuals who practice physical activity as a way of transportation, such as cycling to work, might have been misclassified as sedentary. In addition, the absence of association between ultra-processed food consumption and income level may be explained by the large number of missing values for this variable (approximately 9% of the sample). The difference in consumption of ultra-processed foods according to education level is not very large as well. This might be due to the way this variable is categorized in our study (less than post-secondary graduation vs. post-secondary graduation). Perhaps, a variable discriminating university level would better capture differences in consumption of ultra-processed foods.

Concerning cultural background, it would have been interesting to add a more specific variable discriminating ethnic background in our analyses, instead of relying on immigrant status (immigrant/non-immigrant). However, in the 2004 CCHS 2.2, the variable assessing ethnic/cultural background present important limitations, previously discussed in the literature

(Moubarac, 2013; Tremblay et al., 2005). For instance, the terms "race" and "ethnicity" are used interchangeably in the survey, which may have been confusing for respondents. And, it resulted in inappropriate (and not exclusive) categories, such as "white", "black", "Latin American" and "Aboriginal people" (Statistics Canada, 2008b).

This study has several strengths. This is the first study to assess the association between dietary quality and obesity in the perspective of food processing in Canada using the NOVA food classification. To do so, we used a large nationally representative sample of the Canadian adult population, controlling for several potential confounding factors. To assess dietary intake, we used data from 24-hour food recall which is a validated method largely used in epidemiological studies (Health Canada, 2006). We adjusted our model for the reporting group (plausible reporters, under-reporters, over-reporters) to address misreporting bias in the 24-hour food recall (Jessri et al., 2016). Obesity was assessed through measured weight and height for the majority of the population of study. When measured values were not available, we adjusted self-reported values to increase accuracy (Gorber et al., 2008).

4.4   Recommendations

This study indicates that Canadians' dietary patterns are based on ultra-processed food consumption, and identifies potential determinants of consumption of these foods. In addition, our results further support existing evidence on the association between ultra-processed food consumption and obesity.

In order to promote healthy eating habits and address the problem of obesity and associated chronic diseases in Canada, public health policies should discourage consumption of ultra-processed foods and facilitate consumption of healthy foods. This can be done by

increasing taxes on sugar- or artificially-sweetened beverages and other ultra-processed foods, and by increasing accessibility and affordability of unprocessed and minimally processed foods such as fruits and vegetables (Ogilvie & Eggleton, 2016). Food labeling reformulations may also help individuals make better food choices (Ogilvie & Eggleton, 2016; Pulker et al., 2017). Restricting the use of nutrition or health claims on ultra-processed foods, and adopting clear and informative front-of-package labelling scheme are examples of interventions that may help avoid ultra-processed food labels to give the impression that these foods are healthier than they really are (Ogilvie & Eggleton, 2016; Pulker et al., 2017).

Dietary guidelines should incorporate recommendations based on the degree and nature of food processing (Ogilvie & Eggleton, 2016). The Canadian Food Guide, for instance, overlooks food processing. The food guide is based on a rainbow composed by four main food groups: fruits and vegetables, grain products, dairy, and meat and alternatives (Canadian Ministry of Health, 2011). Within the main food groups, there is no discrimination of foods with different levels of processing. An extra group is briefly referenced in the Canadian Food Guide - the "other foods", composed by nutrient-poor and processed foods such as candies, sugar-sweetened beverages, snack foods, and so on (Canadian Ministry of Health, 2011). This extra group is not included in the rainbow, and may have been remained unnoticed by most Canadians (Ogilvie & Eggleton, 2016).

The report of the Standing Senate Committee on Social Affairs, Science, and Technology of Canada points out that the Canadian Food Guide may be ineffective with respect to the high consumption of ultra-processed foods and high prevalence of obesity in Canada (Ogilvie & Eggleton, 2016). According to the report, the Canada's Food Guide (now under revision) should have a food- and meal-based approach, instead of focusing on specific nutrients

(Ogilvie & Eggleton, 2016). The report also recommends that the Canadian dietary guidelines should describe the benefits of whole and fresh foods compared to ultra-processed foods; make strong statements about restricting consumption of ultra-processed foods; and increase public awareness about the health risks related to high consumption of ultra-processed foods (Ogilvie & Eggleton, 2016). This study supports these recommendations.

Finally, our results show that consumption of ultra-processed foods is higher among men, younger adults, with less years of formal education, smokers, sedentary individuals, and Canadian-born subjects. Additional interventions targeting specific groups of people could complement population-level interventions. For instance, interventions among certain population groups focusing on increasing nutritional knowledge or developing cooking skills may help reduce reliance on ultra-processed food consumption. However, a critical appraisal of the literature is necessary to identify effective strategies for this purpose.

Conclusion

The prevalence of obesity has increased worldwide, impacting healthcare systems and overall health of populations. At the same time, ultra-processed foods are replacing traditional dietary patterns mainly based on fresh and whole foods. This study demonstrates that diets in Canada are mostly based on ultra-processed foods. On average, almost half of daily calories consumed by Canadians is from ultra-processed foods.

Our findings suggest that high consumption of ultra-processed foods is associated with obesity risk. Based on this study, adults living in Canada would improve the quality of their diet and health by reducing consumption of ultra-processed foods. This might be done by maintaining or even rebuilding lost connections to traditional food habits and culture, as well as by increasing consumption of fresh foods and homemade meals prepared from scratch.

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Appendix 1 – The NOVA food groups

Box 1. Group 1 of unprocessed and minimally processed foods. The NOVA food classification, 2017.

<table>
<tr><td>

Group 1. Unprocessed and minimally processed foods

Definition
- Unprocessed foods are edible parts of animals (muscle, offal, eggs, milk), plants (seeds, fruits, leaves, stems, roots), fungi, algae, and water.
- Minimally processed foods are natural foods altered by processes such as removal of inedible or unwanted parts, drying, crushing, grinding, fractioning, filtering, roasting, boiling, pasteurization, refrigeration, chilling, freezing, placing in containers and vacuum packaging.

Purpose
- Preserve natural foods, make suitable for storage or extend self-life.
- Make foods safer, edible or more pleasant to consume.

Characteristics
- No substances are added to the original food (such as salt, sugar or fats).
- May be added of vitamins and minerals with the purpose of replacing nutrients lost during processing.
- May infrequently contain additives to preserve the properties of the original food (such as anti-oxidants and stabilizers).
- Include foods made up from two or more items from this group (e.g. mix of dried fruits and nuts).

Examples
- Fresh fruits, legumes, vegetables, roots, and tubers,
- Fresh or pasteurized fruit or vegetable juices with no added sugar, sweeteners, or flavors,
- Squeezed, chilled, frozen and dried fruits,
- Vacuum-packed vegetables with added anti-oxidants,
- Nuts and seeds with no added salt, sugar or oil,
- Mix of fruits, nuts, cereals (granola) with no added salt, sugar, honey or oil,
- Grains such as rice, beans, lentils, corn and wheat,
- Grits, flakes or flours made from corn, wheat, oats or cassava (fortified or not with iron or folic acid),
- Pasta and couscous made with flours, flakes or grits and water with no salt or oil added,
- Fresh, chilled or frozen meat, poultry, fish, seafood (whole, in the form of steaks, fillets or other cuts),
- Fresh or pasteurized eggs,
- Fresh, pasteurized, powdered or ultra-pasteurized milk with added stabilizers,
- Plain yogurt with no added sugar or artificial sweeteners,
- Fresh or dried spices and herbs,
- Tea, coffee, and drinking water.

</td></tr>
</table>

Source: adapted from Moubarac et al., 2016 and Monteiro et al., 2017.

Box 2. Group 2 of processed culinary ingredients. The NOVA food classification, 2017.

Group 2. Processed culinary ingredients

Definition
- Substances obtained directly from unprocessed and minimally processed foods or from nature by processes such as pressing, refining, grinding, milling and drying.

Purpose
- Make durable products used to prepare, cook and season unprocessed and minimally processed foods.

Characteristics
- They are not meant to be consumed by themselves, but mainly used in combination with Group 1 foods to make homemade dishes and meals.
- May contain additives used to preserve the original properties of foods.
- Include foods consisting of two items from this group, and foods from this group added of vitamins or minerals.

Examples
- Mined or seawater salt, iodized or not,
- Cooking salt with added anti-humectants,
- Sugar and molasses obtained from cane or beet, honey extracted from combs, syrup from maple trees,
- Vegetable oils crushed from olives or seeds, with added anti-oxidants or not,
- Butter and lard obtained from milk and pork, salted or not,
- Starches extracted from corn and other plants,
- Vinegar made by acetic fermentation of wine or other alcoholic drinks, with added preservatives or not.

Source: adapted from Moubarac et al., 2016 and Monteiro et al., 2017.

Box 3. Group 3 of processed foods. The NOVA food classification, 2017.

Group 3. Processed foods

Definition
- Food products typically with two or three ingredients made by adding Group 2 ingredients (such as sugar, oil, salt) to Group 1 foods.
- Processes include various preservation or cooking methods, and non-alcoholic fermentation (in the case of breads and cheeses).

Purpose
- Increase durability of Group 1 foods.
- Modify or enhance sensory qualities of Group 1 foods.

Characteristics
- Relatively simple products, with two or three ingredients.
- May contain additives to preserve the original properties of foods or to resist microbial contamination.

Examples
- Artisanal breads and cheeses,
- Canned and bottled vegetables, fruits, legumes and fish, with added anti-oxidants or not,
- Fruits in syrup, with added anti-oxidants or not,
- Salted or sugared nuts, seeds and dried fruits,
- Salted, cured, dried or smoked meats with added preservatives or not.

Source: adapted from Moubarac et al., 2016 and Monteiro et al., 2017.

Box 4. Group 4 of ultra-processed foods. The NOVA food classification, 2017.

Group 4. Ultra-processed foods

Definition
- Industrial formulations made mostly or entirely from substances derived from foods and additives.
- Contain small or any proportion of whole foods.
- Processes include several industrial methods with no domestic equivalents such as extrusion, molding, hydrogenation, hydrolyzation and pre-processing for frying

Purpose
- Create very convenient food products, with long shelf-life and ready-to-consume.
- Create products liable to displace unprocessed or minimally processed foods as well as freshly prepared dishes.

Characteristics
- Typically contains five or more ingredients, and substances not commonly used in culinary preparations, such as hydrolyzed protein, modified starches, hydrogenated or interesterified oils, etc.
- They are hyper-palatable, sold in attractive packages, intensively marketed, highly profitable food products.
- Contain additives used to imitate sensorial qualities of unprocessed or minimally processed foods, or to disguise undesirable qualities of the final product such as colorants, flavorings, non-sugar sweeteners, emulsifiers, humectants, sequestrants, and firming, bulking, de-foaming, anti-caking and glazing agents.
- Include products made solely of Group 1 or Group 3 foods with added cosmetic or sensory intensifying additives.

Examples
- Breads with added emulsifiers and mass-produced packaged breads and buns,
- Breakfast cereals, energy and cereal bars,
- Margarines and spreads,
- Reconstituted meat products, such as poultry and fish sticks, sausages, burgers, hot dogs and bacon,
- Meat and chicken extracts and instant sauces,
- Powdered and packaged instant soups and noodles,
- Ready to heat pre-prepared pies, pasta, pizza, dishes and desserts,
- Sweet or savory packaged snacks, cookies, pastries, cakes, cake mixes, chocolate, candies, ice-cream, etc.
- Carbonated drinks, energy drinks, "fruit" drinks, milk drinks, and cocoa drinks,
- "Fruit" yogurts and plain yogurt with added artificial sweeteners,
- "Health" and "slimming" products such as powdered or "fortified" meal and dish substitutes,
- Infant formulas, follow-on milks, and other baby products.

Source: adapted from Moubarac et al., 2016 and Monteiro et al., 2017.

Appendix 2 - Ethics approval certificate

N° de certificat
17-017-CERES-D

Comité d'éthique de la recherche en santé

CERTIFICAT D'APPROBATION ÉTHIQUE

Le Comité d'éthique de la recherche en santé (CERES), selon les procédures en vigueur, en vertu des documents qui lui ont été fournis, a examiné le projet de recherche suivant et conclu qu'il respecte les règles d'éthique énoncées dans la Politique sur la recherche avec des êtres humains *de l'Université de Montréal.*

Projet	
Titre du projet	**Consumption of ultra-processed foods and its association with obesity in Canada**
Étudiante requérante	**Milena Nardocci Fusco (ND), ND, ND**
Sous la direction de	Jean-Claude Moubarac, professeur adjoint, Faculté de médecine - Département de nutrition, Université de Montréal & Bernard-Simon Leclerc, professeur adjoint de clinique, École de santé publique - Département de médecine sociale et préventive, Université de Montréal.

Financement	
Organisme	ND
Programme	
Titre de l'octroi si différent	
Numéro d'octroi	
Chercheur principal	
No de compte	

MODALITÉS D'APPLICATION
Tout changement anticipé au protocole de recherche doit être communiqué au CERES qui en évaluera l'impact au chapitre de l'éthique.

Toute interruption prématurée du projet ou tout incident grave doit être immédiatement signalé au CERES

Selon les règles universitaires en vigueur, un suivi annuel est minimalement exigé pour maintenir la validité de la présente approbation éthique, et ce, jusqu'à la fin du projet. Le questionnaire de suivi est disponible sur la page web du CERES.

Dominique Langelier, présidente
Comité d'éthique de la recherche en santé
Université de Montréal

1er mars 2017
Date de délivrance

1er avril 2018
Date de fin de validité

Appendix 3 – Equations to identify implausible reporters

Box 5. Equations to estimate energy requirements (EER) by body mass index (BMI, kg/m^2), sex and age (years).

BMI/Sex/Age	Equation
18.5 ≤ BMI ≤ 25.0	
Men	
18 years	EER = 113.5 – (61.9*Age) + PA$_C$*{(26.7*Weight) + (903*Height)}
≥ 19 years	EER = 661.8 – (9.53*Age) + PA$_C$*{(15.91*Weight) + (539.6*Height)}
Women	
18 years	EER = 160.3 – (30.8*Age) + PA$_C$*{(10.0*Weight) + (934*Height)}
≥ 19 years	EER = 354.1 – (6.91*Age) + PA$_C$*{(9.36*Weight) + (726*Height)}
BMI > 25.0	
Men	
18 years	EER = -114.1- (50.9*Age) + PA$_C$*{(19.5*Weight) + (1161.4*Height)}
≥ 19 years	EER = 1085.6 – (10.08*Age) + PA$_C$*{(13.7* Weight) + (416*Height)}
Women	
18 years	EER = 389.2 – (41.2*Age) + PA$_C$*{(15*Weight) + (701.6*Height)}
≥ 19 years	EER = 447.6 – (7.95*Age) + PA$_C$*{(11.4*Weight) + (619* Height)}

PA$_c$: Physical Activity Coefficient
Source: IOM, 2005 in Garriguet, 2008.

Box 6. Equations to convert physical activity in metabolic equivalents (MET) into change in Physical Activity Level (ΔPAL).

Sex	Equation
Men	ΔPAL = (MET - 1) * N times[a] * Duration[b] * (1.34 / 1440)
Women	ΔPAL = (MET - 1) * N times * Duration * (1.42 / 1440)

a. N times: number of times a physical activity was performed in the last 3 months.
b. Duration: average duration (in minutes) of a physical activity (13, 23, 45 or 60 minutes).
Source: IOM, 2005 in Garriguet, 2008.

Box 7. Physical Activity Coefficients (PA$_C$) by BMI, sex, age and Physical Activity Level (PAL).

BMI/Sex/Age	Sedentary 1.0 ≤ PAL <1.4	Low active 1.4 ≤ PAL <1.6	Active 1.6 ≤ PAL <1.9	Very active 1.9 ≤ PAL <2.5
18.5 ≤ BMI ≤ 25.0				
Men				
18 years	1.00	1.13	1.26	1.42
≥ 19 years	1.00	1.11	1.25	1.48
Women				
18 years	1.00	1.16	1.31	1.56
≥ 19 years	1.00	1.12	1.27	1.45
BMI > 25.0				
Men				
18 years	1.00	1.12	1.24	1.45
≥ 19 years	1.00	1.12	1.29	1.59
Women				
18 years	1.00	1.18	1.35	1.60
≥ 19 years	1.00	1.16	1.27	1.44

Source: IOM, 2005 in Garriguet, 2008.