Dietary Factors Associated with Abdominal Adiposity in Postmenopausal Women

by

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A thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy
Dalla Lana School of Public Health
University of Toronto

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2019

Abstract

Elucidating modifiable dietary factors for adiposity, particularly abdominal adiposity, has important public health implications for the prevention of obesity and subsequent health risks. The emerging epidemiological evidence suggests that the nature of carbohydrate intake may be an etiological factor in adiposity. The objectives of the thesis were to examine the associations between various carbohydrate-related dietary factors (carbohydrate intake, dietary fibre intake, dietary patterns, dietary glycemic index, GI, and dietary glycemic load, GL) and measures of abdominal and total adiposity. These relationships were investigated in a cross-sectional study of Canadian postmenopausal women aged 50–69 years. Dual-energy X-ray absorptiometry (DXA) measures of abdominal adiposity and total adiposity were utilized, in addition to standard anthropometric measures. We found that total dietary fibre intake, but not total carbohydrate intake, was inversely associated with trunk fat mass (β = −0.127 kg; 95% confidence interval, CI: −0.210, −0.044). However, associations with trunk fat mass varied by food source, where there were positive associations between potato sources of carbohydrate (β = 0.096 kg; 95% CI: 0.019, 0.173) and fibre intake (β = 1.110 kg; 95% CI: 0.157, 2.064) and trunk fat mass. Additionally, a Western dietary pattern (high intake of meats, potatoes, and sweetened products) was positively associated with all measures of abdominal and total adiposity, while a Prudent
dietary pattern (high intake of vegetables, fruit, legumes, grains, and cereals) was inversely associated with all measures of adiposity. Specifically, postmenopausal women with the greatest adherence to a Western dietary pattern had 4.52 kg (95% CI: 2.58, 6.45) greater trunk fat mass versus those with the lowest adherence, while postmenopausal women with the greatest adherence to a Prudent dietary pattern had −2.68 kg (95% CI: −4.45, −0.09) trunk fat mass compared to those with the lowest adherence. However, there was no evidence of linear associations between dietary GI or dietary GL and measures of abdominal and overall adiposity. Our findings of the contrasting associations with abdominal adiposity by carbohydrate and dietary fibre food sources and dietary patterns characterized by distinct carbohydrate food groups, suggest a potential role of carbohydrate quality in the accumulation of adipose tissue.
Acknowledgments

This thesis would not be completed without the support of numerous people. First and foremost, I would like to thank my supervisor, Dr. Julia Knight, for her exceptional guidance throughout the doctoral program. I am extremely grateful for Dr. Knight’s expertise, understanding, and encouragement. Dr. Knight was invaluable in furthering my training in epidemiology. I would also like to thank Dr. Anthony Hanley and Dr. Victoria Kirsh for taking time to serve on my supervisory committee. The insights provided by Dr. Hanley and Dr. Kirsh were instrumental to my research and training.

Additionally, I would like to recognize the people at the Prosserman Centre for Population Health Research (Lunenfeld-Tanenbaum Research Institute, Mount Sinai Hospital). I am particularly grateful for the contributions of Ms. Rosemary Sousa, Ms. Jody Wong, and the team of radiation technologists in conducting the data collection for the study. I would also like to extend my gratitude to Dr. Ilona Csizmadi at the University of Calgary for sharing her expertise on the dietary assessment instrument and nutritional epidemiology. The input from Dr. Csizmadi was very valuable during the research process.

Furthermore, I would like to acknowledge the financial support from Dr. Knight, the University of Toronto, and the Ontario Graduate Scholarship during the completion of the doctoral program.

Lastly, I would like to express my sincerest thanks to my family for their continuous support and encouragement.
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List of Abbreviations

BMI  Body mass index
CCHS 2.2  Canadian Community Health Survey, Cycle 2.2
C-DHQ II  Canadian Diet History Questionnaire II
CI  Confidence interval
DASH  Dietary Approaches to Stop Hypertension
DXA  Dual-energy X-ray absorptiometry
EPIC  European Prospective Investigation into Cancer and Nutrition
FFQ  Food frequency questionnaire
GI  Glycemic index
GL  Glycemic load
HEI  Healthy Eating Index
IPAQ  International Physical Activity Questionnaire
NHS  Nurses’ Health Study
NHS II  Nurses’ Health Study II
NIH  National Institutes of Health
OBSP  Ontario Breast Screening Program
PCA  Principal components analysis
RCT  Randomised controlled trial
SAT  Subcutaneous adipose tissue
US-DHQ  U.S. Diet History Questionnaire
VAT  Visceral adipose tissue
WHO  World Health Organization
Chapter 1
Introduction

1.1 Overview

The rising trends in the prevalence rates of overall obesity (1) and abdominal obesity (2–6) are significant public health issues, especially because obesity is associated with numerous health risks. Increasingly, there is a focus on body fat distribution because of evidence showing that abdominal adiposity is independently associated with many health risks (7–11) and that specific physiological functions of abdominal adipose tissue may contribute to the pathogenesis of disease (12–15). Therefore, preventing the accumulation of abdominal adipose tissue is a priority and requires knowledge of the determinants of abdominal adiposity. Diet, in particular, has become an increasing focus of epidemiological research investigating risk factors for abdominal adiposity, as well as total adiposity, because diet is modifiable and thus has the potential for public health interventions.

While there is a significant body of literature investigating dietary factors in relation to overall adiposity, the research-to-date on dietary factors and abdominal adiposity is not as extensive. The complexity of diet has resulted in the examination of the relationship between a wide variety of dietary factors and abdominal adiposity, but the cumulative evidence for any specific dietary factor is limited. The evidence from epidemiological studies on the associations of carbohydrate intake, dietary fibre intake, dietary patterns, glycemic index (GI), and glycemic load (GL) with abdominal adiposity have not been conclusive, but, overall, suggests that specific features of carbohydrate intake (including carbohydrate quality, dietary fibre, and GI) may be important dietary determinants of abdominal adiposity.

The overall aim of this thesis was to investigate the associations between specific aspects of carbohydrate intake (including amount, type, and quality) and measures of abdominal adiposity, as well as total adiposity, in a group of Canadian postmenopausal women. Specifically, the quality of carbohydrate intake was captured using multiple facets of dietary intake including macronutrient content (carbohydrate and dietary fibre), overall diet (dietary patterns), and indices of carbohydrate quality (GI and GL). This research adds to the limited literature on the relationships between carbohydrate-related dietary factors and adiposity by examining the effects
of multiple variables characterizing carbohydrate quality within the same study population. Overall, this research contributes to our understanding of the etiology of abdominal adipose tissue accumulation, with implications for the prevention of abdominal and overall obesity.

1.2 Outline

Chapter 2 presents a review of the literature on the epidemiology of total and abdominal adiposity, including a more detailed review of select dietary factors and adiposity, and the rationale for the thesis research. The hypotheses and objectives of the thesis are outlined in the following chapter (Chapter 3). In Chapter 4, an overview of the methods, including the study design, dietary exposure variables, adiposity outcome variables, and analytic methods, are described. The results of the three objectives are presented in separate manuscripts in Chapter 5, Chapter 6, and Chapter 7. Finally, Chapter 8 addresses methodological considerations in the interpretation of the results and future research directions to add to the discussion presented in the three manuscripts.
1.3 References


Chapter 2
Background and Literature Review

2.1 Overall and abdominal obesity

2.1.1 Descriptive epidemiology

Obesity is one of the foremost global public health concerns at present. Body mass index (BMI) is a widely-used measure for identifying obesity and is defined as an individual’s weight divided by height squared (kg/m²). The World Health Organization (WHO) classifies adults with a BMI $\geq 25$ kg/m² as overweight and adults with a BMI $\geq 30$ kg/m² as obese. From 1975 to 2016, the global age-standardised mean BMI increased from 21.7 kg/m² (95% confidence interval, CI: 21.3, 22.0) to 24.5 kg/m² (95% CI: 24.3, 24.6) and from 22.1 kg/m² (95% CI: 21.7, 22.5) to 24.8 kg/m² (95% CI: 24.6, 25.0) in men and women aged 20 years or older, respectively (1, 2). A continuous rise in the prevalence of obesity was also observed worldwide between 1980 and 2015, where the prevalence of obesity was estimated to be more than two-times higher in over one-third of the world’s countries (3). In 2015, 603.7 million (95% CI: 592.9, 615.6) adults were estimated to be obese, which is a global prevalence of 12.0% (3). The global age-standardised prevalence of obesity increased from 3.0% (95% CI: 2.3, 3.9) to 11.6% (95% CI: 10.6, 12.6) among men and from 6.6% (95% CI: 5.4, 7.9) to 15.7% (95% CI: 14.6, 16.8) among women between 1975 and 2016 (1, 2). The prevalence of obesity was higher among women than men across all ages, but the rates of increase were similar (3). In addition, the prevalence of obesity was generally greater in countries with a higher development level, irrespective of sex and age (3). In Canada, 19.8% (95% CI: 17.2, 22.6) of men aged 20 years or older and 20.8% (95% CI: 18.7, 23.0) of women aged 20 years or older were estimated to be obese in 2015 (3).

An increasing trend in the prevalence of abdominal obesity has also been observed within this time period. A frequently utilized measure for assessing abdominal adiposity is waist circumference. The WHO has established waist circumference cut-offs for identifying abdominal obesity, which are specific for sex and region (4, 5). In the late 2000’s and early 2010’s, national estimates of the prevalence of abdominal obesity among adults in various North American, European, and Asian countries ranged from 36 to 54% (6–10). These estimates were approximately 8 to 24% higher than the prevalences reported in the previous 10 to 20 years (6–10). The prevalence of abdominal obesity was also higher among women compared to men (6–
From 1981 to 2007–2009, the age-adjusted prevalence of abdominal obesity (waist circumference $\geq 102.0$ cm for men and $\geq 88.0$ cm for women) among Canadian men and women aged 20 to 69 years increased from 10.1% (95% CI: 8.5, 11.7) to 30.7% (95% CI: 25.4, 36.1) and 12.8% (95% CI: 11.0, 14.5) to 40.6% (95% CI: 34.4, 46.9), respectively (9).

While the secular increase in waist circumference has coincided with the rise in BMI, there is evidence that the change in waist circumference is independent of BMI. Among Canadians aged 20 to 69 years, the proportion of individuals with abdominal obesity within BMI categories increased significantly from 1981 to 2007–2009 (11). This was reported for men and women in the obese class I (30–34.9 kg/m$^2$) and overweight (25.0–29.9 kg/m$^2$) categories, as well as women in the normal weight (18.5–24.9 kg/m$^2$) category (11). Research using data from the 1999–2000 to 2011–2012 United States National Health and Nutrition Examination Survey cycles also found that secular increases in mean waist circumference were significant among women, independent of BMI, age, and ethnicity (12).

### 2.1.2 Associated health risks

The rising prevalences of overall obesity and abdominal obesity are noteworthy because increased adiposity is a well-established risk factor for mortality and numerous morbidities. It was estimated that being overweight or obese contributed to 7.1% (95% CI: 4.9, 9.6) of all deaths in 2015 (3). Individuals who are overweight or obese have a greater risk of death compared to those who are normal weight, with all-cause mortality hazard ratios for individuals who are overweight or obese versus those who are normal weight of 1.11 (95% CI: 1.10, 1.11) and 1.64 (95% CI: 1.61, 1.67), respectively (13). There is also strong evidence from meta-analyses and pooled analyses of associations between increased total body fatness and higher risks of chronic diseases, including type 2 diabetes mellitus, cardiovascular disease, and various cancers. Compared to individuals of normal weight, the risk of type 2 diabetes mellitus is approximately 3 and 7 times higher among those who were overweight or obese, respectively (14). The risk of any cardiovascular disease is 1.07 (95% CI: 1.03, 1.11) times greater per 4.56 kg/m$^2$ increase in BMI (15), while the risk of coronary heart disease and stroke increases by 1.27 (95% CI: 1.23, 1.31) and 1.18 (95% CI: 1.14, 1.22) times, respectively, for each 5 kg/m$^2$ increase in BMI (16). Furthermore, the International Agency for Research on Cancer’s evaluation of research on body fatness and cancer concluded that there is sufficient evidence of associations
between excess body fatness and risk of thirteen types of cancer (17). Pooled analyses and meta-
analyses have reported that, compared to individuals who are normal weight, those who are
obese have 1.3 to 1.8 times greater risk for cancers of the colon or rectum (18), kidney (renal-
cell) (19), gastric cardia (20), liver (21), gallbladder (22), and pancreas (23), as well as
meningioma (24). Additionally, the risk of postmenopausal breast (25), ovarian (26), and
thyroid (27) cancers increases by 1.1-fold for each 5 kg/m² gain in BMI.

Many obesity-related health risks are also associated with abdominal obesity. More importantly,
measures of abdominal adiposity (i.e. waist circumference or waist-to-hip ratio) have been
shown to predict the risk of morbidities, independent of measures of overall adiposity (i.e. BMI).
For metabolic disorders (i.e. hypertension, dyslipidemia, and metabolic syndrome), increased
waist circumference, but not BMI, was found to be significantly associated with a greater
likelihood of disease, after mutually adjusting for these obesity measures (28). While waist
circumference and BMI were both found to be associated with type 2 diabetes mellitus and
cardiovascular disease, independent of the other measure, the associations were stronger for
waist circumference (29). Similarly, increased waist circumference was reported to be
associated with a moderately higher risk of premenopausal and postmenopausal breast cancers,
after adjustment for BMI (30). Moreover, these findings are supported by research showing that
increased abdominal adipose tissue is associated with higher risk of morbidities. The amounts of
abdominal visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT) have been
found to be associated with an increased likelihood of hypertension, metabolic syndrome, and
type 2 diabetes mellitus with stronger associations for VAT (31). Abdominal VAT has also been
shown to be associated with a higher risk of colorectal adenomas in a meta-analysis (32).

2.1.3 Pathophysiology

The health risks independently associated with abdominal adiposity highlight the importance of
body fat distribution. Body fat is classified into various fat depots based on its location and
physiological functions. The main fat depots are SAT, which is directly beneath the epidermis,
and VAT (also known as intra-abdominal adipose tissue), which surrounds organs (33, 34).
Lower-body SAT encompasses gluteal, leg, and intramuscular fat, while upper-body SAT
includes fat in the arms and trunk region, which is divided into superficial and deep abdominal
SAT (33, 34). The accumulation of deep abdominal SAT is correlated with the accumulation of
VAT, which includes omental and mesenteric fat (33, 34). The primary physiological function of adipose tissue is the storage and release of free fatty acids in order to meet energy balance requirements (33). Adipose tissue is also involved in immune response, endocrine activity, mechanical protection, and thermal function (33). However, there are regional differences in adipocyte characteristics and physiological functions (33, 35). These differences may explain the role of VAT accumulation in the pathogenesis of obesity-related disease.

A possible mechanism for the pathophysiological effects of VAT is related to the location of this fat depot. Unlike other fat depots, omental and mesenteric fat drain into the portal vein (34, 36). The increased release of free fatty acids in response to VAT accumulation may cause hepatic insulin resistance and increased hepatic gluconeogenesis (36). Another hypothesis for the pathogenesis of obesity-related diseases relates to the release of cytokines by VAT adipocytes (34–36). Cytokines that are released differentially by fat depot include adiponectin, leptin, and inflammatory cytokines (34 , 35). Visceral adiposity is associated with reduced adiponectin and leptin secretion, compared to subcutaneous adiposity (34 , 35). In addition, the production of interleukin-6 (34 , 35) and plasminogen activator inhibitor-1 (35, 36) by VAT adipocytes is greater than SAT adipocytes. Adiponectin secretion, which helps regulate insulin sensitivity and inflammation, is reduced in those with visceral obesity (35). Alternatively, VAT has been proposed to be an ectopic fat depot. This hypothesis suggests that the pathophysiological effects of excess adipose tissue are due to SAT dysfunction (33, 34). Specifically, the ability of SAT to store free fatty acids is reduced, which causes free fatty acid storage to be moved to ectopic fat depots, such as VAT (34). Furthermore, abnormal SAT is hypothesized to have greater inflammation and abnormal release of cytokines (33, 34). Although there is growing evidence on the regional differences in adipose tissue biology, further research is needed to understand the mechanisms for obesity-related disease.

2.2 Risk factors for adiposity

The high prevalences of overall obesity and abdominal obesity have led to a greater focus on understanding etiological factors. Obesity arises from the accumulation of fat due to the positive energy balance occurring when caloric intake exceeds energy expenditure (37, 38). However, the etiology of obesity is complex and involves the interaction of multiple non-modifiable and modifiable factors. The following section provides a brief review of non-modifiable and
modifiable factors that influence total and abdominal adiposity. Dietary factors are reviewed in more detail in section 2.3.

2.2.1 Genetic factors

There is strong evidence of a genetic basis for obesity and body fat distribution. The heritability of BMI is estimated to be between 25 to 50% in family studies and between 70 to 80% in twin studies (38). Similarly, estimates for the heritability of waist circumference have been found to range from 37 to 81% (39). The 2005 update of the Human Obesity Gene Map identified 127 candidate genes and approximately 250 quantitative trait loci for obesity phenotypes, including a number that have been replicated in multiple studies (40). Specifically, a genome-wide association meta-analysis in individuals of European ancestry identified a total of 97 BMI-associated loci, with over half being newly identified loci (41). However, these loci only accounted for 2.7% of the inter-individual variation in BMI (41). Furthermore, genetic loci specific to body fat distribution, as measured by waist-to-hip ratio adjusted for BMI, have been identified in a genome-wide association meta-analysis. A total 49 loci for this trait were identified among individuals of European descent, which accounted for 1.4% of the variation (42). Interestingly, there is evidence of sexual dimorphism for traits related to body fat distribution, while traits related to overall obesity have not shown sexual dimorphism consistently (43). Overall, the 49 loci for waist-to-hip ratio adjusted for BMI explained a greater amount of variation in women (2.4%) than men (0.8%) (42). In addition, 20 of the 49 loci showed sexual dimorphism, with stronger effects in women for 19 of the loci (42). Furthermore, a genome-wide association study of abdominal adipose tissue phenotypes found stronger associations between the top single-nucleotide polymorphisms and SAT for women than for men and identified a genetic locus for SAT in women only (44). With such high heritability estimates and established loci explaining so little of the variability in BMI, there must be more susceptibility loci to be discovered.

2.2.2 Demographic factors

Sex, age, and ethnicity are other non-modifiable factors associated with total and abdominal adiposity. As observed in the prevalences of total and abdominal obesity, body fat distribution varies between males and females. Studies have also found that total body fat was significantly lower among men than premenopausal and postmenopausal women (45, 46). In contrast, men
had a greater amount of abdominal fat than both premenopausal women (45, 46) and postmenopausal women (46). Furthermore, at a given waist circumference, postmenopausal women had higher levels of VAT than premenopausal women (46). This finding is supported by small longitudinal studies, which reported a significant increase in abdominal VAT after menopause (47, 48).

Age is also associated with overall and abdominal adiposity. Longitudinal studies have found that total fat mass increases with age (49). Similarly, findings from cross-sectional and longitudinal studies reported that aging is associated with increased waist circumference (49). However, the relationship between age and adiposity varies by ethnicity. Specifically, total adiposity increases with age until the ages of 60 to 70 years among Whites, whereas peak total body fatness in Asian populations is reached at the ages of 50 to 60 years (49). Furthermore, abdominal VAT accumulation varies by ethnicity. A Canadian study found that, compared to European adults, the amount of VAT was significantly greater among Chinese and South Asian adults, but not among Aboriginal adults (50).

2.2.3 Non-dietary lifestyle factors

Modifiable lifestyle risk factors for total and abdominal adiposity are of particular importance because these factors may be targets for interventions. Non-dietary lifestyle factors include physical activity, alcohol use, and smoking. Summerbell et al. (51) conducted a comprehensive systematic review of cohort studies that examined the associations between physical activity and diet and obesity. The systematic review did not find strong evidence of an association between total physical activity and overall obesity (51). Studies either found no effect or a weak inverse association between the total physical activity level and BMI or body weight (51). However, it was noted that the measurement of physical activity level was a concern due to the potential for measurement error and lack of temporality between the exposure and outcome (51). Similarly, a review of randomised clinical trials (RCTs) and non-RCTs did not provide conclusive evidence of a relationship between physical activity and abdominal adiposity (52). Of the 34 studies reviewed, 22 studies did not find a significant change in abdominal adiposity with regular physical activity, while twelve studies reported a significant decrease in abdominal adiposity (52). Prospective cohort studies have noted an inverse association between physical activity and waist circumference, independent of BMI (53, 54). Higher physical activity levels at baseline
and increased levels of physical activity over time (54) were also associated with lower waist circumference.

The relationship between alcohol intake and adiposity has not been shown consistently and may be related to the definition of the alcohol exposure. The comprehensive systematic review by Summerbell et al. (51) identified a cohort study of Canadian adults, which did not find a significant association between the frequency of alcohol intake at baseline and change in BMI over a seven-year period. Additionally, alcohol intake at baseline was not associated with change in waist circumference in two cohort studies identified in the review, while a Danish cohort study did not find a significant association among men, but there was a positive association among women (51). Average alcohol intake (percentage energy intake) was also found to have a moderate positive association with waist circumference adjusted for BMI among women, but not men, in the European Prospective Investigation into Cancer and Nutrition (EPIC) cohort (55). Conversely, there was no evidence of a linear association between energy intake from alcohol (MJ/d) and five-year change in waist circumference in a large Danish cohort (56). However, examination of specific types of alcohol found that there was a U-shaped relationship between energy intake from wine and abdominal adiposity (56). This finding was supported by a cross-sectional study that reported J-shaped relationships between total and wine alcohol intake and waist-to-hip ratio (57). Examination of average lifetime alcohol intake in the EPIC study found a positive association among men and women, where the greatest average lifetime alcohol intake (>96 g/d for men and 60–96 g/d for women) had waist circumferences 1.1 cm and 1.7 cm greater, respectively, than those with an intake of 6 g/d or less (58). Men and women with the greatest lifetime alcohol intake also had 1.40 times (95% CI: 1.32, 1.49) and 1.63 times (95% CI: 1.54, 1.73) higher likelihood, respectively, of having a waist circumference greater than predicted by BMI compared to those in the reference category (58). Interestingly, the positive effect of alcohol intake on waist circumference predicted from BMI was stronger for beer than for wine (58).

There is evidence that cigarette smoking is associated with overall adiposity. Findings from a meta-analysis of cohort studies showed that BMI was increased by 0.63 kg/m² (95% CI: 0.46, 0.80) in individuals who quit smoking compared to individuals who continued smoking (59). Cigarette smoking is also associated with abdominal adiposity. A meta-analysis of observational studies found that waist-to-hip ratio was approximately 0.011 units (95% CI: 0.008, 0.015)
higher among current smokers compared to individuals who have never smoked (60). Although VAT area did not differ significantly among current, former, and never South Korean male smokers, a U- or J-shaped relationship between the quantity of smoking, as measured by total pack-years, and VAT area was observed (61).

2.3 Dietary factors and adiposity

Diet is another important modifiable lifestyle factor that may contribute to the accumulation of adipose tissue. Diet is comprised of a multitude of components, including nutrients, foods, and food groups, which may have independent or joint effects on adiposity. This section provides an overview of research on select dietary components, which have been studied in relation to measures of overall and abdominal adiposity among adults.

2.3.1 Macronutrients

2.3.1.1 Energy

As stated previously, a positive energy balance, where dietary energy intake is greater than energy expenditure, contributes to the accumulation of adipose tissue (37, 38). However, the evidence of a direct association between total energy intake and measures of adiposity are not conclusive. A systematic review of longitudinal studies on various components of diet quality and measures of weight change, including weight, BMI, waist circumference, and percentage of body fat, in adults did not find consistent evidence of an association for energy intake (62). Three of the five studies that examined weight change as the outcome found a positive association with baseline or change in energy intake (62). The review identified one study that examined change in BMI, which did not find an association with change in energy intake (62). Baseline energy intake was not associated with change in waist circumference in the single study identified in the review (62). Similarly, Romaguera et al. (55) did not find a significant association between total energy intake at baseline and change in waist circumference adjusted for BMI among men or women in the EPIC cohort. Both studies that assessed abdominal adiposity were conducted in European populations (55, 62).

In addition to total energy intake, dietary energy density is important because it considers the amount of energy per unit weight of food or diet (kcal/g or kJ/g) (63). Research on dietary energy density and adiposity suggest a direct relationship for select measures of adiposity. A
meta-analysis of observational studies concluded that, compared to individuals in the lowest quintile of dietary energy density, those in the highest quintile had higher mean weight (cohort studies) and mean BMI among female and male subgroups (studies with multivariate-adjusted means) (64). No significant associations were observed between dietary energy density and risk of increased BMI, risk of increased waist circumference, mean waist circumference, or mean waist-to-hip ratio in the meta-analysis (64). However, there was significant heterogeneity and a limited number of studies for these analyses (64). In addition, findings from longitudinal studies that have examined dietary energy density and change in abdominal adiposity measures have not been consistent. A positive association between energy density and change in waist circumference adjusted for BMI was reported in the EPIC cohort (55). Interestingly, another study of the EPIC cohort found a positive association between energy density and annual change in waist circumference among individuals with a BMI <25 kg/m², but not among those who were overweight or obese (BMI ≥25 kg/m²) (63). In contrast, energy density was not associated with change in WHR among individuals with a BMI <25 kg/m² or BMI ≥25 kg/m² in a cohort of French adults (65).

While observational studies do not provide clear evidence of a relationship between dietary energy and overall or abdominal adiposity, the energy density of specific foods or energy from individual macronutrients may be factors. Fats, proteins, and carbohydrates are the macronutrients that provide energy and have been examined for independent associations with adiposity. Dietary fats have the highest energy density of the three macronutrients and provide 9 kcal/g, while dietary proteins and carbohydrates provide 4 kcal/g each. The dietary reference intakes established by the Institute of Medicine for macronutrient intake are acceptable macronutrient distribution ranges of 25 to 35%, 10 to 35%, and 45 to 65% of energy intake from fats, proteins, and carbohydrates, respectively (66).

2.3.1.2 Fats and proteins

A recent Cochrane review examined the relationship between the proportion of energy intake from fats and measures of body fatness in RCTs and cohort studies among individuals who were not aiming to lose weight (67). Specifically, the review examined RCTs comparing diets with less than 30% energy from fat (low-fat) versus diets with greater than 30% energy from fat (usual fat) and the effect on body fatness after at least six months of follow-up. Hooper et al. (67) found that diets with a lower percentage of energy from fat were significantly associated
with lower weight (−1.5 kg; 95% CI: −2.0, −1.1; 24 studies) and lower BMI (−0.5 kg/m²; 95% CI: −0.7, −0.3; 20 studies). Only one RCT examining waist circumference as the outcome was identified in the review and reported a significantly lower waist circumference among women consuming low fat diets compared to usual fat diets (−0.3 cm; 95% CI: −0.06, −0.02) (67).

While evidence from RCTs support an association between lower fat diets and reduced adiposity, evidence from cohort studies do not provide conclusive evidence of a relationship between total fat intake and measures of adiposity over longer periods of time. Hooper et al. (67) identified 39 analyses (14 cohort studies) of the association between baseline total fat intake and changes in body fatness (weight, BMI, or waist circumference) after at least one-year of follow-up in adults. A positive association was reported in 12 of the analyses, while three analyses found an inverse association and the remaining analyses found non-significant or unclear associations (67). The effects of types of dietary fat have also been examined in cohort studies. Ludwig et al. (68) found that neither total fat, saturated fat, nor unsaturated fat intakes were significantly associated with the 10-year change in waist-to-hip ratio among a cohort of young adults in the United States. Among a cohort of adults aged 45 to 60 years, there was no significant association between total fat intake at baseline and change in waist circumference after nine years among males or females (69). However, animal fat and vegetable fat were positively associated with the nine-year change in waist circumference among females only (69).

The comprehensive systematic review by Summerbell et al. (51) identified two studies that examined the relationship between total protein intake and BMI, which did not find a significant association between baseline protein intake and change in BMI (51). The review also identified three cohort studies that assessed the relationship of total protein intake with measures of abdominal adiposity, which did not show consistent findings (51). A few cohort studies have examined the association between baseline protein intake and change in waist circumference among older adults (ranging from age 45 to 69 years) (56, 69, 70). No significant associations were found in a Chinese population (70) and an American population (69) over a four-year and nine-year period, respectively. In contrast, Halkjaer et al. (56) reported a significant inverse association in a Danish population over a five-year period. Studies from the EPIC cohort did not find significant associations between total protein intake and annual change in waist circumference (71) or waist circumference adjusted for BMI (55). Furthermore, neither animal, plant, nor unknown sources of protein were significantly associated with annual change in waist circumference.
circumference in the EPIC cohort (71). Among a population of older adults in the United States, there was no significant association between animal protein and nine-year change in waist circumference (69). However, non-animal protein was positively associated with nine-year change in waist circumference among males, while among women there was an inverse association (69).

2.3.1.3 Carbohydrates

The comprehensive systematic review on diet and obesity identified four cohort studies on the relationship between carbohydrate intake and measures of total adiposity (51). One cohort study among adults in the United States did not find significant associations between total carbohydrate intake or percentage of energy intake from carbohydrates and change in BMI after one year (51). Similarly, two other studies from the United States reported no association between total carbohydrate intake or percentage of energy intake from carbohydrates and change in BMI over 12 and one years, respectively (51). In contrast, a prospective study found that both total carbohydrate intake and percentage of energy intake from carbohydrates were positively correlated with change in body fat (51). However, this study only included females with normal weight and a small sample size as part of an intervention (51).

Table 2.1 presents a summary of four cohort studies which have examined the association between carbohydrate intake and measures of abdominal adiposity, including two studies which were identified in the comprehensive systematic review (51). Three of the cohort studies examined this association among men and women combined (56, 68, 69), but findings were not consistent. Two of these cohort studies did not find a significant association between total carbohydrate intake and measures of abdominal adiposity (56, 68), while another study found that a higher percentage of energy from carbohydrate intake was associated with a decrease in waist circumference over a nine-year period (69). Halkjaer et al. (56) and Lofley and Root (69) found that there was no significant interaction with sex and carbohydrate intake was not associated with change in waist circumference in either sex. Similarly, a study from the EPIC cohort did not find a significant association between the percentage of energy from carbohydrate intake and annual change in waist circumference (55). Interestingly, when sources of carbohydrate intake were considered, significant associations with change in waist circumference were reported among women, but not among men (56). Specifically, carbohydrate intake from refined grain products and potatoes ($\beta = 0.48; 95\% \text{ CI}: 0.18, 0.78$) and products with simple or
added sugars ($\beta = 0.39$; 95% CI: 0.18, 0.60) were positively associated with abdominal adiposity, while carbohydrate intake from fruit and vegetables ($\beta = -0.63$; 95% CI: $-0.87, -0.39$) were inversely associated with abdominal adiposity among women (56). While there is limited evidence to support an association between total carbohydrate intake and abdominal adiposity, the type of carbohydrate may be more relevant in the accumulation of abdominal adipose tissue.

### 2.3.2 Carbohydrate quality

Dietary carbohydrates are an important macronutrient for health because they account for 45 to 70% of energy intake and energy expenditure (72). However, there is considerable diversity among dietary carbohydrates in terms of chemical, physical, and physiological characteristics (73). The site, rate, and extent of digestion and absorption in the gastrointestinal tract play a role in the physiological responses to carbohydrates (72). Carbohydrate digestion in the small intestine and fermentation in the large intestine produce monosaccharides and short chain fatty acids, respectively, for energy metabolism or storage (72). Other physiological characteristics of carbohydrates include effects on satiety, glucose and insulin responses, lipid metabolism, and large bowel function (73). Thus, some of the terminology used to classify carbohydrates are based on physiological and health effects of carbohydrates. Dietary fibre is a class of carbohydrates defined as polysaccharides that are found in the cell walls of fruit, vegetables, and whole-grains, which have positive health effects (73, 74). Likewise, whole grain terminology is used to distinguish carbohydrates based on its importance in healthy dietary recommendations and as a food source of dietary fibre (73). Whole grains are also a source of micronutrients (i.e. vitamin B, vitamin E, iron, and magnesium) and other dietary constituents, which are found in the outer bran and inner germ of the intact grain (75). Furthermore, glycemic carbohydrate is a class of carbohydrates that provides glucose for metabolism, which recognizes the importance of carbohydrates as an energy source for human health (73). Glycemic index (GI) and glycemic load (GL) are measures that are used to classify the effect of carbohydrates on blood glucose concentrations (73). Overall, the health effects of dietary fibre, whole grains, and glycemic carbohydrates reflect carbohydrate quality.

#### 2.3.2.1 Dietary fibre and whole grains

Dietary fibre intake has been hypothesized to have positive effects on weight and adiposity through its ability to lower insulin secretion or increase satiety, which subsequently leads to
greater fat oxidation and reduced fat storage (76). Insulin secretion may be reduced because dietary fibre affects the release of gut hormones, such as cholecystokinin, gastric inhibitory peptide, and glucagon-like peptide-1 (76). Alternatively, fermentation of dietary fibre to short-chain fatty acids in the colon may increase insulin sensitivity and result in lower insulin secretion, as well as affect the secretion of glucagon-like peptide-1 (76). The release of gut hormones is also a potential mechanism through which dietary fibre increases satiety, in addition to delaying gastric emptying due to increased viscosity (76).

2.3.2.1.1 Total adiposity

Although the number of studies is limited, the evidence suggests an inverse association between dietary fibre intake and overall adiposity. Gaesser (77) reviewed epidemiologic studies which compared BMI across quantiles of various carbohydrate exposures, including dietary fibre. The review found that BMI was higher at lower levels of dietary fibre intake. However, not all of the studies identified in the review adjusted for potential confounders. The comprehensive systematic review by Summerbell et al. (51) identified one cohort study which examined measures of total adiposity. This study was from the Nurses’ Health Study (NHS), which found that higher dietary fibre intake was associated with reduced odds of being overweight or obese (51). The effect of whole-grain intake on total adiposity has also been examined, since dietary fibre is found in the cell walls of whole grains. A meta-analysis of studies found that there was an inverse association between whole-grain intake and BMI in individuals aged 13 years and older (78). The analysis of 20 comparisons found that the mean difference in BMI between low or no intake of whole grains versus high intake of whole grains was 0.63 kg/m² (95% CI: 0.46, 0.80) (78).

2.3.2.1.2 Abdominal adiposity

Table 2.2 summarizes observational studies which have examined the relationship between total dietary fibre intake and measures of abdominal adiposity. Two studies from the EPIC cohort found an inverse association between total dietary fibre intake and change in waist circumference or waist circumference adjusted for BMI (55, 79). Cross-sectional studies that have used anthropometric measures of abdominal adiposity have also reported an inverse association for total dietary fibre intake (80, 81). However, McKeown et al. (82) did not find a significant association between total dietary fibre intake and trunk fat mass percentage in a cross-sectional
study of older adults. Interestingly, dietary fibre from cereal was inversely associated with trunk fat mass percentage, but there was no association for dietary fibre from fruits or vegetables in this study population (75). However, the effects of different types of dietary fibre have not been shown consistently in studies. Du et al. (83) found that a 10g/d increase in dietary fibre intake from cereal and fruits and vegetables were associated with −0.10 cm/year (95% CI: −0.18, −0.02) and −0.08 cm/year (95% CI: −0.15, −0.01) change in waist circumference, respectively, in the EPIC cohort. In contrast, a cross-sectional study found that the likelihood of abdominal obesity was reduced with greater intake of dietary fibre from fruits, dried fruits, and nuts, but there was no significant association for cereal, vegetable, or legumes dietary fibre intake (81).

Although the number of studies is limited, the evidence suggests that dietary fibre intake is associated with reduced abdominal adiposity, but the type of dietary fibre may be a factor.

Studies on the effect of whole-grain intake also support the beneficial effects of dietary fibre on abdominal adiposity. A meta-analysis of studies comparing high versus low whole-grain intake found an inverse association with measures of abdominal adiposity (78). The meta-analysis found that the mean difference in waist circumference between low or no intake and high intake of whole grains was 2.7 cm (95% CI: 0.2, 5.2) in six studies (78). Similarly, waist-to-hip ratio was 0.023 units (95% CI: 0.016, 0.030) higher in individuals with low or no intake of whole grains compared to those with high intake in a meta-analysis of four studies (78). A cross-sectional study that examined VAT and SAT volumes as a measure of abdominal adiposity also found an inverse association with whole-grain intake (75). Both VAT and SAT volumes were significantly greater in the lowest quintile of whole-grain intake compared to the highest quintile among adults aged 32 to 83 years (75).

2.3.2.2 Glycemic index and glycemic load

Two concepts that are used to assess the quality of carbohydrates are GI and GL. GI, which is a characteristic of the food, measures the glycemic response produced by 50 g of available carbohydrate in the food relative to the glycemic response produced by 50 g of a reference carbohydrate (i.e. glucose or white bread) (84). GL is the product of the GI of the food and the amount of available carbohydrate in the food, thus measuring both the quality and quantity of carbohydrate (85). The differential glycemic response elicited by high and low GI foods are hypothesized to play a role in adiposity by affecting the level of satiety (86–88). Initial postprandial glucose levels are more highly elevated after the intake of high GI or GL diets in
comparison to low GI or GL diets. In response, the release of insulin is increased, while the release of glucagon is reduced (87, 88). This leads to greater absorption of nutrients and reduction of glucose concentrations in the initial postprandial period. During the two- to five-hour period following the consumption of high GI or GL meals, the rate of nutrient uptake slows, but the hormone levels continue to cause blood glucose concentrations to decrease to hypoglycemic levels (87, 88). The concentration of free fatty acids is also reduced during this period. Thus, there are lower levels of satiety and increased appetite and food intake during this postprandial period in order to restore the balance of these metabolic fuels (87, 88). In contrast, hypoglycemic levels in this postprandial period are not reached after the intake of low GI or GL diets. This is due to slower rates of nutrient absorption in the small intestine, which leads to prolonged stimulation of nutrient receptors and the release of satiety hormones (i.e. cholecystokinin and glucagon-like peptide-1) (87, 88).

2.3.2.2.1 Total adiposity

Literature on the relationship between dietary GI or GL and total adiposity is limited. Gaesser (77) did not find a consistent relationship between GI and BMI in observational studies which compared BMI across quantiles of GI, although not all studies included adjusted for potential confounders. Over one-third of the studies identified in the review did not find a relationship between dietary GI and BMI (77). The review also identified five studies which reported that BMI was higher in increasing quantiles of GI and five studies which found an inverse relationship between GI and BMI (77). Findings from observational studies, which adjusted for a number of potential confounders, are similarly varied. A cohort study among Danish adults found an inverse association between dietary GI and BMI (89), while another cohort study from the United States found a positive association (90). A cross-sectional study conducted in the United Kingdom found that higher dietary GI was associated with an increased likelihood of obesity in men and women, but the association with BMI was not significant (91). Interestingly, Youn et al. (92) found that there was a positive association between GI and obesity among women, but not among men. Other cross-sectional studies have reported positive (91, 93), null (94, 95), and inverse (96) associations between dietary GI and BMI among adults.

For dietary GL, approximately half of the studies identified by Gaesser (77) found that BMI was greater in lower quantiles of GL compared to higher quantiles, while most of the other studies did not find that BMI varied across quantiles of GL. Among studies which adjusted for potential
confounders, an inverse association between dietary GL and BMI among men and women has been reported in cohort (89) and cross-sectional studies (94, 96). Interestingly, Youn et al. (92) found that dietary GL was inversely associated with BMI among men, but positively associated with BMI among women. A positive association has also been reported in a cross-sectional study of adults (93). In contrast, several cross-sectional studies have found no significant associations between dietary GL and measures of total adiposity (91, 95, 97). The varied findings from observational studies do not allow conclusions to be made about dietary GI and dietary GL as determinants of total adiposity.

2.3.2.2.2 Abdominal adiposity

Table 2.3 summarizes observational studies that evaluated the relationship between dietary GI or GL and measures of abdominal adiposity. Findings from three cohort studies did not provide conclusive evidence of an association between dietary GI and abdominal adiposity. Two large studies from the EPIC cohort found that dietary GI was positively associated with annual change in measures of abdominal adiposity (55, 79). In contrast, a smaller study in a Danish cohort did not find a significant association between dietary GI and six-year change in abdominal adiposity (89). Interestingly, there was a significant interaction among GI, sex, and physical activity in the Danish cohort and there was a positive association among sedentary women only (89). The majority of cross-sectional studies did not find significant associations between dietary GI and measures of abdominal adiposity (95, 96, 98–102). Only two cross-sectional studies reported significant associations between dietary GI and abdominal adiposity, where higher dietary GI was associated with increased odds of abdominal obesity (91, 103).

For dietary GL, two of the three cohort studies did not find significant associations with change in abdominal adiposity measures (79, 89). The other study from the EPIC cohort reported a positive association between dietary GL and annual change in abdominal adiposity among women, but not among men (55). Aside from assessing a different measure of abdominal adiposity, the study population was younger (i.e. excluded participants >60 years at baseline or >65 years at follow-up) (55) compared to the other study from the EPIC cohort (79). Findings from cross-sectional studies on GL and abdominal adiposity also varied. Four studies did not report significant associations between dietary GL and measures of abdominal adiposity (95, 96, 98, 100). Interestingly, Rossi et al. (96) noted evidence of a weak inverse association between dietary GL and waist-to-hip ratio among women. In contrast, two studies found inverse
associations between GL and abdominal adiposity among men, while no significant associations were reported for women (102, 103). Only one cross-sectional study found that higher dietary GL was associated with increased odds of abdominal obesity in both women and men (91).

Cohort studies provide important evidence towards understanding whether dietary GI or dietary GL are determinants of abdominal adiposity. However, few cohort studies have examined these associations and are limited to study populations from European countries. A methodological issue that must be considered in epidemiologic studies examining GI and GL is the determination of GI and GL values for foods in studies’ nutrient databases. Since the GI of individual foods needs to be measured, epidemiologic studies have been limited to using GI values available in the literature. All studies which examined abdominal adiposity utilized the International Table of Glycemic Index and Glycemic Load Values (104, 105) as the primary source of GI values. A number of studies supplemented this data with published GI values for foods from specific countries, online sources, or personal communication (55, 79, 95, 101). The available data for GI values are limited because the protocols used to measure the GI of a food are very stringent. In addition, there are a number of factors that can affect the GI of a food, including the preparation method (i.e. cooking or processing) and the variety (106). Thus, while it is not exhaustive, there may be a number of published GI values for a food in the nutrient database (106). The average GI value of a food or similar foods was used in nutrient databases, which may introduce misclassification. Overall, the distribution of dietary GI values was comparable across studies that examined abdominal adiposity, where average dietary GI values ranged from 54 to 59 (glucose reference). However, the potential misclassification of GI values of foods nutrient databases may explain the inconsistent findings among studies.

2.3.3 Dietary patterns

Epidemiologic research on dietary patterns in relation to health outcomes has gained considerable interest because dietary patterns provide a better representation of actual dietary intake and have more useful applications for public health practice (107). Furthermore, examination of dietary patterns considers the effects of combinations of foods and nutrients. This is advantageous because traditional nutrient analysis, which examines individual nutrients, foods, or food groups, does not adequately consider the interactions among dietary factors and individual effects of dietary factors may be too small to detect. The two main approaches for
characterizing overall dietary patterns are *a priori* and *a posteriori* methods (107–110). *A priori* methods involve the creation of scores or indices based on current knowledge about diet, nutrition, and health. These dietary scores and indices usually assess an individual’s adherence to various dietary guidelines and recommendations (107–110). Diet scores and indices that have been used in dietary pattern analysis include the Health Eating Index, Diet Quality Index, Dietary Diversity Score, Mediterranean Diet Score, and Dietary Approaches to Stop Hypertension (DASH) diet score (107–110). In contrast, *a posteriori* approaches use multivariate statistical techniques on the study’s dietary data to derive dietary patterns. The most common statistical methods used to define dietary patterns are principal components analysis (PCA) or factor analysis and cluster analysis. Factor analysis groups food items together based on correlation among dietary variables, while cluster analysis groups individuals into unique dietary patterns based on the variation or mean intakes of clusters (107–110). Both methods for defining dietary patterns provide information on characteristics of an individual’s diet. Thus, examining dietary patterns may provide a valuable perspective for understanding the role of various dietary factors in the accumulation of adipose tissue.

2.3.3.1 Total adiposity

The relationship between dietary patterns and total adiposity has been summarized in several literature reviews. A dietary pattern that has been of interest is the Mediterranean diet due to the positive health profiles observed in Mediterranean countries compared to the United States and other European countries (111). In addition, the Mediterranean diet is characterized by greater dietary fibre and low energy density, which may play a role in adiposity (111). Of the ten observational studies identified in a review by Buckland et al. (111), one cohort study and four cross-sectional studies found that adherence to the Mediterranean diet was inversely associated with total adiposity. Other studies did not find significant associations between adherence to the Mediterranean diet and BMI or weight (111). Another review of observational studies in older adults found that greater adherence to the Mediterranean diet was associated with lower BMI in two out of the three studies identified (112). Findings regarding the effect of the Mediterranean diet on total adiposity are not consistent but suggest a potential beneficial effect on total adiposity. The inconsistent findings may be attributed to the measurement of adherence to the Mediterranean diet, as studies have included different dietary components in the dietary score or index (111).
Reviews of studies on dietary patterns and BMI have also examined dietary patterns derived using a posteriori methods. A review of studies in older adults found that dietary patterns characterized by greater intake of meat and fat were associated with higher BMI in four studies, but this association was not reported in three studies (112). Another review also found inconsistent results among studies using a posteriori defined dietary patterns (113). Among 30 studies identified in the review, eleven studies did not find a significant association between a posteriori dietary patterns and BMI (113). However, a positive association between dietary patterns characterized by higher intake of fats, sweets, and energy dense foods and BMI was reported in 14 studies (113). While there is some evidence of characteristics of diets affecting total adiposity, the heterogeneity of dietary patterns derived using a posteriori methods may have contributed to the inconclusive findings.

2.3.3.2 Abdominal adiposity

Table 2.4 summarizes studies which examined the association between dietary patterns, as characterized using a priori dietary indices and scores, and measures of abdominal adiposity. Specifically, studies which used imaging measures of abdominal adiposity, waist-to-hip ratio, or waist circumference, while adjusting for BMI, were included. Various scores have been developed to assess adherence to the Mediterranean diet and differ by the number of components that constitute the score, as well as the scoring method. Scoring for individual components was based on individual intake versus the median or reference tertile intake in the study population (114–118), frequency of intake (119, 120), and adherence to Mediterranean diet guidelines (121). Over half of the studies, including both cohort studies, found that greater adherence to the Mediterranean diet was associated with decreased abdominal adiposity (114–116, 119, 121). The inverse association was reported in studies from both Mediterranean and non-Mediterranean countries. Interestingly, of the seven countries included in the study from the EPIC cohort, no significant association was found among men and there was a 0.13 cm (95% CI: 0.06, 0.20) increase in waist circumference per unit increase in Mediterranean diet score among women in the Greek cohort (116). Findings from another study conducted in the Greek cohort of the EPIC study were consistent and did not find a significant association between Mediterranean diet score and waist-to-hip ratio (118). Two other studies conducted in Mediterranean countries did not find significant associations between adherence to the Mediterranean diet and waist circumference and waist-to-hip ratio (117, 120). However, Alvarez Leon et al. (120) found that
adherence to the Mediterranean diet was associated with a lower likelihood of abdominal obesity. Recent studies from non-Mediterranean countries in Europe, which did not adjust for BMI, also did not find significant associations between the Mediterranean diet and abdominal obesity (122) and change in waist circumference (123).

Other studies examined *a priori* dietary indices and scores which characterize dietary patterns based on dietary quality. One approach to examining dietary quality is to examine nutrient quantity and quality. Two dietary indices developed based on this approach are the nutrient-rich foods index NRF9.3 model (124) and the dietary phytochemical index (125). Interestingly, the components that contribute to high scores for these indices include food groups characteristic of the Mediterranean diet (124, 125). The NRF9.3 index scores were not associated with WHR; the change in WHR per unit of NRF9.3 was negligible even though the results were statistically significant after further adjusting for underreporting of dietary intake (124). In contrast, a higher phytochemical index score was associated with a smaller percentage change in waist circumference during a three-year period (125). Dietary quality may also be evaluated by assessing the adherence to dietary recommendations and guidelines. Cross-sectional studies with diet scores developed using Finnish nutrition recommendations, the Baltic Sea Diet, or the 2005 Dietary Guidelines for Americans found that greater adherence to these guidelines was associated with lower abdominal adiposity (126–128). Another dietary quality index created based on the American Heart Association guidelines and Mediterranean diet found that dietary quality was inversely associated VAT area (129). Similarly, increased adherence to the American Heart Association dietary guidelines was associated with decreased waist circumference among women in a cross-sectional study of Puerto Rican adults in the United States (130). However, this association was not observed among men (130). Interestingly, a prospective analysis in the same study population did not find significant associations between adherence to the American Heart Association dietary guidelines, Alternate Healthy Eating Index (HEI), HEI, or the DASH recommendations and waist-to-hip ratio at two-year follow up among adults (131). In contrast, a cohort study from the Women’s Health Initiative found that the increased dietary quality, as quantified by the Alternate HEI-2010, HEI-2010, DASH, Alternate Mediterranean Diet recommendations, was associated with smaller changes in waist circumference over a three-year period, even after adjusting for change in weight (BMI was not adjusted for) (132). Likewise, there was a significant inverse association between adherence to
the DASH recommendations and the likelihood of abdominal obesity in a cross-sectional study of Iranian women, where BMI was not included as a potential confounder (133). Greater dietary diversity was also associated with reduced likelihood of abdominal obesity in young Iranian women (134), but no association was found in a study of Iranian men and women (135).

Table 2.5 presents a summary of studies that examined the associations between dietary patterns, characterized using a posteriori methods, and measures of abdominal adiposity (i.e. imaging measures, waist-to-hip ratio, and waist circumference with control for BMI). The majority of studies used principal components or factor analyses to derive dietary patterns. Cluster analysis was another common method used to define dietary patterns, while one study used a combination of both methods and another study used multivariate finite mixture models. Between two and six patterns were derived from dietary data using a posteriori methods. Most studies identified a healthy dietary pattern with components such as increased intake of fruits, vegetables, legumes, whole-grain cereals, and low-fat dairy products. An unhealthy dietary pattern with components including greater intake of sugars, refined-grains, meats, and high-fat foods were also identified in a number of studies. Additionally, some studies identified dietary patterns which reflected traditional ethnic foods (136–141). Overall, there was variation among the findings from these studies. North American studies which identified Western and prudent dietary patterns found that a prudent dietary pattern was associated with lower abdominal adiposity (142, 143) and a Western dietary pattern was marginally significantly associated with increased abdominal adiposity (143). However, the risk of abdominal obesity was not significantly different between individuals with a prudent dietary pattern compared to those with a Western dietary pattern in a cohort study from the United States (144). Among studies which identified three or more dietary patterns, greater adherence to a dietary pattern characterized as healthy was associated with lower abdominal adiposity (137, 141, 145). However, this inverse association was not found consistently among studies which identified a dietary pattern with healthy characteristics, as a number of studies reported no significant associations (136, 139, 146, 147). A recent cross-sectional study in Korean women, which did not adjust for BMI, found that the prudent dietary pattern was associated with a reduced likelihood of elevated waist circumference (i.e. ≥80 cm) (odds ratio = 0.52; 95% CI: 0.41, 0.65), but there was no association for the unhealthy Western dietary pattern (148). Multiple dietary patterns are often characterized by unhealthy foods or food groups in studies with three or more food groups. Interestingly, individuals with an
unhealthy dietary pattern characterized by high fat were less likely to be abdominally obese than individuals with an unhealthy dietary pattern characterized by empty calories (149). Studies have found that adherence to unhealthy dietary patterns was associated with increased abdominal adiposity (136, 139, 140, 145), but no significant associations between unhealthy dietary patterns and abdominal adiposity has also been reported in other studies (136, 137, 141, 147). Similarly, studies have found that individuals with unhealthy dietary patterns had increased abdominal adiposity compared to those with healthy dietary patterns (138, 150), while other studies have found no significant associations (151, 152). It is important to note that studies that identified three or more dietary patterns were not restricted to the identification of healthy and unhealthy dietary patterns. Dietary patterns that included specific foods or food groups only, traditional ethnic foods, or a combination of healthy and unhealthy dietary components were also derived in these studies.

Interpretation of the findings from studies on dietary patterns and abdominal adiposity is complex because there is considerable variability in the dietary patterns defined using a priori or a posteriori methods. A priori dietary indices and scores vary in the components used in the definition, while subjective decisions are involved in a posteriori statistical approaches for defining dietary patterns. However, two overall dietary patterns emerged from studies using a priori or a posteriori methods for defining dietary patterns. These patterns were a healthy pattern of high fruit, vegetable, legume, or whole-grain intake and an unhealthy pattern of high sugars, meats, or other high-fat foods intake. The healthy dietary pattern is also consistent with the foods that characterize the Mediterranean diet. The evidence for the relationships between dietary patterns and abdominal adiposity is not conclusive. However, findings suggest that a healthy dietary pattern and Mediterranean diet are associated with lower abdominal adiposity, while an unhealthy dietary pattern is associated with increased abdominal adiposity.

2.4 Summary and rationale

The WHO has identified obesity as a major public health concern and the strategy identified for reducing obesity includes physical activity and healthy diets. Thus, elucidating dietary factors which play a role in the accumulation of adipose tissue may have important implications for public health practice. To date, the research on the relationship between dietary factors and total and abdominal adiposity is limited and inconclusive. Although studies have not found a
consistent association between total carbohydrate intake and adiposity, there is some evidence to suggest that specific types of carbohydrates may have an effect on abdominal adiposity. Research has shown that whole-grain intake is associated with reduced total and abdominal adiposity, but this inverse association has not been shown consistently for total dietary fibre intake in the limited number of studies. Some studies have shown that the type of dietary fibre, specifically the food source, may be relevant in abdominal adiposity. Furthermore, the literature on dietary patterns has identified healthy and unhealthy patterns which are associated with increased and reduced adiposity, respectively. More interestingly, the foods and food groups in these patterns reflect different types of carbohydrates. Taken together, the emerging evidence suggests that the nature of carbohydrate intake may be an important factor in adiposity and my research was conducted to further understanding in this area.

The majority of studies on dietary factors and adiposity have used anthropometric measures of adiposity, which have limitations. My research utilized dual-energy X-ray absorptiometry (DXA) for direct measures of total and abdominal adiposity, in addition to anthropometric measures, to enhance understanding of the associations with adiposity. In addition, there is some evidence that the effect of dietary intake on abdominal adiposity differs by sex, although this has not been studied extensively. Sex differences are particularly important when examining adiposity because body fat distribution varies between men and women, as well as between premenopausal and postmenopausal women. Furthermore, it is valuable to conduct research in Canadian populations using a dietary assessment tool designed for Canadians due to potential differences in food composition and dietary habits. The work presented here was conducted in postmenopausal Canadian women to address potential varying effects of dietary factors on adiposity in different populations. Therefore, my research aimed to address some of the gaps and limitations of the existing research on dietary factors and adiposity. The findings provide a better understanding of the effects of diet, specifically the nature of carbohydrate intake, on total and abdominal adiposity, which may have implications for future dietary guidelines and recommendations.
2.5 References


118. Trichopoulou A, Naska A, Orfanos P, Trichopoulou D. Mediterranean diet in relation to body mass index and waist-to-hip ratio: the Greek European Prospective Investigation


Table 2.1 Summary of observational studies on total carbohydrate intake and measures of abdominal adiposity

<table>
<thead>
<tr>
<th>Reference</th>
<th>Setting</th>
<th>Participants</th>
<th>Dietary assessment</th>
<th>Abdominal adiposity assessment</th>
<th>Analytic methods</th>
<th>Results</th>
</tr>
</thead>
</table>
| Lofley et al., 2017 | United States (ARIC Study)                   | General population (45–64 y)    | FFQ, interviewer-administered at baseline                                         | Change in WC (cm/9 y)          | Linear regression, Adjustments: change in BMI, age, sex, ethnicity, smoking, physical activity, education, energy intake | ↑ total carbohydrate intake associated with ↓ 9-y change in WC in adults. Association with 9-y change in WC per quartile ↑ in total carbohydrate intake:  
  ▪ Adults: −0.138 cm/9 y (P-trend = 0.046). |
| Romaguera et al., 2010 | Italy, United Kingdom, Netherlands, Germany, Denmark (EPIC-DiOGenes Study) | General population (mean = 49 y) | FFQ (country-specific), self-administered at baseline Carbohydrate intake (% energy, kcal/d): total | Change in WC adjusted for BMI (cm/5 y) | Linear regression, Adjustments: baseline, weight, height, WC adjusted for BMI, age, smoking status, alcohol, physical activity, education, follow-up duration, energy intake, menopausal status, HRT use | ↑ total carbohydrate intake weakly associated with ↓ annual change in WC adjusted for BMI in women, but not in men.  
  Association with annual change in WC adjusted for BMI per 5% energy intake from total carbohydrates:  
  ▪ Women: −0.01 cm/y (95% CI: −0.02, −0.00). |
| Halkjaer et al., 2006 | Denmark (Danish Diet, Cancer and Health Study) | General population (50–64 y)    | FFQ, self-administered at baseline Carbohydrate intake (MJ/d): total, whole-grains, refined-grains, fruit & vegetables, simple & added sugars | Change in WC (cm/5 y)          | Linear regression, Adjustments: baseline WC, BMI, age, smoking, alcohol, alcohol from wine, bear, spirits, physical activity, macronutrients and macronutrient subgroups (mutually adjusted) | No significant association for total carbohydrate intake in women, men, or adults. |
| Ludwig et al., 1999 | United States (CARDIA Study)                 | General population (18–30 y)    | FFQ, interviewer-administered Carbohydrate intake (% energy, kJ/d): total           | WHR                            | Linear regression, Adjustments: baseline WHR, age, sex, smoking, alcohol, physical activity, education, centre, energy intake, vitamin use | No significant associations for total carbohydrate intake in White adults or Black adults. |

Abbreviations: ARIC, Atherosclerosis Risk in Communities; BMI, body mass index; CARDIA, Coronary Artery Risk Development in Young Adults; DHQ, diet history questionnaire; EPIC-DiOGenes, European Prospective Investigation into Cancer and Nutrition–Diet, Obesity, and Genes; FFQ, food frequency questionnaire; HRT, hormone replacement therapy; WC, waist circumference; WHR, waist-to-hip ratio; ↑, higher/increase; ↓, lower/decrease.
Table 2.2  Summary of observational studies on total dietary fibre intake and measures of abdominal adiposity

<table>
<thead>
<tr>
<th>Reference</th>
<th>Setting</th>
<th>Participants</th>
<th>Dietary assessment</th>
<th>Abdominal adiposity assessment</th>
<th>Analytic method</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Du et al., 2010 (83)</td>
<td>Italy, Norfolk, Netherlands, Germany, Denmark (EPIC-DIOGenes)</td>
<td>General population (20–78 y) N = 89,432 (51,870 women; 37,561 men)</td>
<td>FFQ (country-specific), self-administered at baseline Dietary fibre intake (g/d): total, cereal, fruit &amp; vegetable</td>
<td>Change in WC (cm/y)</td>
<td>Linear regression Adjustments: baseline weight, height, WC, age; smoking; alcohol; physical activity; education; follow-up duration; fat, carbohydrate, protein intake; GI; menopausal status; HRT use (analysis of fibre sources: cereal or fruit &amp; vegetable fibre; other fibre)</td>
<td>↑ total dietary fibre intake associated with ↓ annual change in WC in adults. Association with annual change in WC per 10 g/d ↑ in total dietary fibre intake: ▪ Adults: −0.08 cm/y (95% CI: −0.11, −0.05).</td>
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<tr>
<td>Romaguera et al., 2010 (55)</td>
<td>Italy, United Kingdom, Netherlands, Germany, Denmark (EPIC-DIOGenes)</td>
<td>General population (mean = 49 y) N = 48,631 (28,937 women; 19,694 men)</td>
<td>FFQ (country-specific), self-administered at baseline Dietary fibre intake (g/d): total</td>
<td>Change in WC adjusted for BMI (cm/y)</td>
<td>Linear regression Adjustments: baseline, weight, height, WC adjusted for BMI, age; smoking; alcohol; physical activity; education; follow-up duration; energy intake; menopausal status; HRT use</td>
<td>↑ total dietary fibre intake associated with ↓ annual change in WC adjusted for BMI in women; but not in men. Association with annual change in WC adjusted for BMI per 10 g/d ↑ in total dietary fibre intake: ▪ Women: −0.06 cm/y (95% CI: −0.08, −0.03).</td>
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<tr>
<td>Reference</td>
<td>Setting</td>
<td>Participants</td>
<td>Dietary assessment</td>
<td>Abdominal adiposity assessment</td>
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<tr>
<td>Cross-sectional studies</td>
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<tr>
<td>McKeown et al., 2009 (82)</td>
<td>United States (Framingham Heart Study</td>
<td>General population (60–80 y) N = 434</td>
<td>FFQ, self-administered Dietary fibre intake (g/d; quartiles): total, cereal, fruit, vegetable</td>
<td>% trunk fat mass (DXA)</td>
<td>General linear model Adjustments: age; sex; smoking; alcohol; physical activity; energy intake; fat intake; multivitamin use</td>
<td>No significant association for total fibre intake in adults.</td>
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<tr>
<td></td>
<td>MDCT Study)</td>
<td>(257 women; 177 men)</td>
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<td></td>
<td>Italy (Italian Bollate Eye Study)</td>
<td>General population (40–74 y) N = 1,415</td>
<td>FFQ Dietary fibre intake (g/d; categorical: &lt;25, 25–45, &gt;45): total</td>
<td>WC (cm)</td>
<td>Analysis of co-variance Adjustments: height; BMI; HC; truncal subcutaneous fat; age; energy intake</td>
<td>↑ total dietary fibre intake associated with ↓ WC in women, but not in men. % difference in WC vs. &lt;25 g/d of dietary fibre intake in women: • 25–45 g/d: −17.3% (P &lt; 0.05); • &gt;45 g/d: −26.7% (P &lt; 0.01).</td>
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<tr>
<td>Leite et al., 2006 (80)</td>
<td></td>
<td>General population (35–60 y) N = 5,961</td>
<td>Electronic 24-hour dietary recalls Dietary fibre intake (g/d, quintiles): total, non-soluble, soluble, cereal, vegetables, legumes, fruit, dried fruit, nuts and seeds</td>
<td>WHR (binary: ≥0.80 for women; ≥0.95 for men)</td>
<td>Linear regression Adjustments: age; sex; smoking; alcohol; physical activity; energy intake (alcohol-free); saturated fatty acid intake; carbohydrate intake; intervention supplement use</td>
<td>↑ total dietary fibre intake associated with ↓ odds of elevated WHR in adults. OR for elevated WHR for quintile 5 vs. 1 of total dietary fibre intake: • Adults: 0.57 (95% CI: 0.43, 0.74; P-trend &lt; 0.0001).</td>
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<tr>
<td>Lairon et al., 2005 (81)</td>
<td>France (SU.VI.MAX Study)</td>
<td>General population (35–60 y) N = 5,961</td>
<td>Electronic 24-hour dietary recalls Dietary fibre intake (g/d, quintiles): total, non-soluble, soluble, cereal, vegetables, legumes, fruit, dried fruit, nuts and seeds</td>
<td>WHR (binary: ≥0.80 for women; ≥0.95 for men)</td>
<td>Linear regression Adjustments: age; sex; smoking; alcohol; physical activity; energy intake (alcohol-free); saturated fatty acid intake; carbohydrate intake; intervention supplement use</td>
<td>↑ total dietary fibre intake associated with ↓ odds of elevated WHR in adults. OR for elevated WHR for quintile 5 vs. 1 of total dietary fibre intake: • Adults: 0.57 (95% CI: 0.43, 0.74; P-trend &lt; 0.0001).</td>
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Abbreviations: BMI, body mass index; CI, confidence interval; DXA, dual-energy X-ray absorptiometry; EPIC-DiOGenes, European Prospective Investigation into Cancer and Nutrition–Diet, Obesity, and Genes; FFQ, food frequency questionnaire; GI, glycemic index; HC, hip circumference HRT, hormone replacement therapy; MDCT, multidetector-computed tomography; SU.VI.MAX, Supplementation en Vitamines et Mineraux Antioxydants; OR, odds ratio; WC, waist circumference; WHR, waist-to-hip ratio; ↑, higher/increase; ↓, lower/decrease.
Table 2.3  Summary of observational studies on dietary glycemic index and glycemic load and measures of abdominal adiposity

<table>
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<th>Dietary assessment</th>
<th>Abdominal adiposity assessment</th>
<th>Analytic method</th>
<th>Results</th>
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<td><strong>Cohort studies</strong></td>
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</table>
| Romaguera et al., 2010 (55)      | Italy, United Kingdom, Netherlands, Germany, Denmark (EPIC-DiOGenes) | General population (mean = 49 y) \( N = 48,631 \) (28,937 women; 19,694 men) | FFQ (country-specific), self administered Dietary GI & GL (continuous) | Change in WC adjusted for BMI (cm/year) | Linear regression Adjustments: baseline, weight, height, WC adjusted for BMI, age; smoking; alcohol; physical activity; education; follow-up duration; fibre, fat, protein intake; carbohydrate intake (GI only); energy intake (GL only); menopausal status; HRT use | \( \uparrow \) GI associated with \( \uparrow \) annual change in WC adjusted for BMI in women and men. Association with annual change in WC adjusted for BMI per 10-unit \( \uparrow \) in GI:  
  - Women: 0.06 cm/y (95% CI: 0.03, 0.10);  
  - Men: 0.07 cm/y (95% CI: 0.03, 0.12). |
| Du et al., 2009 (79)             | Italy, United Kingdom, Netherlands, Germany, Denmark (EPIC-DiOGenes) | General population (20–78 y) \( N = 89,432 \) (52,307 women; 37,125 men) | FFQ (country-specific), self-administered Dietary GI & GL (continuous) | Change in WC (cm/year) | Linear regression (with random effects meta-analysis) Adjustments: baseline, weight, height, WC, age; smoking; alcohol; physical activity; education; follow-up duration; fibre, protein intake; energy intake; menopausal status; HRT use | \( \uparrow \) GI associated with \( \uparrow \) annual change in WC in adults. Association with annual change in WC per 10-unit \( \uparrow \) in GI:  
  - Adults: 0.19 cm/y (95% CI: 0.11, 0.27). No significant association for GI in adults. |
| Hare-Bruun et al., 2006 (89)     | Denmark (MONICA Project)                     | General population (mean = 49 y) \( N = 376 \) (191 women; 185 men) | Diet history questionnaire, interviewer-administered Dietary GI & GL (continuous) | Change in WC (cm/6 y) | Linear regression Adjustments: baseline WC, HC, weight, age; smoking; physical activity; education; follow-up duration; fibre, protein, fibre intake; energy intake | No significant associations for GI in women or men. No significant associations for GL in women or men. |

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<th>Reference</th>
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<th>Dietary assessment</th>
<th>Abdominal adiposity assessment</th>
<th>Analytic method</th>
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<td>Cross-sectional studies</td>
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<tr>
<td>Castro-Quezada et al., 2015</td>
<td>Spain</td>
<td>General population (60–74 y)</td>
<td>FFQ, interviewer-administered Dietary GI &amp; GL, energy-adjusted (continuous)</td>
<td>WC (cm)</td>
<td>Linear regression</td>
<td>No significant association for GI in adults.</td>
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<td></td>
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<td>N = 351 (215 women; 128 men)</td>
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<td>Murakami et al., 2013</td>
<td>United Kingdom</td>
<td>General population (19–64 y)</td>
<td>7-day dietary records (weighed) Dietary GI &amp; GL, energy-adjusted (continuous)</td>
<td>WC (binary: ≥88 cm for women; ≥102 cm for men)</td>
<td>Logistic regression</td>
<td>↑ GI associated with ↑ odds of elevated WC in women and men.</td>
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<td></td>
<td>(National Diet and Nutrition Survey)</td>
<td>N = 1,487 (809 women; 678 men)</td>
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<td>OR for elevated WC per 10-unit ↑ in GI:</td>
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<tr>
<td>Finley et al., 2010</td>
<td>United States</td>
<td>Healthy population (20–79 y)</td>
<td>3-day dietary record Dietary GI &amp; GL, energy-adjusted (quintiles)</td>
<td>WC (binary: ≥88 cm for women; ≥102 cm for men)</td>
<td>Logistic regression</td>
<td>↑ GI associated with ↑ odds of elevated WC in women and men.</td>
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<tr>
<td></td>
<td>(Cooper Center Longitudinal Study)</td>
<td>N = 10,912 (1,775 women; 9,137 men)</td>
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<td>OR for elevated WC per 50-unit ↑ in GL:</td>
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<td></td>
<td>▪ Women: 2.29 (95% CI: 1.42, 3.69);</td>
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<td>▪ Men: 2.30 (95% CI: 1.30, 4.05).</td>
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<td>▪ GL associated with ↑ odds of elevated WC in men, but not in women.</td>
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<td>OR for elevated WC for quintile 5 vs. 1 of GI:</td>
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<td>▪ Women: 1.74 (95% CI: 1.04, 2.89);</td>
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<td>▪ Men: 1.27 (95% CI: 1.07, 1.51).</td>
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<th>Abdominal adiposity assessment</th>
<th>Analytic method</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rossi et al., 2010 (96)</td>
<td>Italy</td>
<td>Patients in hospital for acute conditions (18–82 y) 7,724 (4,242 women; 3,482 men)</td>
<td>FFQ, interviewer-administered Dietary GI &amp; GL (tertile)</td>
<td>WHR</td>
<td>Linear regression Adjustments: age; alcohol; smoking; physical activity; study centre; education; energy intake (non-carbohydrate and alcohol); fibre intake</td>
<td>No significant associations for GI in women or men. No significant associations for GL in women or men.</td>
</tr>
<tr>
<td>McKeown et al., 2009 (99)</td>
<td>United States (Framingham Offspring Cohort)</td>
<td>General population (32–83 y) 2,941 (1,603 women; 1,338 men)</td>
<td>FFQ, self-administered Dietary GI &amp; GL, energy-adjusted (continuous)</td>
<td>WC (cm)</td>
<td>Generalized linear model Adjustments: BMI; age; sex; smoking; physical activity; alcohol; energy intake; multivitamin use; hypertension treatment; fat, fibre intake</td>
<td>No significant association for GI in adults. N/A</td>
</tr>
<tr>
<td>Kim et al., 2008 (100)</td>
<td>South Korea</td>
<td>Healthy population (≥20 y) 910 (570 women; 340 men)</td>
<td>FFQ, interviewer-administered Dietary GI &amp; GL (continuous; quintiles)</td>
<td>WC (binary: ≥80 cm for women; ≥90 cm for men)</td>
<td>Logistic regression Adjustments: BMI; age; smoking; alcohol; physical activity; education; family history of disease; energy intake; fibre</td>
<td>No significant associations for GI in women or men. No significant associations for GL in women or men.</td>
</tr>
<tr>
<td>Milton et al., 2007 (101)</td>
<td>United Kingdom (National Diet and Nutrition Survey)</td>
<td>General population (≥65 y) 1,153 (571 women; 582 men)</td>
<td>4-day dietary records (weighed) Dietary GI (continuous)</td>
<td>WHR</td>
<td>Linear regression Adjustments: age; social class; region; physical activity; energy intake</td>
<td>No significant associations for GI in women, men, or adults. N/A</td>
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<tr>
<th>Reference</th>
<th>Setting</th>
<th>Participants</th>
<th>Dietary assessment</th>
<th>Abdominal adiposity assessment</th>
<th>Analytic method</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liese et al., 2005 (95)</td>
<td>United States (IRAS)</td>
<td>Population with normal/impaired glucose tolerance (40–69 y) N = 1,087 (598 women; 489 men)</td>
<td>FFQ, interviewer-administered Dietary GI &amp; GL (continuous)</td>
<td>WC (cm)</td>
<td>Linear regression Adjustments: age; sex; ethnicity; smoking; family history of diabetes; energy expenditure; energy intake (non-carbohydrate)</td>
<td>No significant association for GI in adults. No significant association for GL in adults.</td>
</tr>
<tr>
<td>Sahyoun et al., 2005 (102)</td>
<td>United States (Health, ABC Study)</td>
<td>General population (70–80 y) N = 2,248 (1,169 women; 1,079 men)</td>
<td>FFQ, interviewer-administered Dietary GI &amp; GL, energy-adjusted (quintiles)</td>
<td>VAT area (CT)</td>
<td>Generalized linear model Adjustments: baseline VAT area; BMI; age; ethnicity; alcohol; smoking; physical activity; education;</td>
<td>No significant associations for GI in men or women. ↑ GL associated with ↓ VAT area in men, but not in women. Mean VAT area for quintile 5 vs. 1 of GL: • Men: 144.5 ± 3.6 cm² vs. 157.2 ± 3.8 cm² (P-trend = 0.02).</td>
</tr>
</tbody>
</table>

Abbreviations: ABC, Aging and Body Composition; BMI, body mass index; CI, confidence interval; CT, computed tomography; EPIC-DiOGenes, European Prospective Investigation into Cancer and Nutrition–Diet, Obesity, and Genes; FFQ, food frequency questionnaire; GI, glycemic index; GL, glycemic load; HC, hip circumference; IRAS, Insulin Resistance Atherosclerosis Study; MONICA, Monitoring Trends and Determinants in Cardiovascular Disease; OR, odds ratio; VAT, visceral adipose tissue; WC, waist circumference; WHR, waist-to-hip ratio; ↑, higher/increase; ↓, lower/decrease.
Table 2.4  Summary of observational studies on *a priori* dietary indices and scores and measures of abdominal adiposity

<table>
<thead>
<tr>
<th>Reference</th>
<th>Setting</th>
<th>Participants</th>
<th>Dietary assessment &amp; dietary index or score</th>
<th>Abdominal adiposity assessment</th>
<th>Analytic methods</th>
<th>Results</th>
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<tr>
<td>Mediterranean diet scores</td>
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<td>Cohort studies</td>
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<tr>
<td>Funtikova et al., 2014 (114)</td>
<td>Spain</td>
<td>General population (25–74 y)</td>
<td>166-item FFQ, interviewer-administered REGICOR-MDS MDS (Spanish recommendations) 10 components: cereals, fruits, vegetables, legumes, fish, olive oil, nuts, meat, dairy products, red wine</td>
<td>Change in WC (cm/10 y)</td>
<td>Linear regression</td>
<td>↑ adherence to Mediterranean diet was associated with ↓ WC in adults. Association with 10-y change in WC per 10-unit ↑ in score in adults: • REGICOR-MDS: −1.65 cm (95% CI: −2.84, −0.45); • MDS: −1.49 cm (95% CI: −2.85, −0.13).</td>
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<td></td>
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<td>N = 1,879 (970 women; 909 men)</td>
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<td>Rumawas et al., 2009 (121)</td>
<td>United States (Framingham Heart Study Offspring Cohort)</td>
<td>General population, non-diabetic (mean = 54 y)</td>
<td>126-item FFQ, self-administered Mediterranean-style dietary pattern score (range: 0–100) 12 components: whole-grain cereals, fruits, vegetables, olives/nuts/legumes, fish, olive oil, dairy, wine, potatoes, eggs, sweets, meats</td>
<td>WC (cm)</td>
<td>Analysis of covariance</td>
<td>↑ adherence to Mediterranean diet was associated with ↓ WC in adults. Least-squares geometric mean WC for quintile 1 vs. 5 of score: • Adults: 98.9 cm (95% CI: 98.4, 99.4) vs. 97.1 (95% CI: 96.7, 97.6); (P-trend &lt; 0.001).</td>
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<tr>
<td></td>
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<td>N = 2,621</td>
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<td>Cross-sectional studies</td>
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| Boghossian et al., 2013 (115) | United States (BioCycle Study) | General population, premenopausal women (18–44 y) \(N = 248\) | 24-hour dietary recalls (average of up to 8 recalls) Alternate-MDS (range: 0–9) 10 components: whole-grains, fruits, vegetables (no potatoes), legumes, fish, nuts, MUFA:SFA, red/processed meat, red wine | % trunk fat (DXA) WHR | Linear regression Adjustments: age; ethnicity; physical activity; education; energy intake | ↑ adherence to Mediterranean diet was associated with ↓ percent trunk fat and WHR in adults. Association with abdominal adiposity per 1-unit ↑ in score in adults:  
- % trunk fat: −0.85% (95% CI: −1.39, −0.32);  
- WHR: −0.003 units (95% CI: −0.007, 0.001). |
| Romaguera et al., 2009 (116) | Greece, Italy, Spain, France, Germany, Denmark, Norway, Sweden, Netherlands, United Kingdom (EPIC-PANACEA Study) | General population, healthy (25–70 y) \(N = 497,308\) (351,730 women; 145,578 men) | 88- to 266-item FFQ (country-specific), self-administered Mediterranean-style dietary pattern score (range: 0–100) 10 components: cereal, fruits, vegetables, legumes, fish/seafood, nuts, MUFA+PUFA: SFA, dairy products, meat/meat products | WC | Multilevel mixed-effects linear regression Adjustments: BMI; height; age; sex; smoking; physical activity; energy intake; energy misreporting; menopausal status; study centre | ↑ adherence to Mediterranean diet was associated with ↓ WC in women and men.  
Association with WC per 1-unit ↑ in score:  
- Women: −0.06 cm (95% CI: −0.10, −0.01);  
- Men: − 0.09 cm (95% CI: −0.14, −0.04). |
| Rossi et al., 2008 (117) | Italy                                         | Hospital control patients admitted for acute conditions (median = 58 y) \(N = 5,234\) (2,834 women; 2,400 men) | 78-item FFQ, interviewer-administered MDS (range: 0–8) 8 components: cereal, fruit, vegetables, legumes, alcohol, MUFA:SFA, milk/dairy products, meat/meat products | WHR | Linear regression Adjustments: age; sex; energy intake; smoking; physical activity; education; study centre | No association between adherence to Mediterranean diet and WHR in adults. |

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Table 2.4 Continued

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<tr>
<th>Reference</th>
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<tbody>
<tr>
<td>Alvarez Leon et al., 2006 (120)</td>
<td>Canary Islands (Canarian Nutrition Survey)</td>
<td>General population (≥18 y) N = 578 (329 women, 249 men)</td>
<td>81-item FFQ Mediterranean score (range: 10–30) 10 components: cereal, fruit, vegetables, legumes, fish, nuts, MUFA:SFA, alcohol from red wine, whole-fat dairy products, red meat/derivatives</td>
<td>WC (&gt;88 cm women; &gt;102 cm men)</td>
<td>Logistic regression Adjustments: age; sex; energy intake; smoking; physical activity; education; BMI; diet in the past 12 months</td>
<td>No association between adherence to Mediterranean diet and WC in adults.</td>
</tr>
<tr>
<td>Panagiotakos et al., 2006 (119)</td>
<td>Greece (ATTICA study)</td>
<td>General population (mean = 46 y) N = 3,042 (1,514 women; 1,528 men)</td>
<td>156-item FFQ, self-administered MDS (range: 0–55) 16 components: non-refined cereals/products, fruits, vegetables, olive oil, non-/low-fat dairy products, fish, poultry, potatoes, olives, pulses, nuts, eggs, sweets, red meat/meat products, wine, MUFA:SFA</td>
<td>WHR Linear and logistic regression Adjustments: age; sex; smoking; physical activity; education; income; blood pressure; cholesterol; triacylglycerols; glucose</td>
<td>↑ adherence to Mediterranean diet was associated with ↓ WHR in adults. Association with WHR per 1-unit ↑ in score: ▪ Adults: 0.048 units (P = 0.006).</td>
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<tr>
<td>Trichopolou et al., 2005 (118)</td>
<td>Greece (Greek EPIC study)</td>
<td>General population (20–86 y) N = 23,597 (9,612 women; 13,985 men)</td>
<td>150-item FFQ, interviewer-administered MDS (range: 0–10) 10 components: cereal, fruit, vegetables, legumes, fish, nuts, alcohol, MUFA:SFA, dairy products, meat/meat products</td>
<td>WHR Linear regression Adjustments: age; sex; energy intake; smoking; physical activity; BMI</td>
<td>↑ adherence to Mediterranean diet was associated with ↑ WHR in women, but not in men. Association with WHR per 2-unit ↑ in score: ▪ Women: 0.004 units (95% CI: 0.003, 0.006).</td>
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<tbody>
<tr>
<td>Mattei et al., 2017 (131)</td>
<td>United States (Boston Puerto Rican Health Study)</td>
<td>General population (45–75 y) N = 1,194</td>
<td>FFQ, self-administered Alternative HEI (range: 0–110): 11 food groups or nutrients HEI (range: 0–100): 12 components AHA diet score (range: 0–90): 11 components DASH score (range: 8–40): 8 foods and nutrients</td>
<td>WHR at 2-y</td>
<td>Repeated-subjects; linear mixed-effects model Adjustments: baseline WC; age; sex; smoking; physical activity; education; income:poverty; marital status; energy intake; frequency of foods away from home; acculturation; CVD; diabetes; hypertension; time</td>
<td>No associations between adherence to the Alternative HEI, HEI, AHA diet score, or DASH score and WHR in adults.</td>
</tr>
<tr>
<td>Mirmiran et al., 2012 (125)</td>
<td>Iran (Tehran Lipid and Glucose Study)</td>
<td>General population (19–70 y) N = 1,938</td>
<td>168-item FFQ, interviewer-administered Dietary phytochemical index 6 components (phytochemical-rich foods): fruits/vegetables (no potatoes), soy products, olives/olive oil, legumes, whole grains, nuts</td>
<td>Change in WC (cm/3 y)</td>
<td>Linear regression Adjustments: age; sex; BMI; smoking; physical activity; education; energy intake; carbohydrate, protein, fat intake</td>
<td>Adherence to dietary phytochemical index was associated with ↑ 3-y change in WC in adults. Association with 3-y change in WC for quartile 4 vs. 1 of index: Adults: −0.05 cm/3 y (95% CI: −1.15, 1.06); (P-trend = 0.001).</td>
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<td>Cross-sectional studies</td>
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<tr>
<td>Shah et al., 2016 (129)</td>
<td>United States (MESA)</td>
<td>General population, no CVD at baseline (mean = 61 y) N = 1,511</td>
<td>127-item FFQ DietQuality score 11 components: fruits, vegetables (no potatoes), whole grains, nuts, legumes, fish, PUFA+MUFA:SFA, red/processed meat, sugar-sweetened beverages, alcohol, yogurt</td>
<td>VAT area (cm²/m)</td>
<td>General linear model Linear regression Adjustments: weight; age; sex; ethnicity; smoking; energy intake; systolic blood pressure; fasting blood glucose; total cholesterol; total intentional exercise</td>
<td>↑ adherence to DietQuality score was associated with ↓ VAT area in adults. Least-squares mean VAT area for quartile 4 vs. 1 of score: ▪ Adults: 460.5 cm²/m (95% CI: 439.8, 482.2) vs. 523.6 cm²/m (95% CI: 498.6, 549.8); (P &lt; 0.01). Association with VAT area per 1-unit ↑ in DietQuality score: ▪ Adults: 0.009 cm²/m (P &lt; 0.01).</td>
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<tr>
<td>Kanerva et al., 2013a (126)</td>
<td>Finland (DILGOM Study)</td>
<td>General population (25–74 y) N = 4,720 (2,530 women; 2,190 men)</td>
<td>131-item FFQ Recommended Finnish Diet Score (range: 0–24) 8 components: fruits, vegetables, white:red/processed meat, rye, PUFA:SFA+trans fats, salt, sucrose, alcohol</td>
<td>WC (≥90 cm women; ≥100 cm men)</td>
<td>Logistic regression Adjustments: age; sex; energy intake; physical activity; smoking; education; energy misreporting; BMI</td>
<td>↑ adherence to Finnish nutrition recommendations was associated with ↓ odds of elevated WC in men, but not in women. OR for elevated WC for quintile 5 vs. 1 of score: ▪ Men: 0.42 (95% CI: 0.25, 0.75; P-trend &lt; 0.01).</td>
</tr>
<tr>
<td>Kanerva et al., 2013b (127)</td>
<td>Finland (DILGOM Study)</td>
<td>General population (25–74 y) N = 4,720 (2,530 women; 2,190 men)</td>
<td>131-item FFQ Baltic Sea Diet Score (range: 0–25) 8 components (Baltic Sea Diet Pyramid): fruits, vegetables, cereals, low-fat milk, fish, meat products, alcohol, PUFA:SFA+trans fats</td>
<td>WC (≥90 cm women; ≥100 cm men)</td>
<td>Logistic regression Adjustments: BMI; age; physical activity; energy intake</td>
<td>↑ adherence to Baltic Sea Diet Pyramid was associated with ↓ WC in men, but not in women. OR for elevated WC for quintile 5 vs. 1 of score: ▪ Men: 0.48 (95% CI: 0.29, 0.80; P-trend = 0.007).</td>
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<tbody>
<tr>
<td>Mattei et al., 2013 (130)</td>
<td>United States (Boston Puerto Rican Heart Study)</td>
<td>General population (45–74 y) N = 1,318</td>
<td>AHA diet score (range: 0–90) 11 components: fruits/vegetables intake, fruits/vegetables variety, whole grains, fish, saturated fats, trans fat, total fat, dietary cholesterol, added sugars, sodium, alcohol</td>
<td>WC</td>
<td>Linear regression</td>
<td>↑ adherence to AHA dietary recommendations was associated with ↓ WC in women, but not in men. Association with WC per 10-unit ↑ in AHA diet score: Women: −0.883 ± 0.296 cm (P = 0.003).</td>
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<tr>
<td>Nicklas et al., 2012 (128)</td>
<td>United States (NHANES)</td>
<td>General population (≥19 y) N = 18,988</td>
<td>24-hour dietary recall HEI-2005 (range: 0–100) 12 components from 2005 Dietary Guidelines for Americans</td>
<td>WC</td>
<td>Linear and logistic regression</td>
<td>↑ adherence to HEI-2005 was associated with ↓ WC in men, but not in women. Least-squares mean WC for quartile 4 vs. 1 of score: Adults: 95.0 ± 0.31 cm vs. 98.7 ± 0.42 cm (P-trend &lt; 0.001).</td>
</tr>
<tr>
<td>Streppel et al., 2012 (124)</td>
<td>Netherlands (Rotterdam study)</td>
<td>General population (≥55 y) N = 4,969</td>
<td>170-item FFQ, self-administered + interview Nutrient-rich foods index NRF9.3 model (range: 4.7–107.1) 12 components: beneficial nutrients – protein, fibre, vitamin A, vitamin C, vitamin E, calcium, magnesium, iron, potassium; limiting nutrients – saturated fat, total sugar, sodium</td>
<td>WHR</td>
<td>Linear regression</td>
<td>No association between nutrient-rich foods index and WHR in adults.</td>
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<tr>
<td>Reference</td>
<td>Setting</td>
<td>Participants</td>
<td>Dietary assessment &amp; dietary index or score</td>
<td>Abdominal adiposity assessment</td>
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<tr>
<td>Azadbakht et al., 2011 (134)</td>
<td>Iran</td>
<td>University students; women (18–28 y) N = 289</td>
<td>168-item FFQ, interviewer-administered Dietary diversity score (range: 0–10) 5 components (USDA Food Guide Pyramid): bread-grain, fruit, vegetables, meat, dairy</td>
<td>WC (&gt;88 cm)</td>
<td>Logistic regression Adjustments: age; physical activity; total energy intake; BMI</td>
<td>↑ adherence to dietary diversity score was associated with ↓ odds of elevated WC in women. OR for elevated WC for quartile 4 vs. 1 of score: ▪ Women: 0.28 (95% CI: 0.11, 1.12; P-trend = 0.04).</td>
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<tr>
<td>Azadbakht et al., 2005 (135)</td>
<td>Iran (Tehran Lipid and Glucose study)</td>
<td>General population, no CVD, stroke, or diabetes (18–74 y) N = 581 (286 women; 295 men)</td>
<td>168-item FFQ, interviewer-administered Dietary diversity score (range: 0–10) 5 components (USDA Food Guide Pyramid): bread-grain, fruit, vegetables, meat, dairy</td>
<td>WC (&gt;88 cm women; &gt;102 cm men)</td>
<td>Logistic regression Adjustments: age; physical activity; energy intake; fat intake; blood pressure medication; BMI; estrogen replacement therapy</td>
<td>No association between dietary diversity score and WC and abdominal obesity in adults.</td>
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</table>

Abbreviations: AHA, American Heart Association; BMI, body mass index; CVD, cardiovascular disease; DASH, Dietary Approaches to Stop Hypertension; DHQ, diet history questionnaire; DILGOM, Dietary, Lifestyle, and Genetic determinants of Obesity and Metabolic syndrome; DXA, dual-energy X-ray absorptiometry; EPIC, European Prospective Investigation into Cancer and Nutrition; EPIC-PANACEA, EPIC—Physical Activity, Nutrition, Alcohol, Cessation of smoking and Eating out of home in relation to Anthropometry; FFQ, food frequency questionnaire; HEI, Healthy Eating Index; MDS, Mediterranean diet score; MESA, Multi-Ethnic Study of Atherosclerosis; MUFA, monounsaturated fatty acid; NHANES, National Health and Nutrition Examination Study; PUFA, polyunsaturated fatty acid; REGICOR, Registre Gironi del COR; SFA, saturated fatty acid; OR, odds ratio; USDA, United States Department of Agriculture; VAT, visceral adipose tissue; WC, waist circumference; WHR, waist-to-hip ratio; ↑, higher/increase; ↓, lower/decrease.
### Table 2.5  Summary of observational studies on dietary derived using *a posteriori* methods and measures of abdominal adiposity

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<th>Reference</th>
<th>Setting</th>
<th>Participants</th>
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<tr>
<td>North &amp; South America</td>
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<td>Adherence to Higher Fat and Wine &amp; Moderate Eating patterns were associated with ↓ odds of elevated WC vs. Empty Calorie pattern in adults.</td>
</tr>
</tbody>
</table>
| Cohort studies             |                                              |                                                                                                |                                                                                                           |                               |                                                                                                      | OR for elevated WC vs. Empty Calorie pattern in adults:  
  * Higher Fat: 0.52 (95% CI: 0.27, 1.00);  
  * Wine & Moderate Eating: 0.34 (95% CI: 0.13, 0.89).                                                                                     |
| Kimokoti et al., 2012      | United States (Framingham Heart Study Offspring-Spouse Cohort) | General population, no CVD, diabetes, cancer, or metabolic syndrome; women (25–77 y)  
  * N = 1,146                                                                 | 145-item FFQ, self-administered Cluster analysis (42 nutrient-based groups; frequency of intake)  
  Dietary patterns: (1) Heart Healthier, (2) Lighter Eating, (3) Wine & Moderate Eating, (4) Higher Fat, (5) Empty Calorie | WC (≥88 cm)  
  * Adjustments: baseline BMI, WC, age; smoking; physical activity; energy intake; menopausal status | Logistic regression                                                                                                  | Adherence to Higher Fat and Wine & Moderate Eating patterns were associated with ↓ odds of elevated WC vs. Empty Calorie pattern in adults.                                                                 |
| Duffey et al., 2012        | United States (CARDIA Study)                 | General population (18–30 y)  
  * N = 3,524  
    * 2,220 women; 1,304 men                                                                 | DHQ, interviewer-administered at baseline Cluster analysis (42 food groups; frequency of intake)  
  Dietary patterns: (1) Western, (2) Prudent | WC (>80 cm women; >102 cm men)  
  * Adjustments: BMI; age; sex; smoking; physical activity; education; energy intake; family structure; study centre | Proportional hazards regression                                                                                     | No associations between dietary patterns and elevated WC (Prudent vs. Western dietary patterns) in adults.                                                                                           |

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<tbody>
<tr>
<td>Machado et al., 2016 (136)</td>
<td>Brazil (Ribeirao Preto birth cohort)</td>
<td>General population (23–35 y) N = 2,034</td>
<td>75-item FFQ, interviewer-administered Principal components analysis (48 food groups) Dietary patterns: (1) Healthy, (2) Traditional Brazilian, (3) Bar, (4) Energy Dense</td>
<td>WHR (&gt;0.85 women; &gt;0.90 men)</td>
<td>Poisson regression Adjustments: skin colour; education; income; marital status; smoking; physical activity; energy intake; other dietary patterns</td>
<td>↑ adherence to Bar pattern was associated with ↑ likelihood of elevated WHR in adults. PR for elevated WHR for quartile 4 vs. 1 of pattern in adults: • Bar: 2.19 (95% CI: 1.59, 3.01).</td>
</tr>
<tr>
<td>Anderson et al., 2010 (152)</td>
<td>United States (Health, ABC Study)</td>
<td>Whites and Blacks, no cancer or difficulty with daily activities (70–79 y) N = 1,809 (978 women; 831 men)</td>
<td>108-item FFQ, interviewer-administered Cluster analysis (40 food groups; percent energy from food groups) Dietary patterns: (1) Meat, Snacks, Fats &amp; Alcohol, (2) Sweets &amp; Desserts, (3) Refined-Grains, (4) Breakfast Cereal, (5) Healthy Foods, (6) High-Fat Dairy Products</td>
<td>VAT area (CT)</td>
<td>General linear model Adjustments: age; sex; smoking; physical activity; education; energy intake; PPARγ Pro12Ala genotype; study site;</td>
<td>No associations between dietary patterns and VAT area in women. Adherence to Breakfast Cereal pattern was associated with ↓ VAT area vs. Healthy Foods pattern in men. Least-squares mean VAT area in men: • Breakfast Cereal: 157.0 ± 5.8 cm² (vs. Healthy Foods; P ≤ 0.05); • Healthy Foods: 135.4 ± 6.5 cm².</td>
</tr>
<tr>
<td>Deshmukh-Taskor et al., 2009 (142)</td>
<td>United States (Bogalusa Heart Study)</td>
<td>Whites and Blacks (19–39 y) N = 995 (607 women, 388 men)</td>
<td>131-item FFQ Principal component analysis (24 food groups) Dietary patterns: (1) Western, (2) Prudent</td>
<td>WC</td>
<td>Linear regression Adjustments: BMI; age; sex; ethnicity; sex*ethnicity; smoking; alcohol; physical activity; socioeconomic energy intake; status; marital status</td>
<td>↑ adherence to Prudent pattern was associated with ↓ WC in adults. Association with WC per 1-unit ↑ in score in adults: • Prudent: 0.04 cm (P = 0.009).</td>
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<tr>
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<tr>
<td>Paradis et al., 2009 (143)</td>
<td>Canada</td>
<td>General population (18–55 y) N = 664</td>
<td>91-item FFQ, interviewer-administered Factor analysis Dietary patterns: (1) Western, (2) Prudent</td>
<td>WHR</td>
<td>Analysis of variance; Adjustments: age; sex</td>
<td>† adherence to Western pattern was associated with † WHR in adults. † adherence to Prudent pattern was associated with ‡ WHR in adults. Least squares mean WHR for tertile 3 vs. 1 of pattern in adults: ▪ Western: 0.87 ± 0.10 vs. 0.83 ± 0.10 (P = 0.05); ▪ Prudent: 0.83 ± 0.09 vs 0.86 ± 0.10 (P = 0.06).</td>
</tr>
<tr>
<td>Noel et al., 2009 (140)</td>
<td>United States (Boston Puerto Rican Health Study)</td>
<td>Puerto Ricans living in the United States (45–75 y) N = 1,167</td>
<td>128-item FFQ Principal component analysis (34 food groups) Dietary patterns: (1) Meat &amp; French Fries, (2) Traditional, (3) Sweets</td>
<td>WC</td>
<td>General linear model Adjustments: BMI; age; sex; smoking; alcohol; physical activity; education; energy intake; medication and multivitamin use; acculturation</td>
<td>† adherence to Meat &amp; French Fries and Sweets patterns were associated with † WC in adults. Least-squares mean WC for quintile 5 vs. 1 of pattern in adults: ▪ Meat &amp; French Fries: 103.9cm (95% CI: 103, 105) vs. 102.6 cm (95% CI: 101, 104); (P-trend = 0.039); ▪ Sweets: 104.3 cm (95% CI: 103, 106) vs. 102.9 cm (95% CI: 102, 104); (P-trend = 0.045).</td>
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### Table 2.5  Continued

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<tr>
<th>Reference</th>
<th>Setting</th>
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<td>Fonseca et al., 2012 (151)</td>
<td>Portugal (EPIC-Porto Cohort)</td>
<td>General population (mean: 48–58 y) (N = 2,167) (1,330 women, 837 men)</td>
<td>82-item FFQ Multivariate finite mixture models (14 food groups; energy intake) Dietary pattern, by sex: Women – (1) Healthy, (2) Low Fruit &amp; Vegetables, (3) Red Meat &amp; Alcohol, (4) In Transition to Fast-Food; Men – (1) Healthy, (2) Fish, (3) Red Meat &amp; Alcohol, (4) Intermediate</td>
<td>WC</td>
<td>Logistic regression Adjustments: BMI; age; sex; smoking; alcohol; physical activity; energy intake; education; menopausal status</td>
<td>No associations between dietary patterns and WC in women or men vs. Healthy pattern.</td>
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<tr>
<td>Berg et al., 2008 (150)</td>
<td>Sweden (INTERGENE Study)</td>
<td>General population (25–74 y) (N = 3,452) (N = 3,610) (1,908 women, 1,702 men)</td>
<td>92-item FFQ Cluster analysis Dietary patterns: (1) Healthy, (2) Sweet, (3) Coffee, (4) Traditional, (5) Fast Energy</td>
<td>WHR</td>
<td>General linear model Adjustments: age; sex; smoking; physical activity; education; Adherence to Traditional and Fast Energy patterns were associated with ↑ WHR vs. Healthy pattern in adults. Association with WHR vs. Healthy pattern in adults: • Traditional: 0.010 units (95% CI: 0.003, 0.018); • Fast Energy: 0.011 units (95% CI: 0.004, 0.019).</td>
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<td>Panagiotakos et al., 2007 (145)</td>
<td>Greece (ATTICA Study)</td>
<td>General population (mean = 45 y) (N = 3,042) (1,524 women, 1,518 men)</td>
<td>156-item FFQ, self-administered Principal component analysis (22 food groups) Dietary patterns: (1) Healthy, (2) High Glycemic Index &amp; High-Fat, (3) Pasta, (4) Dairy &amp; Eggs, (5) Sweets, (6) Alcohol</td>
<td>WC</td>
<td>Linear regression Adjustments: BMI; age; sex; smoking; physical activity; education; income; medication or use of special diet</td>
<td>↑ adherence to High Glycemic &amp; High-Fat and Alcohol patterns were associated with ↑ WC in adults. ↑ adherence to Healthy pattern was associated with ↓ WC in adults. Association with WC per 1-unit ↑ in score in adults: • High Glycemic &amp; High-Fat: 0.70 ± 0.29 cm ((P = 0.012)); • Alcohol: 0.36 ± 0.29 cm ((P = 0.001)); • Healthy: 0.88 ± 0.28 ((P = 0.002).)</td>
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**Table continues**
### Table 2.5 Continued

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<th>Reference</th>
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<td>Kang et al., 2016 (137)</td>
<td>Korea (2010–2012 Korean National Health and Nutrition Examination Survey)</td>
<td>General population (≥19 y) N = 13,410 (8,026 women, 5,384 men)</td>
<td>24-hour dietary recall Factor analysis (24 food groups; percent energy from food group) Dietary patterns: (1) Traditional, (2) Westernized; Healthy</td>
<td>WC (&gt;80 cm women, &gt;90 cm men)</td>
<td>Logistic regression Adjustments: age; smoking; physical activity; alcohol; energy intake; income; education; BMI</td>
<td>(\uparrow) adherence to Healthy pattern associated with (\downarrow) odds of elevated WC in women. No associations between any dietary patterns and elevated WC in men. OR for elevated WC for quartile 4 vs. 1 of Healthy pattern: (\uparrow) Men: 0.73 (95% CI: 0.60, 0.90).</td>
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<td>Wang et al., 2013 (138)</td>
<td>China (2002 China National Nutrition and Health Survey)</td>
<td>General population; men (18–59 y) N = 13,511</td>
<td>33-item FFQ Principal component analysis and cluster analysis (factor scores used in cluster analysis) Dietary patterns: (1) Yellow Earth, (2) Green Water, (3) New Affluence, (4) Western Adaptor</td>
<td>WC (≥85 cm)</td>
<td>Logistic regression Adjustments: BMI; age; smoking; alcohol; urban/rural; education; income</td>
<td>Adherence to Yellow Earth and Western Adaptor patterns were associated with (\uparrow) odds of elevated WC vs. adherence to Green Water pattern in men. OR for elevated WC vs. Green Water in men: (\uparrow) Yellow Earth: 1.24 (95% CI: 1.05, 1.47); (\downarrow) Western Adaptor: 1.23 (95% CI: 1.02, 1.49).</td>
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<tr>
<td>Chan et al., 2012 (146)</td>
<td>China</td>
<td>General population (≥65 y) N = 3,707 (1,762 women, 1,945 men)</td>
<td>280-item FFQ Factor analysis (32 food groups; percent energy from food groups) Dietary patterns: (1) Vegetables-Fruit, (2) Snacks-Drinks-Milk, (3) Meat-Fish</td>
<td>WHR</td>
<td>Linear regression Adjustments: age; smoking; alcohol; physical activity; education; energy intake; perceived SES</td>
<td>No associations between dietary patterns and WHR in women. (\uparrow) adherence to Snacks-Drinks-Milk pattern was associated with (\downarrow) WHR in men. Association with WHR per 1-unit (\uparrow) in Snacks-Drinks-Milk score: (\uparrow) Men: (-0.004) units (95% CI: (-0.007, -0.001)).</td>
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<td>Reference</td>
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| Ganguli et al., 2011 (147) | India                            | General population, no acute illness or chronic debilitating disease; women (≥35 y)  
N = 645                                                                 | 99-item FFQ  
Principal component analysis (24 food groups; monthly intakes)  
Dietary patterns: (1) Vegetables, Fruits & Pulses, (2) Hydrogenated & Saturated Fat & Vegetable Oil, (3) Red Meat & High-Fat Dairy | WHR                            | Linear regression; Adjustments: age; physical activity; education; income; energy intake; menopausal status | No associations between any dietary patterns and WHR in women.             |
| Daniel et al., 2011 (139)   | India (India Health Study)        | General population, no cancer, cardiac event, or blood disorders (35–69 y)  
N = 3,215                                                               | Principal component analysis (104 food groups; frequency of intake)  
Dietary patterns, by site: Delhi – (1) Fruit-Dairy, (2) Vegetables-Pulses; Trivandrum – (1) Pulses-Rice, (2) Sweets-Snacks; Mumbai – (1) Fruit-Vegetables, (2) Snacks-Meat | WHR (≥0.80 women, ≥0.90 men) | Logistic regression  
Adjustments: age; sex; smoking; alcohol; physical activity; education; income; energy intake; marital status; religion | ↑ adherence to Fruit-Dairy and Sweet-Snacks patterns were associated with ↑ odds of elevated WHR in adults.  
OR for elevated WHR for tertile 3 vs. 1 of pattern in adults:  
▪ Fruit-Dairy: 2.32  
(95% CI: 1.03, 5.23);  
▪ Sweets-Snacks: 2.05  
(95% CI: 1.34, 3.14).                                   |
| Esmailzadeh et al., 2008 (141) | Iran                             | Teachers, no CVD, diabetes, or stroke; women (40–60 y)  
N = 486                                                               | 168-item FFQ, interviewer-administered  
Principal component analysis (41 food groups)  
Dietary patterns: (1) Healthy, (2) Western, (3) Traditional | WC                              | Correlation  
Adjustments: age; smoking; physical activity; energy intake; menopausal status; estrogen use; family history of diabetes and stroke | ↑ adherence to healthy pattern was correlated with ↓ WC in women  
(r = −0.25; P = 0.01).                                               |

Abbreviations: ABC, Aging and Body Composition; CARDIA, Coronary Artery Risk Development in Young Adults; CT, computer tomography; CVD, cardiovascular disease; DHQ, diet history questionnaire; EPIC, European Prospective Investigation into Cancer and Nutrition; FFQ, food frequency questionnaire; HR, hazard ratio; PR, prevalence ratio; OR, odds ratio; VAT, visceral adipose tissue; WC, waist circumference; WHR, waist-to-hip ratio; ↑, higher/increase; ↓, lower/decrease.
Chapter 3
Objectives

3.1 Study hypotheses and objectives

The overall hypothesis was that the amount, type, and quality of carbohydrate intake are associated with measures of adiposity in postmenopausal women. Specifically, total carbohydrate intake was hypothesized to be positively associated with abdominal adiposity, while dietary fibre intake was hypothesized to be inversely associated with abdominal adiposity. Additionally, it was hypothesized that the associations with abdominal adiposity would vary by the type of carbohydrate or dietary fibre. It was also hypothesized that dietary patterns would be characterized by different types of carbohydrates and have varied associations with measures of adiposity. Furthermore, dietary glycemic index (GI) and dietary glycemic load (GL) were hypothesized to be positively associated with total adiposity and abdominal adiposity.

The objectives of the thesis were:

1. To examine the associations between total carbohydrate intake and total dietary fibre intake and abdominal adiposity, as defined by dual-energy X-ray absorptiometry (DXA), in a group of Canadian postmenopausal women, as well as to determine whether the associations with abdominal adiposity varied by carbohydrate and dietary fibre food sources.

2. To examine the associations between \textit{a posteriori}-defined dietary patterns and DXA and anthropometric measures of total adiposity and abdominal adiposity in a group of Canadian postmenopausal women.

3. To examine the associations of dietary GI and dietary GL with DXA and anthropometric measures of total adiposity and abdominal adiposity in a group of Canadian postmenopausal women.

3.2 Candidate’s role

The thesis was incorporated into a Canadian Institutes of Health Research-funded project, which was developed prior to the candidate’s involvement (Chapter 4). The aim of the funded study, titled “Body Composition and Breast Cancer Related Biomarkers” (principal investigator: J.
Knight), was to examine the associations between body composition and various breast cancer-related biomarkers in postmenopausal women. Thus, the principal investigator of the funded study determined the overall study design and data collection methods based on the original aims of the study. The candidate’s role within the research project included conducting a review of the literature and developing specific objectives for the thesis on the topic of nutrition and adiposity, which was not part of the original aims of the study. The candidate participated in part of the data collection process, such as conducting study visits and telephone follow-up. In addition, the candidate was responsible for cleaning the study data relevant to the thesis, adding GI and GL data to the nutrient database, and deriving relevant study variables. The candidate also conducted all statistical analyses and prepared the manuscripts for the thesis objectives.
Chapter 4
Methods

4.1 Study design

As described previously, this thesis utilized data from a cross-sectional study funded by the Canadian Institutes of Health Research, which originally aimed to examine the associations between body composition and various breast cancer-related biomarkers in postmenopausal women. Data collection for the study occurred between September 2011 and January 2014. Data were obtained from three questionnaires, medical imaging, anthropometric measurements, and fasting blood samples. Details on the data collection methods utilized to obtain study variables relevant to the thesis are presented in the following sections.

4.2 Study population

Study participants were postmenopausal women aged 50 to 69 years from the Toronto, Ontario area. Participants were primarily recruited through the Ontario Breast Screening Program (OBSP), which is a provincial, organized screening program. The OBSP collects routine information during the screening appointment, including menopausal status and estrogen use, and, at the time, was asking for consent to being approached for participation in future research studies. The contact information of randomly selected women who met the study’s eligibility criteria (listed below) were requested from the OBSP. Letters containing an explanation of the study and the study coordinator’s contact information were mailed to the list of women provided by the OBSP. Secondary methods utilized for study recruitment were advertisements posted in University Health Network and Mount Sinai Hospitals, in addition to word-of-mouth. Women who were interested in participating in the study called the study coordinator, who then screened them for eligibility. Women who were eligible for inclusion were aged 50 to 69 years, had their last menstrual period more than twelve months earlier without surgical intervention or had both ovaries removed (i.e. postmenopausal), did not have breast cancer, and were not using prescription hormone medications.

The study sample used for the statistical analyses excluded participants who were missing body composition data or dietary intake data. A total of 382 women participated in the study. Of these participants, one (0.2%) did not receive medical imaging and sixteen (4.2%) did not
complete the dietary questionnaire, resulting in 365 (95.6%) with complete data. The study sample also excluded participants with implausible total energy intakes. The cut-off values used to define implausible total energy intake were the 1\textsuperscript{st} and 99\textsuperscript{th} percentiles of energy intake in the study population (1). Thus, participants with total energy intakes less than 566.9 kcal/d ($n = 4$) or greater than 3,597.4 kcal/d ($n = 4$) were excluded. These values are comparable to the cut-off values of 500 kcal/d and 3,500 kcal/d for women, which have been utilized in epidemiologic studies, such as the Nurses’ Health Study (NHS) (2, 3). The use of cut-off values in this range has been shown to estimate a lower proportion of implausible reporters compared to the Goldberg and predicted total energy expenditure methods, which utilize equations to estimate energy requirements (3). However, the effect of excluding implausible reporters using this range of cut-off values on the associations between diet and health outcomes has been shown to be comparable to the Goldberg and predicted total energy expenditure methods (3). Furthermore, the use of the Goldberg and predicted total energy expenditure methods to classify implausible reporters may introduce selection bias when examining outcomes that are correlated with body weight because weight is utilized in the equations (3). After exclusions, the final study sample included 357 participants.

4.3 Data collection

Eligible study participants attended one study visit at the Prosserman Centre for Health Research of the Lunenfeld-Tanenbaum Research Institute at Mount Sinai Hospital. During the visit, a trained technologist performed a whole-body body composition dual-energy x-ray absorptiometry (DXA) scan, obtained anthropometric measurements, and performed a blood draw. After the blood draw and scan, participants received breakfast before research personnel administered a study questionnaire (Appendix A) and a physical activity questionnaire (Appendix B) at the time of the visit. Fifty dollars was provided as compensation for time and transportation. A diet questionnaire (Appendix C) was mailed to participants following the study visit. Participants were instructed to complete and return the diet questionnaire using the self-addressed stamped envelope included in the package. Follow-up telephone calls were made to non-respondents in order to increase the response rate. Details of the measurement instruments are provided in subsequent sections.
The anthropometric measurements and response data for the study and physical activity questionnaires were entered into Access databases by a research assistant. Data from the DXA scans were also automatically stored in an Access database. The completed diet questionnaires were sent to the Department of Cancer Epidemiology and Prevention Research at Alberta Health Services – CancerControl (Calgary, Alberta), where the responses were scanned and the raw data were stored in an ASCII text file. The candidate analyzed the raw diet questionnaire data using the accompanying software (Diet*Calc). In addition, the candidate was responsible for cross-checking values between databases and conducting logic checks. Where errors were suspected, the original copies of the questionnaires were accessed to make corrections.

4.4 Dietary variables

4.4.1 Dietary assessment methods

The most common methods of dietary assessment in epidemiologic studies are dietary records, 24-hour dietary recalls, and food frequency questionnaires (FFQs). The dietary record method requires participants to record the foods that are eaten, at the time of consumption (4). The 24-hour dietary recall method involves a trained interviewer probing the participant about his or her food intake during the past 24 hours (4). An advantage of dietary records and 24-hour dietary recalls is that these methods are open-ended and can assess specific foods (4). In contrast, FFQs are questionnaires which include a list of foods and responses for the frequency of intake, and may also include options to assess the amount of foods consumed (5). Dietary intake using 24-hour dietary recalls and FFQs is self-reported and dependent on the participant’s memory, which leads to the potential for recall bias (4, 5). FFQs are widely used in large epidemiological studies because, compared to 24-hour dietary recalls and dietary records, these instruments are practical, relatively inexpensive, and designed to measure usual dietary intake over a period of time (i.e. several months or one year) that is likely etiologically relevant for chronic disease outcomes (5). Multiple dietary records and 24-hour dietary recalls may be used to assess usual dietary intake, but day-to-day variation in food and nutrient intake is an issue (4).

4.4.2 Canadian Diet History Questionnaire II

Dietary intake was assessed using the Canadian Diet History Questionnaire II (C-DHQ II), which is a comprehensive (full diet) FFQ (Appendix C). The U.S. Diet History Questionnaire (US-DHQ) I was developed by the U.S. National Cancer Institute and aimed to improve dietary
assessment by utilizing cognitive interviewing, population-based dietary data, and a new method for generating the nutrient database (6). The questionnaire was subsequently updated to the US-DHQ II in 2009, which was further adapted to the C-DHQ II for application in Canada (7). Specifically, the paper, past-year version of the C-DHQ II was utilized to assess usual dietary intake in this study population. The 165-question C-DHQ II consists of 152 food and beverage questions, eleven dietary supplement questions, one question about how meat was cooked, and one question on vegetarian diets (8, 9). The line-item food questions assess food groups of individual foods that are similar in nutrient composition and consumption pattern (7). Many line-item questions include embedded questions to assess the intake of food subgroups, seasonal variation, or additions to food. Furthermore, frequency of intake is assessed from a list of nine to ten options for all food groups and subgroups, while portion size is assessed from a choice of three selections for most food groups (8, 9). The C-DHQ II nutrient database includes nutrient values for the 331 food groups (including food subgroups) linked to questionnaire items. The 34 nutrients include energy, macronutrients, carbohydrate components, fatty acids and cholesterol, vitamins, minerals, caffeine, and water (8, 10). There are six nutrient profiles for each food group, which are sex- and portion size-specific (7). Diet*Calc software (version 1.5.0, National Cancer Institute, Applied Research Program, October 2012) and the C-DHQ II nutrient database were used to conduct the nutrient analysis of C-DHQ II data. The nutrient analysis produces daily total nutrient estimates and detailed food group-specific nutrient estimates.

A key element of the design of the C-DHQ II is that nationally-representative dietary data from the Canadian Community Health Survey, Cycle 2.2 (CCHS 2.2) were used to adapt the FFQ to better assess dietary intake in Canadian populations (7). Specifically, 24-hour dietary recall data were used to modify the questionnaire food list, as well as adjust portion size options, to better reflect food consumption patterns in Canada. Additionally, the C-DHQ II nutrient database was developed by analysing data from the CCHS 2.2 dietary recalls and nutrient database (Canadian Nutrient File) with the approach used for the US-DHQ I and II (7). This approach involves calculating mean nutrient intake values for each food group by sex and portion size, which was shown to reduce measurement error of nutrients compared to median methods (11). An evaluation the paper-version of the C-DHQ II showed that dietary intake estimates were reasonably reliable, with intraclass correlation coefficients ≥0.60 reported for fourteen of the seventeen nutrients in men and women. Specifically, among women, the intraclass correlation
coefficients for carbohydrate intake and dietary fibre intake were 0.72 (95% confidence interval, CI: 0.60, 0.81) and 0.81 (95% CI: 0.73, 0.88), respectively (7). The validity of the C-DHQ II has not been studied specifically, but validation studies for the US-DHQ I have been conducted. Overall, when compared to 24-hour dietary recalls, the US-DHQ I performed better than two popular FFQs (i.e. Block FFQ and Willett FFQ) (6). Compared to 24-hour dietary recalls, the validity of the US-DHQ I was good. The deattenuated correlation coefficients for energy intake was 0.48, while the correlation coefficients for energy-adjusted carbohydrate and dietary fibre intakes were 0.69 and 0.77, respectively (6). However, US-DHQ I estimates of total energy and protein intakes were poorly correlated with biomarkers of dietary intake (i.e. doubly labelled water for total energy expenditure; urinary nitrogen for total energy intake) (12) and underreported (13). The correlation and accuracy of the measurement of protein intake by the US-DHQ I compared to urinary nitrogen improved when adjusted for energy intake (12, 13) and was within the range of correlation coefficients reported in validation studies of other FFQs (14).

4.4.3 Food grouping classification

The 331 C-DHQ II food groups were assigned to categories in order to obtain dietary exposure variables. The food groupings and classification were informed by the food groups listed in the Canadian Nutrient File (15). Narrower food groupings were defined for the purposes of deriving dietary patterns, while broader categories were created to examine carbohydrate food sources (Table 4.1).

4.4.4 Carbohydrate and dietary fibre intake

Carbohydrate values in the nutrient database include dietary fibre due to the calculation method used for the Canadian Nutrient File (15). Estimates of total carbohydrate intake (g/d) and total dietary fibre intake (g/d) were directly obtained from the summary daily nutrient analysis and examined as continuous variables. Carbohydrate and dietary fibre intake from specific food sources were also of interest. The following eight food sources, which are characterized by high carbohydrate content, were identified: grains, breakfast cereals and baked products, fruits, vegetables, potatoes, legumes, dairy products, and sweetened products (Table 4.1). Using the detailed output from the nutrient analysis, carbohydrate and dietary fibre intakes (g/d) from each food source were calculated as the sum of the nutrient intakes from all C-DHQ II food groups in the food source category.
4.4.5 Glycemic index and glycemic load

The C-DHQ II nutrient database does not include glycemic index (GI) and glycemic load (GL) values. However, the US-DHQ II nutrient database has available carbohydrate and GL (glucose and bread references) values, which were added using nutrient values from the Nutrition Data Systems for Research nutrient database (10). Since the C-DHQ II was adapted from the US-DHQ II, the GL values from the US-DHQ II database were utilized to add GI and GL to the C-DHQ II database. Figure 4.1 outlines the process used to add GI values to the C-DHQ II nutrient database, which was adapted from the methods that Dixon et al. (16) and Flood et al. (17) used to add carotenoids and GL values, respectively, to the US-DHQ I nutrient database.

Firstly, matches between the 331 C-DHQ II food groups and the 277 US-DHQ II food groups were made using the reclink program (18) in Stata 13 (StataCorp, College Station, Texas) and manual inspection. Approximately 78% of C-DHQ II food groups were matched to US-DHQ II food groups with the same name. There were also about 18% of C-DHQ II food groups with a closely related match in the US-DHQ II, such as being a subgroup or having added fat (i.e. vegetables). The quality of the food group matches was evaluated for the upper 90% of carbohydrate contributing food groups, which was defined using the medium portion size for women by ordering food groups from highest to lowest percentage carbohydrate from all food groups and summing until 90% was reached (17). This evaluation was also restricted to C-DHQ II food groups actually consumed by the study population. The quality of the food group matches was evaluated by assessing the ratios and absolute differences of energy and carbohydrate per 100 g between the C-DHQ II and US-DHQ II. Food groups with ratios less than 0.8 or greater than 1.2 (16) and large absolute differences (i.e. >30 kcal per 100 g for energy and >3 g per 100 g for carbohydrate) for four or more of the six nutrient profiles were considered to be poorly matched. A detailed file of individual foods comprising the US-DHQ II food groups was examined to determine if there was a better match for the eleven poorly matched food groups. However, a better match could not be found for five of these food groups that had exact name matches and for three food groups where the descriptions of individual foods corresponded. The remaining three food groups were matched to US-DHQ II food groups with similar carbohydrate ingredients, which improved the quality of the matches for two food groups (Table E.1). For all of the matched food groups, the GI values from the US-DHQ II nutrient
database, calculated as GL divided by available carbohydrate and multiplied by 100, were assigned to the matching food group in the C-DHQ II nutrient database.

Secondly, the GI value of the unmatched C-DHQ II food groups had to be imputed into the C-DHQ II nutrient database. For the two unmatched food groups identified as being in the top 90% of carbohydrate contributing food groups, the GI values were obtained from the 2008 International Tables of GI and GL values (19). This was calculated as the mean value of studies measuring GI among subjects with normal glucose tolerance (Table E.2). For the 11 unmatched food groups in the lower 10% of carbohydrate contributors, a GI value of zero was imputed for food groups with 0 g of carbohydrate and a GI value of 50 was imputed for food groups with >0 g carbohydrate content.

The variables of interest were average daily dietary GI and daily dietary GL, with glucose as the reference food. Dietary GI is the weighted mean of available carbohydrate intake, where the weight is the GI of the food. Therefore, dietary GI was calculated as sum of the product of the GI and available carbohydrate intake from the C-DHQ II food group across all consumed food groups, and dividing by the total available carbohydrate intake (20). This is equivalent to summary daily GI value produced by the nutrient analysis, with sex- and portion-size specific GI values added to the C-DHQ II nutrient database. Dietary GL is defined as the total GL of all foods and was calculated by summing the product of the food group GI by the available carbohydrate intake across all food groups consumed and dividing by 100 (21). Available carbohydrate intake is not included in the C-DHQ II nutrient database, but was calculated by subtracting dietary fibre intake from carbohydrate intake.

The assessment of dietary GI and GL in epidemiological studies depends on the assignment of published GI values to foods assessed by the dietary instrument (22). However, the validity and reproducibility of dietary GI and GL from FFQs has not been examined extensively. The European Prospective Investigation into Cancer and Nutrition (EPIC) study found that the correlations between semi-quantitative and quantitative dietary questionnaires and 24-hour dietary recalls was acceptable for GI ($r = 0.57$) and strong for GL ($r = 0.76$), and were higher among men (1). The relative validity was similar in a sub-cohort of the EPIC study, but differences between sexes were not significant (23). Additionally, crude mean GI and mean GL from diet questionnaires were significantly different from values from 24-hour dietary recalls.
Energy-adjusted deattenuated correlation coefficients between diet questionnaires and four-day dietary records ranged from 0.42 to 0.72 and 0.44 to 0.71 for GI and GL, respectively, in Japanese and Australian populations (24, 25). The reproducibility of GI and GL from dietary questionnaires has been reported to be good, with energy-adjusted intraclass correlation coefficients ranging from 0.57 to 0.78 for GI and 0.58 to 0.74 for GL (23, 25).

4.4.6 Dietary patterns

As described previously (section 2.3.3), a priori dietary scores and indices and a posteriori data-driven methods are the two main approaches for characterizing dietary patterns. Dietary scores and indices are commonly based on dietary guidelines and recommendations. As such, dietary scores and indices reflect adherence to diets which are considered to be healthy based on current scientific evidence (26). This, however, is a potential limitation since current scientific knowledge about diet and health may be inadequate (26). Other limitations of dietary scores and indices are that the variation of intake of individual components is not adequately captured (27) and there can be significant variation in the components that contribute to a given score (26). While dietary scores and indices are readily reproducible, dietary patterns derived using data reduction methods have limited reproducibility because a number of subjective decisions are made in the analyses (27). The most common data reduction methods are principal components analysis (PCA), factor analysis, and cluster analysis. PCA derives dietary patterns based on the correlations among dietary variables (26). In PCA, dietary patterns (i.e. principal components) are linear combinations of the dietary variables and explain the maximum amount of variance in the dietary data (26, 28, 29). This contrasts with factor analysis, another common approach based on correlations among dietary variables, which identifies underlying dietary patterns (i.e. factors) that account for common variance in the dietary data (26, 29). Although component and factor scores are somewhat abstract (28), PCA and factor analysis allow the degree to which individuals follow the dietary pattern to be characterized, whereas cluster analysis groups individuals together based on the similarity of their dietary intake (30). PCA and factor analysis also have good statistical power, while the power to detect association with health outcomes is lower for cluster analysis, particularly when the sample size is small (26, 28). Furthermore, the reproducibility and validity of dietary patterns derived from FFQs have been demonstrated. Hu et al. (31) found dietary pattern component scores were highly correlated between two FFQs repeated one year apart ($r = 0.70$ for a prudent pattern; $r = 0.67$ for a Western pattern) (31).
Correlations between dietary pattern scores and nutrient intakes and biomarkers, such as total cholesterol, were also in the expected directions (31).

PCA was selected as the method for characterizing dietary patterns in this study because we did not want dietary patterns to be restricted to current dietary recommendations. In addition, PCA was chosen over factor analysis because there was no prior knowledge of underlying dietary patterns for this study population. For PCA, the number of components to retain was determined by evaluating the Scree plot, eigenvalues, proportion of variance explained by each component, and the qualitative interpretability of the components. An orthogonal (varimax) rotation was applied to obtain uncorrelated components, which simplified the component structure and interpretation. Food groupings with absolute values of component loadings ≥0.200 were considered to be an important contributor to the component and were used to describe the dietary pattern. Like other data reduction methods, a number of subjective decisions are made in PCA. Firstly, the number of input variables to use in PCA was considered. Sample size guidelines recommend a minimum ratio of the number of subjects to the number of input variables of five to one to obtain valid and stable results in PCA (32). Thus, the 331 C-DHQ II food groups were initially classified into 63 food groupings to use as input variables in PCA. Based on preliminary PCA results, the number of food groupings was reduced to 46 because food groupings with similar usage or nutrient profiles had comparable component loadings (Table 4.1). Furthermore, the animal fat (i.e. lard and bacon fat), miscellaneous, and unsweetened beverages food groupings were not included as input variables in PCA because these groups were consumed by less than 2% of the population and did not contribute to energy intake. Secondly, the quantification of the input variable was determined. PCA using input variables quantified by gram weights, energy-adjusted weights, and percentage of energy intake was conducted and two components were retained in each analysis. While the component loadings varied, the food groupings with significant loadings were comparable (Table 6.1, Table F.1, and Table F.2). However, using weights as the input variable produced components with positive loadings only, which could be interpreted more easily. Smith et al. (33) showed that there were no differences in derived dietary patterns among types of input variables but suggested that dietary patterns derived by weight produced a more meaningful dietary pattern and also account for the amounts of foods eaten. Thus, in the final analysis dietary patterns were derived by PCA using 43 input variables quantified by weight (g/d). Component scores were calculated for each derived dietary
pattern by summing the product of the standardized weight and the corresponding component
loading of the food grouping across all food groupings. Dietary pattern scores were
conceptualized as categorical variables using quartiles to determine the cut-points of the
categories.

4.5 Adiposity variables

Both imaging and anthropometric methods were utilized to assess adiposity. The use of an
imaging method for assessing adiposity is advantageous because it provides a direct measure of
adipose tissue. Measures of abdominal adiposity and total adiposity were the primary and
secondary outcomes examined in the objectives, respectively. All adiposity measurements were
obtained with the participant wearing a light gown and underwear.

4.5.1 Dual-energy X-ray absorptiometry

DXA was the imaging procedure used for body composition assessment. DXA uses low and
high energy X-ray beams to differentiate tissues of varying density by analysing the ratio of the
attenuation of the X-ray beams (34). Specifically, DXA discriminates bone mineral mass, fat
mass, and lean tissue mass (34). DXA also has the ability to measure body composition in
specific regions, such as the trunk, arms, and legs. Whole-body DXA scans for body
composition were performed on study participants using the Hologic Discovery A DXA system
and analysed with the Hologic APEX software, version 3.3 (Hologic Inc., Bedford
Massachusetts). The DXA measure of total adiposity examined was total fat mass (kg), while
the DXA measures of abdominal adiposity were trunk fat mass (kg) and the android-to-gynoid
ratio (i.e. android fat mass (kg) divided by gynoid fat mass (kg)). The Hologic APEX software
defines the trunk region as the region excluding the head, arms, and legs. The android region is
defined as the area that is 20% of the distance from the iliac crest to the neckline (i.e. upper
abdominal region), while the gynoid region is defined from the upper limit at the top of the great
trochanters (i.e. 1.5 times the height of the android region from the iliac crest) to the lower limit
that is twice the height of the android region.

DXA is an attractive method for assessing body composition because radiation exposure is low
and it is precise. DXA has good precision for measuring soft tissues in the whole body, with
coefficients of variation of 0.4 to 1.3% for lean mass and 0.6 to 4.4% for fat mass or percent
body fat (34). However, the precision of regional measurements of fat mass and percent body fat has been shown to be lower than for whole-body measurements (34). Studies examining the accuracy of percent body fat measured with DXA versus the reference four-compartment model have found varying results. Among healthy adults some studies have reported no significant difference between DXA and the reference method (34, 35), while significant bias has been found in other studies with DXA overestimating percent body fat by 2.0 to 2.9% or underestimating by 1.3 to 5.3% (34, 36). While DXA is able to measure regional body fat, it does not provide direct measures of visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT) (37, 38). Computed tomography and magnetic resonance imaging are considered the gold standard techniques for measuring VAT and SAT (38). Studies have shown that the DXA regional fat measures have strong correlations with VAT. The correlations between DXA trunk fat mass and CT- or MRI-measured VAT have been reported to be between 0.61 and 0.84 among adult females (39, 40). DXA android fat mass has also been found to be strongly correlated with CT-measured VAT ($r = 0.72–0.79$) (41, 42). A good correlation between DXA android-to-gynoid ratio and CT-measured VAT has also been found among individuals with type 2 diabetes ($r = 0.70$ in females) (43).

4.5.2 Anthropometric measurements

Body mass index (BMI) was the anthropometric measure of total adiposity investigated. Weight (nearest 0.1 kg) and height (nearest 1 cm) were measured using a digital clinical scale and stadiometer, respectively. BMI ($\text{kg/m}^2$) was calculated by dividing weight by height squared. The anthropometric measures of abdominal adiposity examined were waist circumference and waist-to-hip ratio. The measurements of waist circumference and hip circumference followed the protocols described by the U.S. National Institutes of Health (NIH) (44) and U.S. National Health and Nutrition Examination Survey III (45). Measurements were taken with the participant in a standing position using the Gulick II tape measure. The Gulick II tape measure does not stretch and is equipped with a tension meter, which helps ensure that measurements were accurate and reproducible (46). Waist circumference was measured at the level directly above the iliac crest and hip circumference was measured around the widest part of the buttocks (44, 45). Waist and hip circumferences were measured to the nearest 0.1 cm and repeated three times. The waist circumference variable was defined as the average of the three waist
circumference measurements, while the waist-to-hip ratio variable was calculated by dividing the average waist circumference by the average hip circumference.

Waist circumference is widely used in clinical practice to assess abdominal adiposity and related health risks (44). However, a standard protocol for measuring waist circumference has not been established and waist circumference has been measured at different anatomic sites (46, 47). Studies have found that waist circumference varies significantly across different measurement sites among females (46, 48–50). However, a systematic literature review concluded that the associations between waist circumference and the risk of morbidity and mortality were not significantly affected by the measurement protocol (47). An advantage of the NIH protocol is that the measurement location uses a bony landmark and only requires one landmark to be identified (47, 50). Bosy-Westphal et al. (49) found that waist circumference measured using the NIH protocol was very strongly correlated with abdominal SAT \( r = 0.87 \) among female adults and was comparable with correlations between two other waist circumference sites and SAT \( r = 0.87–0.88 \). However, the correlation between waist circumference measured above the iliac crest and VAT \( r = 0.62 \) was weaker than the correlations for waist circumference measured below the lowest rib \( r = 0.70 \) and at the midpoint between the lowest rib and iliac crest \( r = 0.66 \) (49). Similarly, among female adults, the correlations for waist circumference with VAT \( r = 0.68–0.75 \) have been reported to be lower than the correlations with SAT \( r = 0.76–0.80 \) and total abdominal adipose tissue \( r = 0.82–0.91 \) (40, 51). The strong correlations between waist circumference and VAT have been observed consistently among different populations, with correlation coefficients ranging from 0.61 for African-American females aged 70 to 79 years (39) to 0.78 for French-Canadian females aged 18 to 40 years (52). Waist-to-hip ratio is another commonly used measure of abdominal adiposity, which is proposed to capture VAT (waist circumference) and SAT (hip circumference) (38, 53). Rankinen et al. (52) reported strong correlations between waist-to-hip ratio and VAT in male adults \( r = 0.74–0.79 \), but the correlations in female adults were weaker \( r = 0.39–0.49 \). Although the correlations between these two anthropometric measures of abdominal adiposity and VAT are good, these measures have limitations because they encompass other tissues including SAT, muscles, and organs (54). Thus, waist circumference or waist-to-hip ratio measurements are affected by variation in other tissues (i.e. edema, abdominal wall tension) and are not specific to abdominal adipose tissue (54).
4.6 Potential confounders

Potential confounders of the associations between dietary factors and measures of adiposity were identified from the literature based on the associations of these variables with abdominal adiposity (section 2.2) or dietary exposure variables. Five demographic and lifestyle covariates were evaluated as potential confounders in the analyses. In addition, adjustment for dietary variables was necessary due to strong correlations with the dietary exposure variables (55, 56).

The covariates age, ethnicity, alcohol use, and smoking status were determined from the study questionnaire (Appendix A), which is a four-page questionnaire that assessed demographics, menstrual and reproductive history, breast cancer family history, alcohol and smoking consumption, and body size and shape. Age was a continuous variable that was defined as age at the time of the study visit. The ethnicity variable was dichotomized as European and non-European, based on the 13 ethnicity options included on the questionnaire. Alcohol use and smoking status variables were derived from questions on current and past behaviours. The alcohol use variable assessed regular alcohol consumption of at least one drink per week (57). The four categories for the alcohol use variable were: never used, former use, current use of five or fewer drinks per week, and current use of five or more drinks per week. The smoking status variable assessed whether cigarettes were smoked at least once per week. The three categories for smoking status were: non-smoker, former smoker, and current smoker.

The physical activity level covariate was derived from responses collected using the long, interviewer-administered version of International Physical Activity Questionnaire (IPAQ) (Appendix B) for activity in the last seven days. The IPAQ assesses the duration and intensity of occupational, transportation, household (indoor and outdoor), and leisure physical activities, in addition to the duration of sitting. The IPAQ has been shown to have acceptable reliability, concurrent validity, construct validity, and criterion validity in various populations (58, 59). The IPAQ data were processed according to the data processing rules and scoring protocols accompanying the questionnaire to create the physical activity level covariate with three categories: low, moderate, and high (60). However, using the standard guidelines, which were developed primarily for the short version of the questionnaire, resulted in approximately 75% of the study population being classified as having a moderate physical activity level, which was greater than the 31% of Canadian females aged 40 to 65 years reported to have moderate
physical activity levels according to the short-form IPAQ (61). Although it is noted that the long-form IPAQ likely produces higher estimates than the short version (60), moderate physical activity level in the population was likely overestimated. The IPAQ assesses walking in the transportation and leisure domains, moderate-intensity activities in the transportation, occupational, household, and leisure domains, and vigorous activities in the occupational and leisure domains. The overestimation of the moderate physical activity level in this population of older females may be attributed to the greater number of moderate-intensity activities, particularly household activities, included. Therefore, the three categories of physical activity level were defined by the frequency, duration, and intensity of occupational, transportation, and leisure physical activities only in the thesis research. Participants who reported total physical activity time greater than 960 minutes were classified as unreliable, per the IPAQ guidelines.

The dietary covariates were obtained from the nutrient analysis of the C-DHQ II data. Total energy intake (kcal/d) was included as a covariate for the three objectives in order to examine the independent effects of the dietary factors on adiposity outcomes. Adjustment for total energy intake is important because almost all of the dietary exposure variables have a strong positive correlation with energy (Table 4.2). Additionally, adjusting for total energy intake may reduce measurement errors for the dietary exposure variables because these errors are strongly correlated with measurement errors for total energy intake (55, 56). Total carbohydrate intake and total dietary fibre intake were other dietary covariates included in the analyses for objective 1, while there was adjustment for total dietary fibre intake for objective 3. Reasons for controlling for these dietary covariates are detailed in the manuscripts (Chapter 5 and Chapter 7).

4.7 Statistical analyses

Statistical analyses for objectives 1 to 3 were conducted on a sample of 357 participants with complete data (section 4.2). Stata 13 (StataCorp, College Station, Texas) was utilized to perform all statistical analyses. Two-sided \( P \) values <0.05 were defined as statistically significant results. This section provides an overview of the statistical methods, while methods specific to each objective are described in the manuscripts (Chapter 5, Chapter 6, and Chapter 7).

Descriptive analyses were initially performed to check the data and examine the distributions of the dietary exposure variables, adiposity outcome variables, and potential confounders. Pairwise correlations between dietary variables and between body composition variables were also
examined. Furthermore, bivariate analyses were performed to examine the relationships of the
dietary variables and potential confounders with the adiposity outcome variables, and the
relationships between dietary variables and potential confounders.

Separate multivariable linear regression analyses were conducted to assess the associations
between dietary exposure variables and adiposity outcomes for objectives 1 to 3. For categorical
exposure variables, linear trends across ordinal categories were analysed using linear contrasts.
The change-in-estimate approach was used to determine whether the demographic and lifestyle
covariates confounded the associations of interest in all analyses. Specifically, confounders that
changed the regression coefficients by 10% or more were identified as confounders and included
in the model (62). This was assessed by starting with a model adjusted for all potential
confounders and identifying which variable produced the smallest change when removed from
the model. This assessment was repeated until all remaining confounders changed the estimate
by 10% or more. Although age and ethnicity did not meet the criteria for confounders, these
demographic variables were forced into the models because they have been shown to be
important predictors of adiposity in the literature. The analyses for abdominal adiposity
outcomes did not adjust for BMI because it was very strongly correlated with trunk fat mass and
waist circumference (Figure 4.2), which were the primary DXA and anthropometric measures of
abdominal adiposity, respectively. Thus, including BMI as a covariate in the models would
impact the ability to examine the effects of dietary factors on the abdominal adiposity outcomes.
However, supplemental sensitivity analyses, where analyses were stratified by BMI categories,
were conducted to explore the effects of dietary factors on abdominal adiposity, while
accounting for total adiposity (Chapter 8 and Appendix G).

As mentioned previously, adjustment for total energy intake was included in all multivariable
regression analyses. The standard multivariate model for energy adjustment was selected, where
total energy intake is included in the model as a covariate. An advantage of the standard
multivariate approach is that it can be used to control for confounding by energy whether the
dietary exposure variable is an energy-bearing nutrient (i.e. carbohydrate intake) or a non-
energy-bearing dietary factor (i.e. GI) (56). Since total energy intake is included in the standard
multivariate model, it was not necessary to include the percentage of energy intake from other
macronutrients in the model. Furthermore, the standard multivariate model shows the effect of
increasing the intake of the energy-bearing nutrient of interest by replacing an equal amount of a
different energy-bearing nutrient (i.e. isocaloric diet) (56). Since there are differences in interpretation between various energy adjustment methods, Willett et al. (56) recommended the use of multiple methods to aid in understanding the diet-outcome associations of interest. Thus, the nutrient density method of energy adjustment was also examined for the associations of energy-bearing nutrients (i.e. carbohydrate, dietary fibre, and GL) and adiposity outcomes in objectives 1 and 3. Overall, the energy adjustment method had limited impact on the overall findings. Furthermore, ethnicity was investigated as a potential effect modifier by evaluating the interactions between ethnicity and dietary exposure variables. Regression diagnostics for the final models were evaluated to check that the assumptions of linear regression were satisfied and that multicollinearity was not an issue.

4.8 Ethics

The funded study, “Body Composition and Breast Cancer Related Biomarkers”, received ethics approval from the Mount Sinai Hospital Research Ethics Board. Since the thesis research was a secondary data analysis, the student also obtained administrative approval from the University of Toronto Office of Research Ethics (Appendix D). All study participants provided written, informed consent at the beginning of the study visit. In order to maintain the privacy and confidentiality of the data, personal identifiers were removed from the study data and participants were only identified using the study identification number.

4.9 Presentation of Results

The results of the thesis research are presented in the format of three independent manuscripts, with each manuscript corresponding to a thesis objective. The candidate was the author of each manuscript and was responsible for revising the manuscripts based on the comments provided by the other authors. The aim of the three manuscripts is to study the relationships of carbohydrate quantity and quality with abdominal adiposity by examining three dietary factors. The first manuscript investigates total and food sources of carbohydrate and dietary fibre intakes in relation to abdominal adiposity (Chapter 5). The second manuscript examines the associations between overall dietary patterns and measures of total and abdominal adiposity (Chapter 6). Finally, the third manuscript evaluates the effects of dietary GI and dietary GL on total and abdominal adiposity (Chapter 7).
4.10 References


Table 4.1 Classification of Canadian Diet History Questionnaire II food groups by carbohydrate food source and food groupings

<table>
<thead>
<tr>
<th>Carbohydrate food source</th>
<th>Food groupings</th>
<th>C-DHQ II food groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grains</td>
<td>Rice, grains &amp; pasta</td>
<td>chow mein noodles; pasta (FA; NFA); rice/grains (FA; NFA)</td>
</tr>
<tr>
<td>Breakfast cereals &amp; baked</td>
<td>Breakfast cereals</td>
<td>Other: hot breakfast cereals (FA; NFA); ready-to-eat cereal (highly fortified; other)</td>
</tr>
<tr>
<td>products</td>
<td></td>
<td>Added fiber: ready-to-eat cereal (good fiber; high-fiber)</td>
</tr>
<tr>
<td>Bread, white</td>
<td>Bread, white</td>
<td>bread/rolls (white); English muffin/bagel (white)</td>
</tr>
<tr>
<td>Bread, whole-grain</td>
<td>Bread, whole-grain</td>
<td>bread/rolls (whole-grain); English muffin/bagel (whole-grain)</td>
</tr>
<tr>
<td>Baked products, other</td>
<td>Baked products, other</td>
<td>biscuits; cornbread/muffins; crackers; croissants;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>stuffing/dumplings; tortillas/taco shell</td>
</tr>
<tr>
<td>Baked products, sweet</td>
<td></td>
<td>added fiber: ready-to-eat cereal (good fiber; high-fiber)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cakes; cheesecake; cookies, brownies (regular; low-fat);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>crisps/cobblers; donuts/sweet rolls/Danish/pop tarts; granola</td>
</tr>
<tr>
<td></td>
<td></td>
<td>bars; muffins/deep breads; pancake/waffles/French toast;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pies (cream/custard/other; fruit; pecan; pumpkin/sweet potato/etc.)</td>
</tr>
<tr>
<td>Fruits</td>
<td>Fruit juice</td>
<td>orange/grapefruit juice (all; calcium-fortified); other juice</td>
</tr>
<tr>
<td>Fruits</td>
<td></td>
<td>apples; applesauce/cooked apples; avocado/guacamole; bananas;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>berries; cantaloupe; dried fruit (apricots; other); fruit salads/other;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>grapefruit; grapes; mangos; oranges/tangelo/etc.; other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>melon; peaches/nectarines/plums; pears; pineapple; plantains;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>strawberries</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Vegetables</td>
<td>Cruciferous: broccoli (FA; NFA); brussel sprouts (FA; NFA);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cabbage/sauerkraut; cauliflower (FA; NFA); coleslaw</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leafy greens: lettuce mixtures; lettuce (not dark green; dark green); cooked</td>
</tr>
<tr>
<td></td>
<td></td>
<td>spinach/greens (FA; NFA); raw spinach/greens</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other: asparagus (FA; NFA); corn (FA; NFA); olives; onions (FA; NFA); other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>vegetables (FA; NFA); peas (FA; NFA); peppers (FA; NFA); hot peppers;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pickled vegetable/fruit; string beans (FA; NFA); vegetable medley (FA; NFA);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>vegetable juice; vegetable mixtures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yellow/orange: carrots (FA; NFA); sweet potatoes (FA; NFA);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>winter squash (FA; NFA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Herbs: dried oregano/rosemary/thyme; fresh basil/cilantro/parsley</td>
</tr>
<tr>
<td>Tomatoes</td>
<td></td>
<td>tomato catsup; tomato juice; tomato salsa; tomato sauce; cooked</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tomatoes; raw tomatoes</td>
</tr>
<tr>
<td>Potatoes</td>
<td></td>
<td>Cooked: potato salads; white potatoes (FA; NFA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fried: fried potatoes</td>
</tr>
<tr>
<td>Legumes</td>
<td>Legumes &amp; legume products</td>
<td>baked beans; beans (FA; NFA); soy burger or meat substitute; tofu</td>
</tr>
<tr>
<td>Dairy products, regular &amp;</td>
<td>Dairy products, regular &amp; high-fat</td>
<td>Regular-fat dairy: cottage/ricotta cheese; evaporated/condensed milk (in coffee/tea;</td>
</tr>
<tr>
<td>high-fat</td>
<td></td>
<td>sour cream (regular)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High-fat dairy: cream, reg or 1/2&amp;1/2 in coffee or tea; cream, reg,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>whipped; milk, whole not in coffee/tea; milk, whole, in cereal;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>milk, whole, in coffee or tea; milk/ chocolate, whole to drink;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>yoghurt/whole milk</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Regular-fat cheese: cheese mixtures; cheese (regular); cream cheese (regular)</td>
</tr>
<tr>
<td>Dairy products, low-fat</td>
<td></td>
<td>Low-fat dairy: 1% milk (in coffee/tea; not in coffee/tea; in cereal);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2% milk (in coffee/tea; not in coffee/tea; in cereal);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>non-fat/skim milk, (in coffee/tea; not in coffee/tea; in cereal);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>chocolate milk (reduced-fat); sour cream (low-fat); yoghurt (low-fat/non-fat)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low-fat cheese: cheese (low-fat); cream cheese (low-fat)</td>
</tr>
</tbody>
</table>

Table continues
<table>
<thead>
<tr>
<th>Carbohydrate food source</th>
<th>Food groupings</th>
<th>C-DHQ II food groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweetened products</td>
<td>Sweets</td>
<td>Frozen dessert: frozen yogurt/ices/sorbet/etc.; ice cream/ice milk (regular; low-fat)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Confectionary: candy; chocolate candy; chocolate/fudge/butterscotch toppings; dark chocolate; gelatins; puddings/custards</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jams/syrups/honey: jams/jelly (regular); maple syrup on pancakes/etc.; miscellaneous syrups/toppings; sugars/honey (in coffee/tea; not in coffee/tea)</td>
</tr>
<tr>
<td>Sweetened beverages, regular</td>
<td></td>
<td>coffee drinks with cream/sugar (regular; decaffeinated); decaffeinated energy drink (regular); fruit drinks (regular); milkshakes/sodas; decaffeinated soft drinks (regular); decaffeinated soft drinks (regular); sports drinks; bottled water (sweetened)</td>
</tr>
<tr>
<td>Eggs</td>
<td></td>
<td>eggs (regular; whites/substitutes); eggs salad</td>
</tr>
<tr>
<td>Fish &amp; seafood</td>
<td></td>
<td>battered/fish sticks; fish (NFA); salmon/fresh tuna/trout; shellfish (FA; NFA); canned tuna (oil pack; water pack); tuna salad</td>
</tr>
<tr>
<td>Meat</td>
<td></td>
<td>Lean: beef, burgers, lean; beef, steaks, lean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Regular: beef stews/pot pies/mixtures; beef burgers (regular); ground beef/meatballs/loaf/mixtures; beef roast; beef steaks (regular); ham; liver/liverwurst; pork; pork neck/feet/etc.; shortribs/spareribs; veal/venison/lamb (plain)</td>
</tr>
<tr>
<td>Processed meat</td>
<td></td>
<td>Lean: bacon (lean/Canadian); cold cuts (low-fat; poultry); cold cut ham/luncheon meat (low-fat); hot dogs (turkey/low-fat); sausage (turkey/low-fat)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Regular: bacon (regular); cold cuts (regular); cold cut ham/luncheon meat (regular); hot dogs (regular); roast beef in sandwich; sausage (regular)</td>
</tr>
<tr>
<td>Poultry</td>
<td></td>
<td>No skin: chicken without skin (dark; light); fried chicken without skin (dark; light); chicken mixtures; ground chicken/turkey; turkey</td>
</tr>
<tr>
<td></td>
<td></td>
<td>With skin: chicken with skin (dark; light); fried chicken with skin (dark; light)</td>
</tr>
<tr>
<td>Mixed dishes, Mexican &amp; other</td>
<td></td>
<td>Mexican: chili; Mexican mixtures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other: egg mixed dishes; egg rolls; fish mixed dishes; frozen meals; game foods; ham mixed dishes; hot dog mixed dishes; luncheon meat mixed dishes; pork mixed dishes; poutine; rice/grains mixed dishes; sushi; tuna mixed dishes; turkey mixed dishes; veal/venison/lamb dishes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fast food: beef, burgers with bun; beef cheeseburgers with bun; cheeseburger (fast food); hamburger (fast food)</td>
</tr>
<tr>
<td>Mixed dishes, pasta &amp; pizza</td>
<td></td>
<td>Pasta: lasagna/ravioli/shells/etc.; macaroni and cheese; pasta salad; meat/fish sauce pasta</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pizza: pizza (meat; without meat)</td>
</tr>
<tr>
<td>Soups</td>
<td></td>
<td>bean-type soups; broth soups with noodles/rice; creamed soups; vegetable soups</td>
</tr>
<tr>
<td>Snack foods</td>
<td></td>
<td>corn chips; meat-based snacks (jerky); popcorn; potato chips; pretzels</td>
</tr>
<tr>
<td>Nuts &amp; seeds</td>
<td></td>
<td>flaxseeds; nut seed mixtures; nuts, whole; nuts/seeds butters; other seeds; peanuts</td>
</tr>
<tr>
<td>Meal replacement</td>
<td></td>
<td>liquid meal replacement; meal replacement bar</td>
</tr>
</tbody>
</table>
Table 4.1 Continued

<table>
<thead>
<tr>
<th>Carbohydrate food source</th>
<th>Food groupings</th>
<th>C-DHQ II food groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-dairy products</td>
<td>Non-dairy creamer: liquid non-dairy creamer in coffee/tea (regular; diet); powdered non-dairy creamer in coffee/tea (regular; diet)</td>
<td>Other non-dairy products: whipped cream substitute; almond milk (in coffee/tea; not in coffee/tea; in cereal); other milk (not in tea/coffee); rice milk (in coffee/tea; not in coffee/tea; in cereal); soy milk (in coffee/tea; not in coffee/tea; in cereal)</td>
</tr>
<tr>
<td>Butter</td>
<td>butter for other uses (regular; reduced-fat); butter on bread (regular; reduced-fat); butter on pancakes/waffles (regular; reduced-fat); butter on potatoes (regular; reduced-fat); butter on vegetables (regular; reduced-fat)</td>
<td></td>
</tr>
<tr>
<td>Margarine</td>
<td>margarine for other uses (regular; reduced-fat); margarine on bread (regular; reduced-fat); margarine on pancakes/waffles (regular; reduced-fat); margarine on potatoes (regular; reduced-fat); margarine on vegetables (regular; reduced-fat)</td>
<td></td>
</tr>
<tr>
<td>Mayonnaise</td>
<td>mayonnaise on salad (regular; diet); mayonnaise diet on sandwich (regular; diet)</td>
<td></td>
</tr>
<tr>
<td>Oils, olive</td>
<td>olive oil</td>
<td></td>
</tr>
<tr>
<td>Oils, vegetable</td>
<td>oil sprays/Pam; canola oil; corn oil; other oil</td>
<td></td>
</tr>
<tr>
<td>Salad dressing</td>
<td>Regular: salad dressing on salad/vegetables (regular)</td>
<td>Low-fat: salad dressing on salad/vegetables (low-fat/fat-free)</td>
</tr>
<tr>
<td>Sauces, high-fat</td>
<td>cheese sauce; gravy; white sauce</td>
<td></td>
</tr>
<tr>
<td>Beer</td>
<td>beer</td>
<td></td>
</tr>
<tr>
<td>Liquor</td>
<td>liquor alcoholic beverage; alcoholic beverage mixtures</td>
<td></td>
</tr>
<tr>
<td>Wine</td>
<td>red wine; other wine</td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>coffee without cream/sugar (regular; decaffeinated); coffee with cream/sugar (regular)</td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>hot/cold herbal tea; tea without cream/sugar (regular; decaffeinated); tea with cream/sugar (regular)</td>
<td></td>
</tr>
<tr>
<td>Unsweetened beverages</td>
<td>bottled water (fortified; unsweetened); tap water</td>
<td></td>
</tr>
<tr>
<td>Sweetened beverages, diet</td>
<td>fruit drinks (diet); caffeinated soft drinks (diet); decaffeinated soft drinks (diet)</td>
<td></td>
</tr>
<tr>
<td>Artificial sweeteners</td>
<td>artificial sweeteners; aspartame; saccharin; Splenda</td>
<td></td>
</tr>
<tr>
<td>Animal fat</td>
<td>lard fatback/bacon fat</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>miscellaneous (i.e. flour batter, baking cocoa); sauces (excluding gravy and tomato sauce)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: C-DHQ II, Canadian Diet History Questionnaire II; FA, fat added; NFA, no fat added.
**Table 4.2** Correlations between dietary exposure variables and total energy intake (kcal/d)

<table>
<thead>
<tr>
<th>Dietary exposure variable</th>
<th>Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total carbohydrate intake (g/d)</td>
<td>0.91</td>
</tr>
<tr>
<td>Total dietary fibre intake (g/d)</td>
<td>0.68</td>
</tr>
<tr>
<td>Western dietary pattern score</td>
<td>0.71</td>
</tr>
<tr>
<td>Prudent dietary pattern score</td>
<td>0.54</td>
</tr>
<tr>
<td>Dietary glycemic index</td>
<td>0.12</td>
</tr>
<tr>
<td>Dietary glycemic load</td>
<td>0.90</td>
</tr>
</tbody>
</table>
Figure 4.1 Steps for assigning glycemic index values to the Canadian Diet History Questionnaire II nutrient database.
Figure 4.2 Scatterplots of the relationships between body mass index and (A) trunk fat mass ($r = 0.92$) and (B) waist circumference ($r = 0.90$) ($N = 357$).
Chapter 5
Manuscript 1:
Dietary sources of carbohydrate and dietary fibre are associated with trunk fat mass in postmenopausal women

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5.1 Abstract

**Background:** Research on the relationships of carbohydrate and dietary fibre intake with abdominal adiposity is limited, but findings suggest that carbohydrate quality may play a role.

**Objectives:** The objectives were to examine the associations of total carbohydrate and dietary fibre intake with abdominal adiposity among a group of Canadian postmenopausal women, and to determine if associations varied by food source.

**Methods:** This cross-sectional study included 348 postmenopausal women, aged 50–69 years. The Canadian Diet History Questionnaire II (C-DHQ II) was used to assess past-year usual dietary intake. Trunk fat mass, measured directly by dual-energy x-ray absorptiometry (DXA), characterized abdominal adiposity. Multivariable linear regression was used to examine associations of total and food sources of carbohydrate and fibre intake with trunk fat mass, adjusting for energy intake and covariates.

**Results:** Total dietary fibre intake was inversely associated with trunk fat mass ($\beta = -0.127$ kg; 95% confidence interval, CI: $-0.210$, $-0.044$). Total carbohydrate intake was not associated
with trunk fat when accounting for fibre intake. Carbohydrate from potatoes and grains were positively ($\beta = 0.096$ kg; 95% CI: 0.019, 0.173) and inversely ($\beta = -0.048$ kg; 95% CI: $-0.083, -0.012$) associated with trunk fat, respectively, independent of other carbohydrate sources and energy. After accounting for total carbohydrate, carbohydrate from potatoes, breakfast cereals and baked products, as well as dairy products were positively associated with trunk fat. Fibre intake from potatoes and grains were also positively ($\beta = 1.110$ kg; 95% CI: 0.157, 2.064) and inversely ($\beta = -1.382$ kg; 95% CI: $-2.678, -0.086$) associated with trunk fat, respectively, independent of other fibre sources and energy. After adjustment for total fibre, these associations remained and fibre from breakfast cereals and baked products as well as vegetables were positively associated with trunk fat.

**Conclusions:** The contrasting effects of carbohydrate and dietary fibre intake from different sources on trunk fat mass support the importance of the type and quality of carbohydrate and fibre in abdominal adiposity among postmenopausal women.

**Keywords:** carbohydrate, dietary fibre, abdominal adiposity, trunk fat, dual-energy x-ray absorptiometry, postmenopausal women
5.2 Introduction

In Canada, the burden of obesity among adults has increased substantially over the past three decades. The prevalence of obesity, defined by a body mass index (BMI) of 30 or greater, was estimated to be 18.3% in 2011 (according to the Canadian Community Health Survey) (1) compared to 6.1% in 1985 (according to the Health Promotion Survey) (1, 2). A significant increasing trend in the prevalence of abdominal obesity has also been observed. The number of abdominally obese (i.e. waist circumference ≥102 cm for men and ≥88 cm for women) Canadians aged 20 to 69 years has increased by approximately 24% between 1981 and 2007–2009 (3). It was estimated that, in the 2007–2009 period, 30.7% of adult men and 40.6% of adult women were abdominally obese (3). These trends are concerning because abdominal obesity is a strong risk factor for increased morbidity and mortality, independent of general obesity (4–6).

The accumulation of abdominal adipose tissue is hypothesized to contribute to the pathogenesis of obesity-related health risks due to the detrimental metabolic and endocrine activities of this adipose tissue depot (4, 7). Research has shown that genetic factors, age, sex, and ethnicity are non-modifiable factors associated with the amount of abdominal adipose tissue (8). However, epidemiologic studies on the relationship between modifiable dietary factors and measures of abdominal adiposity, independent of BMI, are more limited.

The effect of dietary carbohydrates on abdominal adiposity is of interest because it is a major constituent of the diet and may constitute 45 to 70% of total energy intake (9). Dietary carbohydrates are comprised of simple sugars and polysaccharides that have different physiological effects in terms of digestion, absorption, and metabolism (9, 10). Two previous prospective studies found that total carbohydrate intake was not associated with a change in waist circumference adjusted for BMI (11, 12). To our knowledge, only one study examined the relationship between different sources of carbohydrate and abdominal fat. This study reported varied associations for subgroups of carbohydrate intake among women, but not among men (12). The Joint Food and Agriculture Organization/World Health Organization Scientific Update on Carbohydrates in Human Nutrition defines dietary fibre as “intrinsic plant cell wall polysaccharides” (10). Dietary fibre is found in the cell walls of fruit, vegetables, and whole grains and has been shown to have positive health effects (10, 13). Total dietary fibre intake was associated with decreased abdominal adiposity in several cross-sectional and prospective studies of adults (11, 14–16), but no association was found in another cross-sectional study of older
adults (17). The relationship between various food sources of dietary fibre and abdominal adiposity was also inconsistent among studies (14, 16, 17).

Based on the emerging literature, we hypothesized a priori that the amount and type of carbohydrate intake are associated with abdominal adiposity. Therefore, the objective of this study was to examine the associations between total carbohydrate and total dietary fibre intake and abdominal adiposity, as defined by dual-energy x-ray absorptiometry (DXA) trunk fat mass, among postmenopausal women. Additionally, we aimed to determine if the associations differed according to the food sources of carbohydrate and dietary fibre. Most published studies have used anthropometric measures of abdominal adiposity. This study adds to the existing literature by examining these relationships using DXA measures to objectively and more accurately quantify the amount of abdominal adipose tissue.

5.3 Methods

5.3.1 Study population

In this analysis, we examined data from a study designed to investigate the associations between body composition and breast cancer-related biomarkers. This was a cross-sectional study of postmenopausal women from the Toronto, Ontario area. Participants were primarily recruited through a list of women from the provincial breast cancer screening program who consented to be contacted for research. Other methods of recruitment included advertisements in local hospitals and word-of-mouth. Eligible women were between the ages of 50 to 69 years, had their last menstrual period more than 12 months earlier without surgical intervention or had both ovaries removed (i.e. postmenopausal), did not have breast cancer, and were not taking any prescription hormone medications at the time of the study. The study was conducted from September 2011 to January 2014, during which 382 women participated. For the current study, 348 participants were included in the analyses. The reasons for exclusion were the following: the DXA scan was not performed (n = 1); the dietary intake questionnaire was not completed (n = 16); total energy intake was in the lower (<566.9 kcal/d) or upper (>3,597.4 kcal/d) 1% of the study population and deemed to be implausible levels of intake over the long-term (n = 7); and invalid responses of greater than 960 minutes of physical activity per day on the physical activity questionnaire (n = 10). This study was approved by the Mount Sinai Hospital Research Ethics
Board and the University of Toronto Human Research Ethics Board. Written informed consent was obtained from all study participants at the beginning of the study visit.

5.3.2 Dietary intake assessment

Usual dietary intake for the past year was assessed using the Canadian Diet History Questionnaire II (C-DHQ II) (18, 19). The questionnaire was mailed to participants following their study visit and participants were asked to complete and return the questionnaire via mail. Participants were not provided with their body composition results before completing the diet questionnaire and we made follow-up telephone calls to ensure completion. The response rate for the diet questionnaire was 96%.

The C-DHQ II is an updated version of a comprehensive food frequency questionnaire (FFQ) that was modified from the U.S. National Cancer Institute Diet History Questionnaire (US-DHQ) for use in Canadian populations (20). The C-DHQ II is comprised of 152 food questions and 11 nutritional supplements questions (18). For each food, the C-DHQ II assesses frequency of intake from a list of nine or ten options and three portion size choices. Specific foods also contain embedded questions that assess variations in seasonal intake, types of foods, and additions to foods. Nutrient analysis of the C-DHQ II data was performed using Diet*Calc software (version 1.5.0, National Cancer Institute, Applied Research Program, October 2012) and the C-DHQ II nutrient database. The nutrient database is based on the nutrient profiles of foods included on the C-DHQ II from the Canadian Community Health Survey, Cycle 2.2 (CCHS 2.2), Nutrition (2004) (19–22). Summary daily and question-specific intakes were estimated for energy, macronutrients, and micronutrients for each participant. The dietary variables of interest were total carbohydrate intake (g/d) and total dietary fibre intake (g/d). Carbohydrate and dietary fibre intake from specific food sources were also examined. Foods on the C-DHQ II were classified according to eight food sources which have high carbohydrate content. The food sources were: grains, breakfast cereals and baked products, fruit, vegetables, potatoes, legumes, dairy products, and sweetened products. The amounts of carbohydrate and dietary fibre intake of individual foods in each category were summed to derive total nutrient intakes from each food source. Since dietary fibre from dairy products and sweetened products were very low, fibre intakes from these food sources were subsequently excluded from the analyses.
5.3.3 Body fat distribution assessment

Whole-body DXA scans were performed at the study visits using the Hologic Discovery A DXA system (Hologic, Inc., Bedford, Massachusetts). DXA is a valid and reliable method for assessing body composition (23, 24). This imaging method is able to distinguish between fat mass, lean mass, and bone mineral content (23, 24). Hologic APEX software, version 3.3 (Hologic, Inc.) was used to provide whole-body and regional analysis of the DXA scans. The analysis provided measures of the three types of body tissue for the total body, as well as the trunk, arm, and leg regions. For this study, fat mass (kg) from the standard trunk region was the measure of abdominal adiposity. DXA measures of trunk fat mass have been shown to be strongly correlated with abdominal visceral adipose tissue (VAT) measures from computed tomography, which is the gold standard measure of this adipose tissue depot (25). These correlations range from 0.61 to 0.84, depending on sex and ethnicity (26).

5.3.4 Covariate assessment

Demographic, lifestyle, and health information were collected through an interviewer-administered questionnaire during the study visit. Potential confounding variables examined in the analyses included age, ethnicity (European or non-European descent), and lifestyle covariates. Regular alcohol use (i.e. at least once per week) was categorized into never, former, or current use. Current alcohol use was further categorized into five or fewer drinks per week and greater than five drinks per week, where a drink was defined as an alcoholic beverage containing 13.5 g of pure alcohol (27). Smoking status was classified as never, former, and current smoker. Physical activity levels were assessed using the long form International Physical Activity Questionnaire (IPAQ) (28, 29). Total physical activity was categorized into low, moderate, or high physical activity levels based on the frequency, duration, and intensity of work, transportation, and leisure physical activities. The dietary covariates included in the analyses were total energy intake (kcal/d), total carbohydrate intake (g/d), and total dietary fibre intake (g/d).

5.3.5 Statistical analyses

Multivariable linear regression analyses were used to examine the associations between dietary variables and trunk fat mass. The distributions of all variables were examined prior to regression analyses. Total carbohydrate and total dietary fibre intakes were analyzed in the same model and
total energy intake was also included. The nutrient density method of energy adjustment was also examined and produced comparable results to the standard multivariate model (results not shown). We selected the standard multivariate approach for energy adjustment to represent the effect of varying absolute amounts of carbohydrate and dietary fibre in an isocaloric diet (30). Since dietary fibre is a subcomponent of total carbohydrate and the analysis included both dietary variables simultaneously, the regression coefficient for total carbohydrate intake represents the association between available carbohydrate intake (i.e. carbohydrate excluding dietary fibre) and trunk fat mass, independent of fibre intake, in this substitution model. The regression coefficient for dietary fibre intake is the association of fibre intake with trunk fat mass, independent of total carbohydrate intake. A sensitivity analysis compared this model to a model with available carbohydrate, calculated by subtracting dietary fibre from total carbohydrate, and total dietary fibre intakes (Supplemental Table 5.1). The results of the two models were similar.

Carbohydrate intake from eight food sources and dietary fibre intake from six food sources were analyzed separately, using two different approaches. First, the independent associations of sources of carbohydrate or dietary fibre intake on trunk fat mass were examined by including the amounts of nutrient intake from each source simultaneously in the same model (Model 1). Thus, each food source of carbohydrate intake was adjusted for the other seven food sources in the model (i.e. mutual adjustment), while each food source of dietary fibre intake was adjusted for the other five food sources. Total energy intake was also included in these models using the standard multivariate method. The regression coefficient for each source of carbohydrate or fibre is the association of the specific nutrient source with trunk fat mass, independent of the other nutrient food sources in the model and total energy intake. As such, the coefficients can be interpreted as the difference in trunk fat mass associated with substituting 1 g/d of the specific carbohydrate or fibre source for an equivalent amount of energy from a source not specified in the model, while the other nutrient food sources and total energy are held constant (31). The second approach was a substitution model, which considered the associations of carbohydrate or dietary fibre food sources in relation to other sources of these nutrients (Model 2). In these models, sources of carbohydrate or fibre were modeled simultaneously (i.e. mutual adjustment), together with total carbohydrate or fibre intake and total energy intake. The regression coefficient for each source of carbohydrate or fibre is the association of the specific nutrient
source with trunk fat mass, independent of the other nutrient food sources in the model, total carbohydrate or fibre, and total energy. Since this is a substitution model, total carbohydrate or dietary fibre represents all other sources of carbohydrate or fibre not specified in the model. Therefore, the regression coefficients can be interpreted as the differences in trunk fat mass associated with substituting 1 g/d of the specific carbohydrate or fibre source for the same amount of other unspecified sources of carbohydrate or fibre, while other nutrient sources, total carbohydrate or fibre, and total energy are held constant (31).

Potential confounding variables for the multivariable analyses were identified using the change-in-estimate approach (32). Covariates that changed the coefficients of the dietary variables of interest by 10% or greater were included in the models (32). Of the demographic and lifestyle covariates, only alcohol use and physical activity level met the criteria. However, the multivariable models also included adjustment for age and ethnicity since these are strong predictors of abdominal adiposity. For the analyses of food sources of carbohydrate intake, additional adjustment for dietary fibre was investigated. The analyses of dietary fibre food sources were also adjusted for total carbohydrate intake. All statistical analyses were conducted using Stata 13 (StataCorp, College Station, Texas), with two-sided P values <0.05 considered significant. Ethnicity was examined as a potential effect modifier, but the interaction term was not statistically significant.

5.4 Results

Characteristics of the study population are presented in Table 5.1. Participants were postmenopausal women predominantly of European ethnicity. Approximately three-quarters of the study participants had low or moderate levels of physical activity. Among study participants, about half were current alcohol users, and only a small percent were current smokers. Over 50% of study participants were classified as overweight or obese based on BMI. The mean percent fat of the trunk region was similar to the mean percent fat of the total body. The mean energy intake of study participants was in accordance with the estimated energy requirement for our study population of postmenopausal women, calculated using the mean age, weight, and height (33). The mean ± SD percentage of total energy intake from carbohydrate, protein, and fat were 49.7 ± 8.6%, 16.7 ± 3.1%, and 33.5 ± 6.9%, respectively. The mean carbohydrate, protein, and fat intakes were within the acceptable macronutrient distribution ranges (33). Additionally, the
mean total dietary fibre intake was on par with the recommended adequate intake of 21 g/d for women aged 50 and older (33). The food sources with the greatest mean carbohydrate and dietary fibre intakes were fruit and vegetables, respectively (Table 5.2).

Table 5.3 presents findings from the simultaneous analysis of total carbohydrate and total dietary fibre intake, adjusted for covariates. Total dietary fibre intake was inversely associated with trunk fat mass in this population of postmenopausal women, independent of total carbohydrate intake. For example, each 1-SD (9.4 g/d) increase of dietary fibre intake was associated with $-1.19$ kg difference in trunk fat mass ($P < 0.001$). However, the association between total carbohydrate intake and trunk fat mass was only borderline statistically significant, after accounting for total fibre intake ($P = 0.06$). Similar results were found in a model of the simultaneous analysis of available carbohydrate (total carbohydrate minus fibre) and total dietary fibre intakes, adjusted for covariates (Supplemental Table 5.1). The inverse association of fibre intake with trunk fat mass was slightly stronger in this model.

The independent associations between individual food sources of carbohydrate intake and trunk fat mass varied significantly in these postmenopausal women (Table 5.4). As shown in Model 1, the intakes of carbohydrate from grains as well as fruit were inversely associated with trunk fat mass, independent of the other seven sources of carbohydrate and total energy intakes (Figure 5.1A and Figure 5.1B). In contrast, carbohydrate intake from potatoes was positively associated with trunk fat mass, when accounting for intake of the other carbohydrate sources and total energy (Figure 5.1C). Model 2 shows the associations between each source of carbohydrate and trunk fat mass, controlling for the other seven sources of carbohydrate and total energy intakes, as in Model 1, but also accounting for total carbohydrate intake (Table 5.4). The positive association for potato sources of carbohydrate intake remained statistically significant. Thus, the substitution of 5 g of carbohydrate from potatoes for 5 g of carbohydrate from unspecified sources was associated with 0.71 kg increase of trunk fat mass, with the other sources of carbohydrate, total carbohydrate, and total energy held constant. Carbohydrate intakes from grains as well as fruit were no longer significant in this model. However, carbohydrate from breakfast cereals and baked products as well as dairy products were positively associated with trunk fat mass. Replacing 5 g of carbohydrate from breakfast cereals and baked products or dairy products for 5 g of carbohydrate from unspecified sources was associated with 0.28 kg or 0.37 kg greater trunk fat mass, respectively, after accounting for the other sources of
carbohydrate, total carbohydrate, and total energy. Further adjustment for total dietary fibre intake did not have a considerable effect on the significant associations for carbohydrate from grains or potatoes in Model 1, or for carbohydrate from potatoes, breakfast cereals and baked products, or dairy products in Model 2. However, adjusting for total fibre intake attenuated the independent association between carbohydrate intake from fruit sources and trunk fat mass in Model 1 and was no longer statistically significant. Carbohydrate intake from vegetable sources also became significantly, positively associated with trunk fat mass after accounting for total dietary fibre intake in Model 2.

Differences in the associations of sources of dietary fibre with trunk fat mass were also observed among these postmenopausal women (Table 5.5). In Model 1, there were strong, significant associations between dietary fibre intake from grains as well as potatoes and trunk fat mass, independent of the other five sources of fibre, total carbohydrate, and total energy intakes. The intake of dietary fibre from grain sources was independently associated with lower trunk fat mass, while dietary fibre from potatoes was independently associated with greater trunk fat mass (Figure 5.2A and Figure 5.2B). These findings were similar to the relationships of carbohydrate from grains and potatoes with trunk fat mass. Unlike the association for carbohydrate from fruit, the inverse association with dietary fibre from fruit did not reach significance, after accounting for the other fibre sources, total carbohydrate intake, and total energy intake ($P = 0.08$). Similar to the significant, independent associations found in Model 1, in Model 2, fibre intake from potatoes was positively associated with trunk fat mass while fibre from grains had a borderline statistically significant inverse association with trunk fat mass ($P = 0.06$), with the other five sources of dietary fibre, total dietary fibre, total carbohydrate, and total energy held constant. As such, substituting 5 g of dietary fibre from grains or potatoes for 5 g of dietary fibre from unspecified sources was associated with 6.1 kg lower or 6.3 kg greater trunk fat mass, respectively. Interestingly, dietary fibre intake from breakfast cereals and baked products as well as vegetables were positively associated with trunk fat mass, after accounting for total dietary fibre in addition to the other sources of fibre, total carbohydrate, and total energy. Thus, replacing 5 g of breakfast cereals and baked products or vegetables of dietary fibre for 5 g of fibre from unspecified sources was associated with 2.5 kg or 1.9 kg greater trunk fat mass, respectively. Additionally, unspecified sources of dietary fibre, represented by total dietary fibre in the model, was significantly, inversely associated with trunk fat mass, independent of the six
sources of dietary fibre, total carbohydrate and total energy intakes. These unspecified food sources include foods that are not major sources of carbohydrate intake but are relatively high in fibre (e.g. nuts and seeds) since food sources were chosen based on carbohydrate instead of fibre content.

5.5 Discussion

In this cross-sectional study of postmenopausal women, we found that the intake of total dietary fibre, but not total carbohydrate, was statistically significantly associated with decreased abdominal adiposity, as measured by DXA trunk fat mass, in a mutually adjusted model. Overall, potato sources of carbohydrate and fibre were most consistently associated with trunk fat mass. Our analyses showed that substituting carbohydrate intake from potatoes for an equal amount of energy from other energy sources (Model 1) or from other unspecified carbohydrate sources (Model 2) were associated with greater trunk fat mass, independent of the other carbohydrate sources and total energy, as well as total fibre. Similarly, dietary fibre intake from potatoes was positively associated with trunk fat mass, independent of the other fibre sources, total carbohydrate, and total energy, in both models. Associations for other food sources depended on the model. After also accounting for total carbohydrate, an inverse association between carbohydrate from grains and trunk fat mass was no longer observed, while positive associations for carbohydrate from breakfast cereals and baked products as well as dairy products became apparent. Dietary fibre from grains was inversely associated with trunk fat mass and became borderline statistically significant with further adjustment for total fibre. Fibre from breakfast cereals and baked products was positively associated with trunk fat mass, only after also adjusting for total fibre.

Our finding for total carbohydrate intake in postmenopausal women agrees with cohort studies that found no significant associations between total carbohydrate and change in waist circumference in various populations (11, 12). Using an energy partition model, Halkjaer et al. (12) found that carbohydrate from refined-grain products plus potatoes was positively associated with abdominal adiposity, while carbohydrate from fruit plus vegetables was inversely associated with abdominal adiposity. We used more narrowly defined food groups and found associations in the same directions for carbohydrate from potatoes in both models, and carbohydrate from fruit in the model adjusting for total energy and other carbohydrate sources only. Halkjaer et al.
(12) did not find a significant association for carbohydrate from whole-grain products. In contrast, we found that carbohydrate from grains was associated with less trunk adiposity after adjusting for total energy and other carbohydrate sources, but was not significant after also adjusting for total carbohydrates. Differences in results may be due to our inability separate whole- and refined-grain sources and their effects.

We found an inverse association between total dietary fibre intake and trunk fat mass independent of total carbohydrate and energy, which was consistent with findings from a large European cohort (11, 14) and cross-sectional studies (15, 16) that used anthropometric measures of abdominal adiposity. However, a cross-sectional study that used DXA percent trunk fat mass as a measure of abdominal adiposity did not find a significant association (17). This difference may be because McKeown et al. (17) defined the trunk region as the area between the L2 and iliac crest, while we defined the standard trunk region as the area excluding the head, arms, and legs. Also, their study population was older and included both females and males (17). The associations of dietary fibre sources with abdominal adiposity are not consistent among studies, likely due at least in part to variations in the categorization of food sources. Studies have reported an inverse association for cereal (14, 17) and fruit (14, 16) fibre, while no associations were found in other studies of these fibre sources (16, 17). We observed an inverse association for fibre from grains with trunk fat mass in both models, while there was a positive association for fibre from breakfast cereals and baked products, only after also accounting for total fibre. We did not find significant associations between fibre from fruit and trunk fat mass in either model. However, we found that fibre from potatoes was associated with greater trunk fat mass in both models, which, to our knowledge, has not been examined.

A hypothesized mechanism through which dietary fibre intake may have beneficial effects on weight and abdominal adiposity is by reduced insulin secretion, leading to greater fat oxidation and reduced fat storage (34). This may be caused by the effect of fibre on the release of gut hormones or fermentation of fibre in the colon (34). However, in this study of postmenopausal women, the contrasting associations of dietary fibre from grains and potatoes with abdominal adiposity suggest that the type of fibre may affect abdominal adipose tissue accumulation. We also found that further adjusting for total dietary fibre attenuated the association between carbohydrate from fruit and trunk fat mass, but dietary fibre from fruit was not independently associated with trunk fat mass. Moreover, the association for carbohydrate from vegetable,
independent of total carbohydrate, became significant after further adjusting for dietary fibre. These findings suggest that factors, other than fibre, may play a role in the relationship between abdominal adiposity, such as patterns of food intake, other nutrients in foods, or other characteristics of carbohydrate (i.e. type or quality). A possible mechanism for abdominal fat accumulation is through the glycemic response elicited by carbohydrates. Foods that produce a high glycemic response cause insulin levels to increase rapidly and may affect abdominal adiposity by increasing glucose oxidation, while decreasing fat oxidation (35).

This study adds to the limited existing research on the associations between carbohydrate intake and abdominal adiposity. A strength of this study is that we used a direct measure of fat mass in the abdominal region, whereas most studies have used anthropometric measures. However, DXA trunk fat mass cannot differentiate between subcutaneous and visceral abdominal adipose tissue, but is strongly correlated with visceral fat (26). This study also had adequate power to detect significant associations of interest. Our sample size of 348 participants is in accordance with recommendations of 20 subjects per variable (36), as our models had up to 17 variables. We restricted the study population to postmenopausal women, so our findings are generalizable to other populations with similar characteristics. However, the volunteer study population may have healthier behaviours that affect both dietary intake and abdominal adiposity, although lifestyle factors were included as potential confounders in the analyses.

There are other methodological issues to consider when interpreting this study’s findings. Firstly, a temporal sequence cannot be established between carbohydrate intake and trunk fat mass because of the cross-sectional design, so a causal association cannot be inferred directly. However, diet is relatively stable in adulthood (37, 38) and current diet likely indicates diet over a lengthy past period. Also, the complex cooperative effects of foods and nutrients consumed together are difficult to discern in cross-sectional analyses of the associations of dietary factors with health outcomes. We used two modeling approaches to consider the effects of each source of carbohydrate and fibre in relation to both another source of energy (Model 1) and unspecified nutrient sources (Model 2). Analyses of dietary patterns would also advance our understanding of the cooperative effects of foods on health outcomes. There are also limitations to the dietary intake assessment method. The list of queried foods on the FFQ may be incomplete. Also, due to limitations of the nutrient database, we could not examine soluble and insoluble fibre, which are hypothesized to have different mechanisms of action (13, 34). Moreover, dietary intake was
self-reported, which is known to be a potential source of random and systematic measurement error. Underreporting of dietary intake is particularly problematic in individuals with obesity (39). To partially mitigate this, participants were blinded to their body composition results until the diet questionnaire was completed. Participants with extremely low or high total energy intakes were also excluded from the analyses to address outliers.

In conclusion, the varied associations between carbohydrate and dietary fibre food sources and trunk fat mass support the importance of the amount, type, and quality of carbohydrate intake in abdominal adipose tissue accumulation among postmenopausal women; however, longitudinal studies are required to further investigate these findings. Research examining other measures of carbohydrate quality, such as glycemic index and load (GI and GL), and abdominal adiposity is also warranted. This epidemiologic research may inform future studies on the biological mechanisms that affect body fat distribution and abdominal fat gain. Furthermore, elucidating modifiable dietary risk factors for abdominal adiposity can contribute to the future development of dietary recommendations and prevention strategies.

5.6 Acknowledgments

We would like to thank Rosemary Sousa and Jody Wong of the Lunenfeld-Tanenbaum Research Institute for conducting the data collection. F. G. L., A. J. H., V. A. K., and J. A. K. designed the research; J. A. K. designed the larger study on body composition and breast cancer related biomarkers; F. G. L. performed statistical analyses, wrote paper, and had primary responsibility for final content; I. C., A. J. H., V. A. K., and J. A. K. provided instrumental feedback on the analyses and manuscript. All authors read and approved the final manuscript.
5.7 References


Table 5.1  Characteristics of postmenopausal women in the study population

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>( N = 348^a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>62.0 ± 4.0</td>
</tr>
<tr>
<td>Ethnicity, %</td>
<td></td>
</tr>
<tr>
<td>European</td>
<td>85.1</td>
</tr>
<tr>
<td>Other</td>
<td>14.9</td>
</tr>
<tr>
<td>Physical activity level, %</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>35.9</td>
</tr>
<tr>
<td>Moderate</td>
<td>49.7</td>
</tr>
<tr>
<td>High</td>
<td>14.4</td>
</tr>
<tr>
<td>Alcohol use, %</td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>36.8</td>
</tr>
<tr>
<td>Former</td>
<td>10.9</td>
</tr>
<tr>
<td>Current: ≤5 drinks/week(^b)</td>
<td>31.0</td>
</tr>
<tr>
<td>Current: &gt;5 drinks/week(^b)</td>
<td>21.3</td>
</tr>
<tr>
<td>Smoking, %</td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>51.2</td>
</tr>
<tr>
<td>Former</td>
<td>42.2</td>
</tr>
<tr>
<td>Current</td>
<td>6.6</td>
</tr>
<tr>
<td>Body fat distribution</td>
<td></td>
</tr>
<tr>
<td>Body mass index, %</td>
<td></td>
</tr>
<tr>
<td>Underweight (&lt;18.5 kg/m(^2))</td>
<td>2.0</td>
</tr>
<tr>
<td>Normal weight (18.5–24.9 kg/m(^2))</td>
<td>44.3</td>
</tr>
<tr>
<td>Overweight (25–29.9 kg/m(^2))</td>
<td>31.0</td>
</tr>
<tr>
<td>Obese (≥30 kg/m(^2))</td>
<td>22.7</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>88.2 ± 12.9</td>
</tr>
<tr>
<td>Total body fat mass, kg</td>
<td>29.0 ± 10.1</td>
</tr>
<tr>
<td>Total body % fat</td>
<td>40.3 ± 6.3</td>
</tr>
<tr>
<td>Trunk fat mass, kg</td>
<td>13.3 ± 5.3</td>
</tr>
<tr>
<td>Trunk % fat</td>
<td>38.3 ± 7.7</td>
</tr>
<tr>
<td>Dietary intake</td>
<td></td>
</tr>
<tr>
<td>Energy, kcal/d</td>
<td>1,542 ± 532</td>
</tr>
<tr>
<td>Total protein, g/d</td>
<td>64.5 ± 25.9</td>
</tr>
<tr>
<td>Total fat, g/d</td>
<td>58.0 ± 25.2</td>
</tr>
<tr>
<td>Total Carbohydrate, g/d</td>
<td>190 ± 70.8</td>
</tr>
<tr>
<td>Dietary fibre, g/d</td>
<td>20.3 ± 9.4</td>
</tr>
</tbody>
</table>

\(^a\)Values are means ± SDs or percentages.

\(^b\)A drink was defined as an alcoholic beverage containing 13.5 g of pure alcohol.
Table 5.2  Carbohydrate and dietary fibre intakes from food sources of postmenopausal women in the study population

<table>
<thead>
<tr>
<th>Food Source</th>
<th>Carbohydrate intake, g/d</th>
<th>Dietary fibre, g/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grains</td>
<td>12.1 ± 18.2</td>
<td>0.4 ± 0.5</td>
</tr>
<tr>
<td>Breakfast cereals &amp; baked products</td>
<td>36.8 ± 24.2</td>
<td>3.3 ± 2.5</td>
</tr>
<tr>
<td>Fruit</td>
<td>44.9 ± 34.5</td>
<td>5.2 ± 3.7</td>
</tr>
<tr>
<td>Vegetables</td>
<td>21.3 ± 15.7</td>
<td>6.1 ± 5.4</td>
</tr>
<tr>
<td>Potatoes</td>
<td>5.9 ± 8.0</td>
<td>0.5 ± 0.6</td>
</tr>
<tr>
<td>Legumes</td>
<td>2.8 ± 4.4</td>
<td>0.7 ± 1.0</td>
</tr>
</tbody>
</table>

aValues are means ± SDs.

Table 5.3  Associations of total carbohydrate and total dietary fibre intake with trunk fat mass (kg) in postmenopausal women (N = 348)

<table>
<thead>
<tr>
<th></th>
<th>β (95% CI)a</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total carbohydrate, g/d</td>
<td>−0.018 (−0.037, 0.001)</td>
<td>0.06</td>
</tr>
<tr>
<td>Total dietary fibre, g/d</td>
<td>−0.127 (−0.210, −0.044)</td>
<td>0.003</td>
</tr>
</tbody>
</table>

aβ (95% CI) is the association for each 1-g/d increase in nutrient intake. Adjusted for total carbohydrate intake or total dietary fibre intake (mutually adjusted), total energy intake, age, ethnicity, physical activity level, and alcohol use. Total carbohydrate intake has a borderline statistically significant inverse association with trunk fat mass, independent of total dietary fibre intake. Total dietary fibre intake has a significant inverse association with trunk fat mass, independent of total carbohydrate intake.
Table 5.4: Associations between carbohydrate intake from eight food sources and trunk fat mass (kg) in postmenopausal women, with and without adjustment for total dietary fibre intake (g/d) (N = 348)

<table>
<thead>
<tr>
<th>Food Source</th>
<th>Unadjusted for dietary fibre intake</th>
<th>Adjusted for dietary fibre intake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β (95% CI)</td>
<td>P-value</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------</td>
<td>---------</td>
</tr>
<tr>
<td><strong>Model 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbohydrate intake, g/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grains</td>
<td>-0.048 (-0.083, -0.012)</td>
<td>0.008</td>
</tr>
<tr>
<td>Breakfast cereals &amp; baked products</td>
<td>0.012 (0.016, 0.041)</td>
<td>0.39</td>
</tr>
<tr>
<td>Fruit</td>
<td>-0.031 (-0.048, -0.013)</td>
<td>0.001</td>
</tr>
<tr>
<td>Vegetables</td>
<td>-0.016 (-0.060, 0.028)</td>
<td>0.47</td>
</tr>
<tr>
<td>Potatoes</td>
<td>0.096 (0.019, 0.173)</td>
<td>0.02</td>
</tr>
<tr>
<td>Legumes</td>
<td>-0.006 (-0.140, 0.127)</td>
<td>0.92</td>
</tr>
<tr>
<td>Dairy products</td>
<td>0.033 (-0.010, 0.076)</td>
<td>0.13</td>
</tr>
<tr>
<td>Sweetened products</td>
<td>-0.016 (-0.049, 0.017)</td>
<td>0.35</td>
</tr>
<tr>
<td><strong>Model 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbohydrate intake, g/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grains</td>
<td>-0.004 (-0.061, 0.053)</td>
<td>0.89</td>
</tr>
<tr>
<td>Breakfast cereals &amp; baked products</td>
<td>0.055 (0.003, 0.108)</td>
<td>0.04</td>
</tr>
<tr>
<td>Fruit</td>
<td>0.015 (-0.035, 0.066)</td>
<td>0.55</td>
</tr>
<tr>
<td>Vegetables</td>
<td>0.027 (-0.036, 0.089)</td>
<td>0.40</td>
</tr>
<tr>
<td>Potatoes</td>
<td>0.141 (0.051, 0.230)</td>
<td>0.002</td>
</tr>
<tr>
<td>Legumes</td>
<td>0.047 (-0.096, 0.191)</td>
<td>0.52</td>
</tr>
<tr>
<td>Dairy products</td>
<td>0.073 (0.014, 0.132)</td>
<td>0.02</td>
</tr>
<tr>
<td>Sweetened products</td>
<td>0.032 (-0.027, 0.090)</td>
<td>0.29</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>-0.055 (-0.111, 0.002)</td>
<td>0.06</td>
</tr>
</tbody>
</table>

*a* Adjusted for total energy intake, age, ethnicity, physical activity, and alcohol use. Carbohydrate intake from grains, breakfast cereals & baked products, fruit, vegetables, potatoes, legumes, dairy products, and sweetened products are mutually adjusted. β (95% CI) are the associations for each 1-g/d increase of carbohydrate intake from the food source, independent of other food sources of carbohydrate and total energy intakes.

*b* Model 1 additionally adjusted for total carbohydrate intake. β (95% CI) are the associations for each 1-g/d increase of carbohydrate intake from the food source, independent of other sources of carbohydrate intake, total carbohydrate, and total energy intakes.

*c* β (95% CI) is the association for each 1-g/d increase of other carbohydrate sources not specified in the model.
**Table 5.5** Associations between dietary fibre intake from six food sources and trunk fat mass (kg) in postmenopausal women \((N = 348)\)

<table>
<thead>
<tr>
<th></th>
<th>(\beta) (95% CI)</th>
<th>(P)-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dietary fibre intake, g/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grains</td>
<td>(-1.382 (-2.678, -0.086))</td>
<td>0.04</td>
</tr>
<tr>
<td>Breakfast cereals &amp; baked products</td>
<td>0.105 (-0.147, 0.357)</td>
<td>0.41</td>
</tr>
<tr>
<td>Fruit</td>
<td>(-0.208 (-0.437, 0.021))</td>
<td>0.08</td>
</tr>
<tr>
<td>Vegetables</td>
<td>(-0.067 (-0.183, 0.049))</td>
<td>0.26</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1.110 ( 0.157, 2.064)</td>
<td>0.02</td>
</tr>
<tr>
<td>Legumes</td>
<td>(-0.078 (-0.611, 0.455))</td>
<td>0.77</td>
</tr>
<tr>
<td><strong>Model 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dietary fibre intake, g/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grains</td>
<td>(-1.213 (-2.496, 0.071))</td>
<td>0.06</td>
</tr>
<tr>
<td>Breakfast cereals &amp; baked products</td>
<td>0.506 (0.151, 0.860)</td>
<td>0.005</td>
</tr>
<tr>
<td>Fruit</td>
<td>0.266 (-0.108, 0.640)</td>
<td>0.16</td>
</tr>
<tr>
<td>Vegetables</td>
<td>0.372 ( 0.073, 0.670)</td>
<td>0.02</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1.265 ( 0.319, 2.211)</td>
<td>0.009</td>
</tr>
<tr>
<td>Legumes</td>
<td>0.499 (-0.140, 1.138)</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>(-0.444 (-0.724, -0.165))</td>
<td>0.002</td>
</tr>
</tbody>
</table>

\(^a\) Adjusted for total carbohydrate intake, total energy intake, age, ethnicity, physical activity, and alcohol use. Dietary fibre intake from grains, breakfast cereals & baked products, fruit, vegetables, potatoes, and legumes, are mutually adjusted. \(\beta\) (95% CI) are the associations for each 1-g/d increase of dietary fibre intake from the food source, independent other food sources of dietary fibre, total carbohydrate, and total energy intakes.

\(^b\) Model 1 additionally adjusted for total dietary fibre intake. \(\beta\) (95% CI) are the associations for each 1-g/d increase of dietary fibre intake from the food source, independent of other food sources of dietary fibre, total dietary fibre, total carbohydrate, and total energy intakes.

\(^c\) \(\beta\) (95% CI) is the association for each 1-g/d increase of other dietary fibre sources not specified in the model.

**Supplemental Table 5.1** Associations of available carbohydrate and total dietary fibre intake with trunk fat mass (kg) in postmenopausal women \((N = 348)\)

<table>
<thead>
<tr>
<th></th>
<th>(\beta) (95% CI)(^b)</th>
<th>(P) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available carbohydrate(^a), g/d</td>
<td>(-0.018 (-0.037, 0.001))</td>
<td>0.06</td>
</tr>
<tr>
<td>Total dietary fibre, g/d</td>
<td>(-0.145 (-0.222, -0.068))</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

\(^a\) Available carbohydrate intake = total carbohydrate intake – total dietary fibre intake.

\(^b\) \(\beta\) (95% CI) are the association for each 1-g/d increase in nutrient intake. Adjusted for available carbohydrate intake or total dietary fibre intake (i.e. mutually adjusted), total energy intake, age, ethnicity, physical activity level, and alcohol use.
Figure 5.1  Associations of carbohydrate intake from (A) grains \((P = 0.008)\), (B) fruit \((P = 0.001)\), and (C) potatoes \((P = 0.02)\) with trunk fat mass (kg) in postmenopausal women, independent of other food sources of carbohydrate and total energy intakes \((N = 348)\). Regression coefficient \((\beta)\) and 95% CI are represented by the line and shaded area, respectively. Adjusted for carbohydrate intake from other sources (i.e. mutually adjusted), total energy intake, age, ethnicity, physical activity level, and alcohol use.
Figure 5.2  Associations of dietary fibre intake from (A) grains ($P = 0.04$) and (B) potatoes ($P = 0.02$) with trunk fat mass (g) in postmenopausal women, independent of other food sources of dietary fibre, total carbohydrate, and total energy intakes ($N = 348$). Regression coefficient ($\beta$) and 95% CI are represented by the line and shaded area, respectively. Adjusted for dietary fibre intake from other sources (i.e. mutually adjusted), total carbohydrate intake, total energy intake, age, ethnicity, physical activity level, and alcohol use.
Chapter 6
Manuscript 2:
Associations between dietary patterns and body composition among postmenopausal women

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6.1 Abstract

\textbf{Background}: Examining dietary patterns accounts for complex interactions among dietary components and has greater public health translatability. However, research on the relationships of dietary patterns and body composition is not conclusive.

\textbf{Objective}: The objective was to examine the associations between dietary patterns and measures of overall and abdominal adiposity in a group of Canadian postmenopausal women.

\textbf{Methods}: A cross-sectional study of 357 postmenopausal women, aged 50–69 years was conducted. Dietary patterns were derived using principal components analysis (PCA) and dietary data obtained from the Canadian Diet History Questionnaire II (C-DHQ II). Dual-energy X-ray absorptiometry (DXA) and anthropometric measures of adiposity were examined. Separate multivariable linear regression analyses were performed to examine the associations between each dietary pattern and each measure of overall and abdominal adiposity. All analyses were adjusted for total energy intake and other demographic and lifestyle covariates.
**Results:** Western and Prudent dietary patterns were identified in this study population. The Western dietary pattern was positively associated with trunk fat mass (highest vs. lowest quartiles: $\beta = 4.52$ kg; 95% confidence interval, CI: 2.58, 6.45; $P$-trend < 0.0001) and total fat mass ($\beta = 7.99$ kg; 95% CI: 4.20, 11.69; $P$-trend = 0.0001). The Prudent dietary pattern was inversely associated with trunk fat mass ($\beta = -2.68$ kg; 95% CI: $-4.45$, $-0.09$; $P$-trend = 0.001) and total fat mass ($\beta = -4.90$ kg; 95% CI: $-8.29$, $-1.51$; $P$-trend = 0.002). The Western and Prudent dietary patterns also had significant positive and inverse associations, respectively, with body mass index (BMI), waist circumference, waist-to-hip ratio, and android-to-gynoid ratio.

**Conclusions:** Among postmenopausal women, a Western dietary pattern characterized by greater consumption of meats, potatoes, and sweets is associated with increased adiposity, while a Prudent dietary pattern characterized by greater intake of vegetables, fruits, and legumes is associated with lower overall and abdominal adiposity.
6.2 Introduction

Obesity is a significant health concern due to its increasing prevalence and associated health risks. The global prevalence of obesity among adults was estimated to be approximately 13% in 2014, which is greater than two times the prevalence in 1980 (1). Over the last few decades, a 17 to 24% increase in the prevalence of abdominal obesity has also been observed in various populations (2–4). While excess total body fat is recognized to be associated with higher risks of mortality and numerous morbidities (5–7), regional distribution of body fat, particularly accumulation within the abdominal region, may be a more important risk factor than overall adiposity (8). There is evidence that abdominal adiposity is a strong predictor of chronic diseases, such as type 2 diabetes and cardiovascular disease, independent of general adiposity (9–11). It is hypothesized that abdominal visceral adipose tissue (VAT) contributes to the development of obesity-related morbidities through its metabolic and endocrine effects (8, 12).

Age, sex, ethnicity, and genetics are non-modifiable factors involved in the etiology of abdominal adipose tissue accumulation (8). Diet and physical activity, which are modifiable lifestyle factors, may also be important determinants of abdominal adiposity (8). However, the evidence with regard to the relationship between diet and abdominal adiposity has been inconclusive, owing to the inconsistent findings and limited number of studies (13–19). There is growing interest in studying the effects of dietary patterns on abdominal adiposity because overall dietary patterns account for the complex interactions among dietary components that cannot be adequately studied in traditional analyses of individual foods and nutrients (20, 21). Dietary patterns can be defined empirically using multivariate statistical techniques (20, 21). The most commonly utilized method in epidemiologic studies is principal components analysis (PCA), which evaluates the correlations among dietary variables and retains the components that account for the greatest amount of variation in dietary intake (22).

Several studies have examined the associations between dietary patterns, derived using PCA, and anthropometric measures of abdominal adiposity (13–19). These studies identified between two and six dietary patterns, with most studies identifying a healthy pattern that was characterized by high intake of vegetables, legumes, and fruits. Most (13–17), but not all (18, 19) studies found that the healthy dietary pattern was inversely associated with measures of abdominal adiposity. Studies also found that dietary patterns characterized by high intake of meat, high-fat foods,
sweets, or alcohol were associated with increased abdominal adiposity (14, 15). However, this association was not shown consistently (13, 17–19). More studies have addressed the relationship between dietary patterns and overall adiposity, as measured by body mass index (BMI), but without conclusive evidence (23, 24).

Elucidating the effects of overall dietary patterns on body composition is important because of potential implications for public health interventions. Thus, this study aimed to describe the dietary patterns of a population of Canadian postmenopausal women using PCA to examine the associations between these patterns and dual-energy X-ray absorptiometry (DXA) measures, in addition to standard anthropometric measures, of overall and abdominal adiposity. The use of DXA to provide direct measures of fat complements the anthropometric measures more commonly used in clinical settings and adds to our understanding of the relationship between dietary patterns and body composition.

6.3 Methods

6.3.1 Study population and study design

We conducted a cross-sectional study in postmenopausal women recruited from the Toronto, Ontario area between September 2011 and January 2014 using a list of women, provided by the provincial breast cancer screening program, who had consented to being contacted for research studies. Advertisements in local hospitals and word-of-mouth were also utilized to increase recruitment. Women were eligible for the study if they were between the ages of 50 to 69 years, had their last menstrual period at least 12 months prior to the study without surgical intervention or had both ovaries removed (i.e. postmenopausal), did not have breast cancer, and were not taking prescription hormone medications at the time of the study. Participants attended one study visit during which a research assistant administered two questionnaires and a technologist performed a medical imaging procedure and anthropometric measurements. The dietary questionnaire was mailed to participants following their study visit and follow-up telephone calls were made to encourage completion of unreturned questionnaires. Body composition results were not available to participants until the questionnaire was returned. A total of 382 women participated in the study. Participants were excluded from the analyses if there was missing information for body composition \((n = 1)\) or dietary intake \((n = 16)\), or total energy intakes were less than 566.9 kcal/d or greater than 3,597.4 kcal/d (i.e. the upper and lower 1% of energy
intake (25) in the study population) \((n = 8)\). These extreme levels of total energy intake were deemed to not be valid because sustained intakes at these levels were considered implausible. Thus, 357 study participants were included in these analyses. Ethics approval for the study was obtained from the Mount Sinai Hospital Research Ethics Board and the University of Toronto Research Ethics Board. All participants gave written informed consent at the start of the study visit.

**6.3.2 Assessment of body composition**

DXA was employed to assess body composition. DXA has been shown to differentiate between bone, lean soft tissue, and fat with good precision (26, 27). Whole-body body composition scans were performed and analyzed using the Hologic Discovery A DXA system and Hologic APEX software, version 3.3 (Hologic, Inc., Bedford, Massachusetts). Analyses of the DXA scans provided measures of the three types of body tissue for the whole body and specific regions, including the trunk, arms, and legs. Total body fat mass (kg) and fat mass in the standard trunk region (kg) were the primary measures of overall and abdominal adiposity, respectively. DXA is a precise method of assessing total body fat mass, with a reported coefficient of variation of approximately 2% (28). Studies have found that DXA measures of trunk fat correlate well with abdominal VAT measures from computed tomography or magnetic resonance imaging, which are considered the gold standard techniques for assessing this compartment of adipose tissue (28). These correlations range from 0.6 to 0.9 (29–32). An additional measure of abdominal adiposity that was examined was the android-to-gynoid ratio, which was obtained from the DXA scans. Android fat mass was measured in the region defined by 20% of the distance from the iliac crest to the neckline, while gynoid fat mass was measured in the region defined by the upper part of the greater trochanters to a lower limit that is twice the height of the android region. The Hologic APEX software defined the android and gynoid regions and calculated the android-to-gynoid ratio from the DXA scans.

The anthropometric measure of total adiposity in this study was BMI, which was calculated by dividing weight (kg) by squared height (m²). Weight was measured to the nearest 0.1 kg using a digital clinical scale and height was measured to the nearest 1 cm using a stadiometer. Waist circumference and waist-to-hip ratio were the anthropometric measures of abdominal adiposity examined. Waist circumference was measured directly above the iliac crest, while hip
circumference was measured at the widest part of the buttocks (33). The Gulick II tape measure was utilized to measure waist and hip circumferences to the nearest 0.1 cm. These measurements were performed three times and averaged. Studies have also reported strong correlations between waist circumference and gold standard measures of VAT, ranging from 0.6 to 0.8 (30, 31, 34, 35). Similarly, studies have found good correlations between waist-to-hip ratio and VAT \( r = 0.6–0.75 \) (36, 37).

6.3.3 Assessment of dietary intake

The Canadian Diet History Questionnaire II (C-DHQ II) was utilized to assess usual dietary intake in the past year (38, 39). The C-DHQ II is a comprehensive food frequency questionnaire (FFQ) that was updated and modified for use in Canadian populations from the U.S. National Cancer Institute Diet History Questionnaire (US-DHQ) (40, 41). The C-DHQ II queries the intake of foods (152 questions) and nutritional supplements (11 questions) (38). Each food item includes nine to ten choices to assess the frequency of consumption and three options for portion size. Additionally, some food items include expanded questions pertaining to seasonal variations in intake, and embedded questions to better capture variations in the composition of the meal (e.g. fat added to potatoes) (39). The C-DHQ II data was analyzed using Diet*Calc software (version 1.5.0, National Cancer Institute, Applied Research Program, October 2012) and the C-DHQ II nutrient database. The nutrient database was generated using nutrient values of foods reported on 24-hour dietary recalls in the Canadian Community Health Survey, Cycle 2.2 (CCHS 2.2), Nutrition (2004) (42) and consists of sex- and portion size-specific nutrient profiles for each food question. The nutrient analysis produced summary daily and food item-specific estimates of weight (g/d), energy (kcal/d), macronutrients, and micronutrients. C-DHQ II food items were assigned to food groups based on the similarity of nutrient content in order to derive dietary patterns using PCA. A total of 43 food groups were defined and nutrient estimates for each of these food groups were calculated by summing the food item-specific nutrient estimates that comprised the group.

6.3.4 Assessment of covariates

Demographic data collected from the study questionnaire included age and ethnicity (European or non-European ancestry). Lifestyle information included alcohol use, smoking status, and physical activity levels. Regular alcohol use was defined as at least one drink per week, where a
drink was defined as an alcoholic beverage containing 13.5 g of pure alcohol (43). Alcohol use was classified as never used, former use, five or fewer drinks per week, or greater than five drinks per week. Smoking status was categorized as never smoked, former smoker, or current smoker. Physical activity was assessed using the long form International Physical Activity Questionnaire (IPAQ) (44, 45). Physical activity levels were classified as low, moderate, or high based on the total frequency, duration, and intensity of work, transportation, and leisure physical activities.

### 6.3.5 Statistical analyses

Dietary patterns were derived from PCA using the weight (g/d) of the 43 food groups as the input variables. Dietary patterns derived using different input variables (i.e. weight and percentage energy) have been shown to be comparable, but weight has been reported to have greater interpretability and may also account for the amount of food consumed (46, 47). This was found in our study as well, where PCA using weight, energy-adjusted weight, and percentage of energy intake as input variables produced similar dietary patterns, although the component loadings for weight were most meaningful (results not shown). The Scree plot (Supplemental Figure 6.1) and eigenvalues were examined to determine the number of components to retain. The component loadings and the interpretability of two- and three-component solutions were assessed. An orthogonal (varimax) rotation was applied to components to simplify the component structure and aid interpretation. Food groups with component loadings $\geq 0.200$ were deemed to be significant to the component and contributed to the description of the dietary pattern. For each dietary pattern, component scores were calculated as the total sum of the standardized weight (g/d) of all food groups multiplied by the corresponding component loading. The dietary pattern scores were categorized into quartiles to characterize the relative degree to which participants adhered to a dietary pattern.

The associations between each dietary pattern and measures of adiposity were examined separately using multivariable linear regression models. Linear contrasts were used to test for linear trends across the quartiles of dietary pattern scores. All models were adjusted for total energy intake (kcal/d) using the standard multivariate method (48). Demographic and lifestyle covariates were tested for their confounding effects; however, physical activity was the only covariate that changed dietary pattern regression coefficients by more than 10%, when
comparing highest with lowest quartiles (49). Age and ethnicity were forced into the models because they are strong predictors of abdominal adiposity (50, 51). All statistical analyses were conducted using Stata 13 (StataCorp, College Station, Texas). Two-sided $P$-values <0.05 were considered statistically significant.

6.4 Results

Two dietary patterns were retained in the PCA based on an evaluation of the Scree plot, eigenvalues, and component loadings (Table 6.1). The two-component solution was selected over the three-component solution because the significant components loadings for the two-component solution had a more meaningful interpretation. Component 1, identified as a Western dietary pattern, was characterized by high positive loadings on meat, processed meat, potatoes, sweetened foods, pasta and pizza, and mayonnaise. Component 2 was labeled as a Prudent dietary pattern and had high positive loadings on vegetables, legumes, fruits, vegetable oil, rice, grains and pasta, breakfast cereals, soups, and fish and seafood. These two dietary patterns together explained approximately 15% of the variation in dietary intake in this population of postmenopausal women (8.2% and 6.3% in Components 1 and 2, respectively).

The age distribution was similar between women in the highest quartile of the Western dietary pattern and women in the highest quartile of the Prudent dietary pattern (Table 6.2). There was a greater proportion of women with European ethnicity in the highest quartile of the Western pattern versus the highest quartile of the Prudent pattern. Compared to those in the highest quartile of the Western pattern, women in the highest quartile of the Prudent pattern were more likely to have moderate or high levels of physical activity, never used alcohol regularly, and never smoked. Women in the highest quartile of the Prudent pattern were also less likely to be overweight or obese and had lower waist circumference, total body fat, and trunk fat. Waist-to-hip ratio was similar for women in the highest quartiles of the Prudent and Western dietary patterns. Average daily total energy intake was higher for women in the highest quartile of the Western dietary pattern than those for women in the highest quartile of the Prudent dietary pattern. Women in the highest quartile of the Prudent pattern also had a greater proportion of energy intake from carbohydrates than women in the highest quartile of the Western pattern.

The adjusted associations between dietary pattern scores and body composition measures are presented in Table 6.3. After adjusting for age, ethnicity, total energy intake and physical
activity level, the Western dietary pattern was significantly associated with increased BMI, total fat mass, waist circumference, trunk fat mass, waist-to-hip ratio, and android-to-gynoid ratio. The estimated least-squares mean total fat mass for women in the lowest and highest quartiles of the Western dietary pattern were 25.6 kg (95% confidence interval, CI: 22.9, 28.4) and 33.6 kg (95% CI: 30.3, 36.9), respectively (Figure 6.1). In contrast, the Prudent dietary pattern was associated with decreased total adiposity (as measured by BMI and total fat mass) and abdominal adiposity (as measured by waist circumference, trunk fat mass, waist-to-hip ratio, and android-to-gynoid ratio). Women in the lowest quartile of the Prudent dietary pattern had an estimated least-squares mean trunk fat mass of 14.3 kg (95% CI: 12.7, 15.8) compared to 11.6 kg (95% CI: 10.1, 18.1) for those in the highest quartile (Figure 6.2). There were no significant interactions between dietary patterns and ethnicity. When dietary pattern scores were mutually adjusted, the positive associations between the Western dietary pattern and all measures of body composition were slightly attenuated but remained statistically significant (Table 6.4). However, the associations between the Prudent dietary patterns and measures of total and abdominal adiposity were no longer statistically significant after mutually adjusting for dietary patterns.

6.5 Discussion

Western and Prudent dietary patterns emerged as the two main dietary patterns in this population of postmenopausal women. The Western dietary pattern was positively associated with all measures of overall and abdominal adiposity even after controlling for age, ethnicity, total energy intake, and physical activity level, and showed evidence of a linear trend across quartiles of the dietary pattern score. In contrast, there was a significant inverse linear trend between quartiles of the Prudent dietary pattern score and all measures of total and abdominal adiposity. The associations between the two dietary patterns and waist-to-hip ratio and android-to-gynoid ratio were weaker than the associations with other adiposity measures. Furthermore, the associations between dietary pattern scores and all measures of total and abdominal adiposity were attenuated after mutual adjustment for dietary patterns, but only the Western dietary pattern remained statistically significant. The attenuation of the estimates also suggests that adherence to one dietary pattern is related to adherence to the other dietary pattern. Additionally, the significant positive association for the Western dietary pattern, after accounting for the Prudent dietary pattern, suggests that the intake of foods that characterize the Western dietary pattern has
a stronger effect on abdominal adiposity than the intake of foods that characterize the Prudent dietary pattern.

The dietary patterns identified in this study are comparable to those reported in other studies that have used PCA to derive dietary patterns in various study populations. The two dietary patterns in this study accounted for approximately 15% of the variance in the dietary data, which is somewhat lower than that reported in another study that identified two dietary patterns (approximately 20% variance explained) (13). The Western dietary pattern in this study was characterized by high intakes of meats, potatoes, sweetened foods, as well as pasta and pizza, while high intake of these food items were captured by one (13, 14, 17) or more (15, 16, 18, 19) patterns in other studies. In this study, the Western dietary pattern was associated with increased BMI, total fat mass, waist circumference, waist circumference, waist-to-hip ratio, and android-to-gynoid ratio, when accounting for age, ethnicity, total energy intake, and physical activity level. Similar to our findings, studies of adult populations in North America and Europe found that a less healthy pattern of meats, potatoes, or sweets, derived from PCA, was positively associated with BMI (52, 53) and abdominal adiposity (14–16). However, this relationship has not been found consistently across populations. In a study of male health professionals, the Western pattern was not associated with BMI (54). Deshmukh-Taskar et al. (13) did not find an association between a less healthy pattern and waist circumference in a population of young adults from a rural community in the United States. Studies from Western and Southern Asia also did not find significant associations (17, 19). Additionally, in contrast to our findings, Chan et al. (18) found positive associations for these patterns among older Chinese men, but not among older Chinese women. The different demographics of the study populations and presence of regional foods in the diet may explain the varied findings.

The effects of less healthy dietary patterns on abdominal adiposity may be related to the fat content and glycemic index of foods that characterize this pattern. Although the percentage of energy from fat was similar between women in the highest quartiles of the Western and Prudent dietary patterns, those in the highest quartile of the Western pattern had a greater percentage of energy intake from saturated fats compared to those in the highest quartile of the Prudent pattern (11.2% and 9.0%). It has been hypothesized that the type of dietary fat impacts the accumulation of adipose tissue (8). The Mediterranean diet, which is characterized by higher intake of unsaturated fats and lower intake of saturated fats, has been shown to be associated with lower
abdominal adiposity (55). Thus, the higher saturated fat content in meats may have an adverse effect on abdominal adiposity. The intake of trans fatty acids has also been found to be positively associated with abdominal adiposity and is hypothesized to act through decreased insulin sensitivity (56). Similarly, the increased insulin levels in response to the intake of foods with a high glycemic index is another hypothesized mechanism for abdominal adipose tissue accumulation (57).

A healthy dietary pattern, consistent with the Prudent pattern in this study, was identified throughout studies utilizing PCA to derive dietary patterns (13, 14, 16–19). The Prudent pattern in this study was characterized by greater consumption of vegetables, legumes, fruits, grains, as well as fish and seafood. Higher intakes of vegetables, legumes, and fruits were a consistent characteristic of the healthy dietary pattern in some studies (13, 16–19), but in other studies a healthy pattern was also characterized by increased intakes of whole grains (13, 14, 17) and lean protein sources (i.e. poultry, fish, and seafood) (13, 14, 16, 17, 19). We found that the Prudent dietary pattern was inversely associated with all measures of total and abdominal adiposity after controlling for age, ethnicity, total energy intake, and physical activity level. Findings from studies examining anthropometric measures of adiposity have not been consistent, but these studies have not examined postmenopausal women specifically. Similar to our findings, some studies found that a healthy dietary pattern was associated with lower BMI (53), as well as lower waist circumference or waist-to-hip ratio (13, 14, 16, 17). However, other studies have not found a significant association between healthy patterns and BMI (54) or waist-to-hip ratio (18, 19). The contrasting results among studies may be attributed to the specific food items that characterized healthy dietary patterns. Studies which found an inverse association between a healthy dietary pattern and abdominal adiposity derived patterns which were characterized by whole-grain products or cereals, in addition to vegetables, fruits, and legumes (13, 14, 16, 17, 53). In this study, the prudent pattern was characterized by the intake of rice, grains, and pasta, which was a broad grouping that encompassed whole- and refined-grain sources of these food items. However, the specific food group of whole-grain English muffins and bagels did not contribute significantly to the dietary pattern. Other studies have found that the intake of whole-grains was inversely associated with abdominal adiposity in older adults (58, 59). It has been hypothesized that the fermentable carbohydrates found in whole grains may affect body fat distribution through prebiotic effects in the intestine or increased release of satiety hormones.
Furthermore, the increased dietary fibre in whole grains, vegetables, fruits, and legumes may increase fat oxidation through reduced insulin secretion (60).

An advantage of using an empirical method to derive dietary patterns is that the patterns directly describe the overall eating behaviours of this population of postmenopausal women. However, a recognized limitation of PCA is that decisions on the input variables, number of components to retain, and rotations are subjective. To address this, we followed standard conventions to the extent possible. This study also contributes to existing research because we examined a direct measure of abdominal fat in addition to anthropometric measures of abdominal adiposity that are commonly used in clinical practice. The limitations of the dietary assessment method also need to be considered. Dietary intake assessment was restricted to the list of foods included in the C-DHQ II, which may be incomplete and did not query food types of specific items, such as whole-grain or refined-grain sources of pasta. However, extensive work has been done to ensure that the foods included in the C-DHQ II and the nutrient database are relevant to the Canadian population (61). Additionally, there is the potential for measurement error because dietary intake was self-reported, which would attenuate the effect estimates observed in the study. The weaker associations between dietary patterns and waist-to-hip ratio and android-to-gynoid ratio may be attributed to greater measurement error due to error in each of the measurements that comprise the ratios. Dietary energy intake underreporting has been documented to be substantial in individuals with obesity (24). Thus, participants were not provided with results of their body composition assessment prior to the completion of the diet questionnaire to partly address this issue. We also excluded participants who reported extremely high or low total energy intakes from the analyses to exclude outliers likely to represent implausible intakes. The cross-sectional design of this study, and most previous studies, does not allow for the inference of causal relationships between dietary patterns and abdominal adiposity. While there is evidence that diet remains relatively stable during adulthood (62, 63), prospective studies are required to determine the temporal sequence of this association. Finally, findings from this study may not be generalizable to premenopausal women or men due to different biological factors which influence adiposity, or to populations in non-Western countries because of regional dietary variations. Thus, studies in other populations are warranted to further understanding of the relationship between dietary patterns and adiposity.
In conclusion, findings from this study suggest that the Western and Prudent dietary patterns affect both abdominal and total adipose tissue accumulation in postmenopausal women. A diet high in meats, potatoes, and sweets is associated with greater total and abdominal adiposity in postmenopausal women, while a diet with greater intakes of vegetables, fruits, and legumes is associated with lower adiposity. However, further research is needed to determine a causal association between dietary patterns and adiposity. Epidemiologic research on dietary patterns and abdominal adiposity is valuable for generating hypotheses on biological mechanisms that affect the distribution and accumulation of adipose tissue. Furthermore, research on dietary patterns has the potential to be translated to public health interventions and dietary recommendations more readily.
6.6 References


### Table 6.1 Component loadings from principal components analysis for two dietary patterns among postmenopausal women (N = 357)

<table>
<thead>
<tr>
<th>Food group (g/d)</th>
<th>Component 1: Western dietary pattern</th>
<th>Component 2: Prudent dietary pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat</td>
<td>0.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.01</td>
</tr>
<tr>
<td>Potatoes, all</td>
<td>0.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.06</td>
</tr>
<tr>
<td>Meat, processed</td>
<td>0.24&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–0.06</td>
</tr>
<tr>
<td>Sweets</td>
<td>0.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–0.10</td>
</tr>
<tr>
<td>Mixed dishes, pasta/pizza</td>
<td>0.21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.07</td>
</tr>
<tr>
<td>Jams, syrups, honey</td>
<td>0.21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–0.10</td>
</tr>
<tr>
<td>Mayonnaise</td>
<td>0.21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–0.09</td>
</tr>
<tr>
<td>Baked products, sweet</td>
<td>0.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–0.04</td>
</tr>
<tr>
<td>Vegetables, all</td>
<td>0.18</td>
<td>0.47&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Legumes</td>
<td>–0.04</td>
<td>0.32&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fruits</td>
<td>0.03</td>
<td>0.31&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.14</td>
<td>0.29&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Oil, vegetable</td>
<td>0.01</td>
<td>0.25&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Soups</td>
<td>0.13</td>
<td>0.24&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rice, grains, pasta</td>
<td>–0.08</td>
<td>0.23&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Breakfast cereals</td>
<td>–0.01</td>
<td>0.23&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fish and seafood</td>
<td>–0.04</td>
<td>0.20&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Artificial sweeteners</td>
<td>0.14</td>
<td>–0.09</td>
</tr>
<tr>
<td>Baked products, bread white</td>
<td>0.18</td>
<td>0.07</td>
</tr>
<tr>
<td>Baked products, bread whole-grain</td>
<td>0.17</td>
<td>–0.03</td>
</tr>
<tr>
<td>Baked products, other</td>
<td>0.17</td>
<td>–0.01</td>
</tr>
<tr>
<td>Beer</td>
<td>0.12</td>
<td>–0.05</td>
</tr>
<tr>
<td>Butter</td>
<td>0.20</td>
<td>–0.07</td>
</tr>
<tr>
<td>Coffee</td>
<td>0.14</td>
<td>0.00</td>
</tr>
<tr>
<td>Dairy products, regular &amp; high-fat</td>
<td>0.19</td>
<td>–0.02</td>
</tr>
<tr>
<td>Dairy products, low-fat</td>
<td>0.16</td>
<td>0.04</td>
</tr>
<tr>
<td>Eggs</td>
<td>0.16</td>
<td>0.02</td>
</tr>
<tr>
<td>Fruit juice</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Liquor</td>
<td>0.06</td>
<td>–0.06</td>
</tr>
<tr>
<td>Margarine</td>
<td>0.19</td>
<td>–0.01</td>
</tr>
<tr>
<td>Meal replacement</td>
<td>–0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>Mixed dishes, Mexican &amp; other</td>
<td>0.13</td>
<td>0.02</td>
</tr>
<tr>
<td>Non-dairy products</td>
<td>–0.09</td>
<td>0.11</td>
</tr>
<tr>
<td>Nuts and seeds</td>
<td>–0.05</td>
<td>0.17</td>
</tr>
<tr>
<td>Oil, olive</td>
<td>0.05</td>
<td>0.20</td>
</tr>
<tr>
<td>Poultry</td>
<td>0.17</td>
<td>0.14</td>
</tr>
<tr>
<td>Salad dressing</td>
<td>0.09</td>
<td>0.14</td>
</tr>
<tr>
<td>Sauces, high-fat</td>
<td>0.11</td>
<td>0.09</td>
</tr>
<tr>
<td>Snack foods</td>
<td>0.19</td>
<td>–0.08</td>
</tr>
<tr>
<td>Sweetened beverages, diet</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>Sweetened beverages, regular</td>
<td>0.10</td>
<td>–0.13</td>
</tr>
<tr>
<td>Tea</td>
<td>0.10</td>
<td>0.03</td>
</tr>
<tr>
<td>Wine</td>
<td>0.08</td>
<td>–0.07</td>
</tr>
<tr>
<td>Variance explained (%)</td>
<td>8.2</td>
<td>6.3</td>
</tr>
</tbody>
</table>

<sup>a</sup> Component loadings ≥|0.200|.
Table 6.2 Characteristics of the total study population of postmenopausal women and those with scores in the highest quartiles of each dietary pattern\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Western dietary pattern (Q4)</th>
<th>Prudent dietary pattern (Q4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n)</td>
<td>357</td>
<td>89</td>
<td>89</td>
</tr>
<tr>
<td><strong>Age, y</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>61.9 ± 4.1</td>
<td>61.3 ± 4.3</td>
<td>61.4 ± 4.0</td>
</tr>
<tr>
<td><strong>Ethnicity, %</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-European</td>
<td>14.8</td>
<td>11.2</td>
<td>28.1</td>
</tr>
<tr>
<td>European</td>
<td>85.2</td>
<td>88.8</td>
<td>71.9</td>
</tr>
<tr>
<td><strong>Physical activity level, %</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>35.0</td>
<td>40.5</td>
<td>32.6</td>
</tr>
<tr>
<td>Moderate</td>
<td>48.5</td>
<td>41.6</td>
<td>48.3</td>
</tr>
<tr>
<td>High</td>
<td>14.0</td>
<td>14.6</td>
<td>15.7</td>
</tr>
<tr>
<td>Unreliable</td>
<td>2.5</td>
<td>3.4</td>
<td>3.4</td>
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<tr>
<td><strong>Alcohol use, %</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>37.3</td>
<td>37.1</td>
<td>44.9</td>
</tr>
<tr>
<td>Former</td>
<td>10.9</td>
<td>12.4</td>
<td>12.4</td>
</tr>
<tr>
<td>Current: ≤5 drinks/week(^b)</td>
<td>30.8</td>
<td>24.7</td>
<td>24.7</td>
</tr>
<tr>
<td>Current: &gt;5 drinks/week(^b)</td>
<td>21.0</td>
<td>25.8</td>
<td>18.0</td>
</tr>
<tr>
<td><strong>Smoking, %</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>51.3</td>
<td>48.3</td>
<td>64.0</td>
</tr>
<tr>
<td>Former</td>
<td>41.4</td>
<td>40.5</td>
<td>28.1</td>
</tr>
<tr>
<td>Current</td>
<td>7.3</td>
<td>11.2</td>
<td>7.9</td>
</tr>
<tr>
<td><strong>Body fat distribution</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body mass index, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight or normal weight (&lt;24.9 kg/m(^2))(^c)</td>
<td>42.0</td>
<td>24.7</td>
<td>47.1</td>
</tr>
<tr>
<td>Overweight (25–29.9 kg/m(^2))</td>
<td>31.0</td>
<td>39.3</td>
<td>31.5</td>
</tr>
<tr>
<td>Obese (≥30 kg/m(^2))</td>
<td>23.0</td>
<td>36.0</td>
<td>21.4</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>88.2 ± 12.8</td>
<td>93.3 ± 13.9</td>
<td>86.8 ± 12.4</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.86 ± 0.06</td>
<td>0.87 ± 0.06</td>
<td>0.86 ± 0.06</td>
</tr>
<tr>
<td>Total body fat mass, kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>29.0 ± 10.2</td>
<td>33.2 ± 11.6</td>
<td>27.4 ± 9.0</td>
</tr>
<tr>
<td>Total body % fat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>40.3 ± 6.4</td>
<td>42.0 ± 6.7</td>
<td>38.9 ± 6.0</td>
</tr>
<tr>
<td>Trunk fat mass, kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13.3 ± 5.3</td>
<td>15.5 ± 6.1</td>
<td>12.5 ± 4.7</td>
</tr>
<tr>
<td>Trunk % fat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>38.3 ± 7.8</td>
<td>40.3 ± 8.0</td>
<td>37.0 ± 7.2</td>
</tr>
<tr>
<td><strong>Dietary intake</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy, kcal/d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,551.9 ± 541.9</td>
<td>2,110.4 ± 439.3</td>
<td>1,990.6 ± 543.2</td>
</tr>
<tr>
<td>% energy from carbohydrate(^d)</td>
<td>49.8</td>
<td>47.1 ± 7.1</td>
<td>51.5 ± 8.9</td>
</tr>
<tr>
<td>% energy from protein(^d)</td>
<td>16.6</td>
<td>16.9 ± 3.0</td>
<td>17.0 ± 3.2</td>
</tr>
<tr>
<td>% energy from fat(^d)</td>
<td>33.5 ± 6.9</td>
<td>34.3 ± 5.4</td>
<td>33.5 ± 7.5</td>
</tr>
<tr>
<td>Dietary glycemic index (glucose reference)</td>
<td>55.0</td>
<td>56.0 ± 3.3</td>
<td>54.9 ± 3.7</td>
</tr>
</tbody>
</table>

\(^a\) Values are mean ± SD unless specified.

\(^b\) A drink contains 13.5 g of pure alcohol.

\(^c\) Approximately 2% were underweight (BMI <18.5 kg/m\(^2\)) in all groups.

\(^d\) % energy from carbohydrate, protein, and fat do not sum to 100% since these are mean values and may have rounding errors.
Table 6.3  Adjusted associations between dietary pattern scores (not mutually adjusted) and body composition measures among postmenopausal women (N = 357)

<table>
<thead>
<tr>
<th>Body composition</th>
<th>Western dietary pattern score quartiles&lt;sup&gt;a,b&lt;/sup&gt;</th>
<th>Prudent dietary pattern score quartiles&lt;sup&gt;a,b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q2</td>
<td>Q3</td>
</tr>
<tr>
<td>Body mass index</td>
<td>0.76 (−0.77, 2.29)</td>
<td>1.05 (−0.56, 2.67)</td>
</tr>
<tr>
<td>Total fat mass (kg)</td>
<td>1.67 (−1.21, 4.55)</td>
<td>1.72 (−1.33, 4.76)</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>2.06 (−1.57, 5.68)</td>
<td>3.74 (−0.10, 7.58)</td>
</tr>
<tr>
<td>Trunk fat mass (kg)</td>
<td>0.92 (−0.59, 2.42)</td>
<td>1.31 (−0.29, 2.90)</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.00 (−0.02, 0.02)</td>
<td>0.02 (0.00, 0.04)</td>
</tr>
<tr>
<td>Android-to-gynoid ratio</td>
<td>0.02 (−0.03, 0.07)</td>
<td>0.04 (−0.01, 0.09)</td>
</tr>
</tbody>
</table>

<sup>a</sup>All values are β (95% confidence interval), where Q1 was the reference category.

<sup>b</sup>All models are adjusted for age, ethnicity, total energy intake, and physical activity level (dietary patterns are not mutually adjusted).

Table 6.4  Adjusted associations between dietary pattern scores (mutually adjusted) and body composition measures among postmenopausal women (N = 357)

<table>
<thead>
<tr>
<th>Body composition</th>
<th>Western dietary pattern score quartiles&lt;sup&gt;a,b&lt;/sup&gt;</th>
<th>Prudent dietary pattern score quartiles&lt;sup&gt;a,b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q2</td>
<td>Q3</td>
</tr>
<tr>
<td>Body mass index</td>
<td>0.02 (−0.03, 0.06)</td>
<td>0.88 (−0.80, 2.56)</td>
</tr>
<tr>
<td>Total fat mass (kg)</td>
<td>1.47 (−1.43, 4.36)</td>
<td>1.19 (−1.97, 4.36)</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>1.88 (−1.76, 5.53)</td>
<td>3.31 (−0.67, 7.29)</td>
</tr>
<tr>
<td>Trunk fat mass (kg)</td>
<td>0.82 (−0.70, 2.33)</td>
<td>1.05 (−0.60, 2.71)</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.00 (−0.02, 0.02)</td>
<td>0.01 (−0.01, 0.03)</td>
</tr>
<tr>
<td>Android-to-gynoid ratio</td>
<td>0.02 (−0.03, 0.06)</td>
<td>0.04 (−0.01, 0.09)</td>
</tr>
</tbody>
</table>

<sup>a</sup>All values are β (95% confidence interval), where Q1 was the reference category.

<sup>b</sup>All models are adjusted for age, ethnicity, total energy intake, and physical activity level (dietary patterns are mutually adjusted).
Figure 6.1  Estimated total fat mass least-squares means (kg) of each quartile of the Western ($P$-trend = 0.0001) and Prudent ($P$-trend = 0.002) dietary patterns ($N = 357$). The models are adjusted for age, ethnicity, total energy intake, and physical activity level.
Figure 6.2  Estimated trunk fat mass least-squares (kg) means of each quartile of the Western ($P$-trend < 0.0001) and Prudent ($P$-trend = 0.001) dietary patterns ($N = 357$). The models are adjusted for age, ethnicity, total energy intake, and physical activity level.
Supplemental Figure 6.1  Scree plot from principal components analysis of 43 food groups (g/d) ($N = 357$).
Chapter 7
Manuscript 3:
Associations of dietary glycemic index and glycemic load with adiposity among postmenopausal women

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\textsuperscript{2}Lunenfeld-Tanenbaum Research Institute, Mount Sinai Hospital, Toronto, Ontario
\textsuperscript{3}Department of Community Health Sciences and Oncology, Cumming School of Medicine, University of Calgary, Calgary, Alberta
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\textsuperscript{5}Department of Nutritional Sciences, University of Toronto, Toronto, Ontario

7.1 Abstract

\textbf{Background:} Understanding the determinants of increased adiposity is necessary to address the growing prevalence and associated adverse health effects of obesity. Glycemic index (GI) and glycemic load (GL) are modifiable dietary factors which may contribute to the accumulation of adipose tissue. However, the evidence on the relationship between GI and GL and adiposity is inconclusive. Thus, the objective of this study was to examine the associations between dietary GI and GL and total and abdominal adiposity in postmenopausal women.

\textbf{Methods:} A cross-sectional study of 357 postmenopausal women aged 50–69 years was conducted. Dietary GI and GL were calculated from past-year dietary data collected using a comprehensive food frequency questionnaire (FFQ). Total and abdominal adiposity were assessed using dual-energy X-ray absorptiometry (DXA) and anthropometric measurements. Multivariable linear regression analyses were conducted to assess the associations between dietary GI and GL and each adiposity measure, while adjusting for dietary, demographic, and lifestyle variables.
**Results:** Mean dietary GI and GL among these postmenopausal women were 55.1 units/day and 94.7 units/day, respectively. Dietary GI quartiles were not associated with total fat mass, trunk fat mass, android-to-gynoid ratio, body mass index (BMI), waist circumference, or waist-to-hip ratio, after adjusting for potential confounders ($P$-trend > 0.05). Likewise, there were no linear trends across dietary GL quartiles for all measures of total and abdominal adiposity in adjusted models ($P$-trend > 0.05).

**Conclusion:** There was no evidence of linear associations between dietary GI and GL and both DXA and anthropometric measures of total and abdominal adiposity in this population of Canadian postmenopausal women.
7.2 Introduction

The prevalence of obesity has increased significantly over the past few decades. In 2014, the global prevalence of obesity among adults was reported to be approximately 13%, which is more than twice the estimated prevalence in 1980 (1). More importantly, there has been a simultaneous, and perhaps even more marked, increase in the prevalence of abdominal obesity. The prevalence of abdominal obesity is estimated to have increased by 17 to 24% in different populations globally (2–4). Excess total body fat is a known risk factor for mortality and various morbidities (5–7); however, the regional distribution of adipose tissue, specifically accumulation within the abdomen, may be a more important factor than overall obesity. It is hypothesized that abdominal visceral adipose tissue (VAT) plays a role in the pathophysiology of obesity-related diseases through its metabolic and endocrine effects (8, 9). Studies have shown that abdominal obesity is a strong predictor of chronic diseases, such as type 2 diabetes and cardiovascular disease, independent of general obesity (10–12).

Non-modifiable factors related to the accumulation of abdominal adipose tissue include age, ethnicity, and genetics (8). However, understanding modifiable determinants of abdominal adiposity, such diet, is also valuable. An element of the diet hypothesized to contribute to the development of obesity is the glycemic response related to the quality and quantity of carbohydrate intake. The glycemic index (GI) and glycemic load (GL) are two measures that were developed to capture carbohydrate quality. GI is a measure of the glycemic response elicited by the available carbohydrate in a food relative to the response of glucose or white bread (i.e. reference food) (13). GL measures both the quality and quantity of carbohydrate and is defined as the product of the GI and the amount of available carbohydrate of a food, divided by 100 (14).

In observational studies of dietary GI and body mass index (BMI) in adult populations, both inverse (15), positive (16), and non-significant (17) associations have been reported. Hare-Bruun et al. (18) examined percentage body fat and found a positive association with dietary GI among women, but not among men. Similarly, inconsistent results have been found when examining the relationship between dietary GL and measures of overall adiposity (15–18). Studies examining measures of abdominal adiposity have found positive associations among women only (18, 19). Du et al. (20) also reported a positive association between dietary GI and
annual change in waist circumference in a cohort study of European adults. However, a study examining waist-to-hip ratio did not find a significant association with dietary GI (15). Studies have found that dietary GL is not significantly associated with abdominal adiposity (15, 18, 20). However, a positive association between dietary GL and changes in waist circumference adjusted for BMI was reported among women only (19).

Taken together, previous research on the associations between dietary GI and GL and total and abdominal adiposity is limited and has provided inconsistent findings. Furthermore, the majority of studies that have examined these associations have utilized anthropometric measures, which do not directly quantify the amount of adipose tissue. Thus, the aim of this study was to investigate the associations between dietary GI and GL and total and abdominal adiposity in postmenopausal women, using both dual-energy X-ray absorptiometry (DXA) and anthropometric measurements.

7.3 Methods

7.3.1 Study population and study design

We analyzed data from a cross-sectional study in postmenopausal women. Recruitment of participants from the Toronto, Ontario area took place between September 2011 and January 2014. The recruitment methods utilized were: contacting women who consented to being approached for research studies through the provincial breast screening program, advertising in local hospitals, and participants referred through word-of-mouth. Postmenopausal (i.e. last menstrual period occurred at least 12 months before the study without surgical intervention or had both ovaries removed) women between the ages of 50 to 69 years, who did not have breast cancer, and were not taking prescription hormone medications, were eligible for the study. A total of 382 women participated in the study. All participants completed two interviewer-administered questionnaires during the study visit and approximately 96% of participants completed a mailed dietary questionnaire following the visit. Anthropometric measurements and DXA were also performed by a trained technologist during the study visit. Data from 357 study participants were utilized for the statistical analyses. Reasons for exclusion were: missing body composition data (n = 1), missing dietary intake data (n = 16), and energy intakes within the upper and lower 1% (21) of the study population (i.e. <566.9 kcal/d or >3,597.4 kcal/d) (n = 8), which were considered outliers. Written informed consent was obtained from all participants at
the beginning of the study visit. The study was approved by the Mount Sinai Hospital Research Ethics Board and the University of Toronto Research Ethics Board.

7.3.2 Body composition assessment

Body composition was determined using DXA and anthropometric measurements. The Hologic Discovery A DXA system was used to perform whole body scans, which were analyzed with the Hologic APEX software, version 3.3 (Hologic, Inc., Bedford, Massachusetts). The analyses provided estimates of bone, lean soft tissue, and fat for the whole body and specific regions, including the trunk, arms, and legs. Total body fat mass (kg) and fat mass in the standard trunk region (kg), were the primary measures of total and abdominal adiposity, respectively. DXA has been shown to be a precise method for measuring total body fat mass, with a coefficient of variation of approximately 2% (22). Studies have also found a good correlation ($r = 0.6$–$0.9$) between DXA measures of trunk fat mass and measures of abdominal VAT from computed tomography or magnetic resonance imaging, which are the gold standard methods for measuring adipose tissue in this region (22–26). Another measure of abdominal adiposity obtained from the analyses of the DXA scans was the android-to-gynoid ratio, which has been shown to correlate well with VAT ($r = 0.7$) (27). Android-to-gynoid ratio has also been found to be associated with increased risk of metabolic syndrome and cardiometabolic risk factors among healthy and normal weight individuals (28, 29). The software provided estimates of fat mass for the defined android (20% of the distance from the iliac crest to the neckline) and gynoid (upper part of the greater trochanters to a lower limit that is twice the distance of the android region) regions.

All anthropometric measurements were obtained at the study visit by a trained technologist. Weight was measured using a digital clinical scale (nearest 0.1 kg) and height was measured using a stadiometer (nearest 1 cm). Waist and hip circumferences were measured three times and averaged, using the Gulick II tape measure (nearest 0.1 cm). Waist circumference was measured above the iliac crest and hip circumference was measured at the widest point of the buttocks. BMI ($\text{weight} / \text{height}^2; \text{kg/m}^2$) was the measure of total adiposity, while waist circumference and waist-to-hip ratio were measures of abdominal adiposity. Studies have found that there are strong correlations for waist circumference ($r = 0.6$–$0.8$) (24, 25) and waist-to-hip ratio ($r = 0.6$–$0.75$) (30, 31) with gold standard measures of VAT.
7.3.3 Dietary intake assessment

Past-year dietary intake was assessed using the Canadian Diet History Questionnaire II (C-DHQ II) (32, 33). The C-DHQ II is a comprehensive food frequency questionnaire (FFQ), which was updated and modified from the U.S. Diet History Questionnaire (US-DHQ) II to be specific to Canadian populations (34). The C-DHQ II is comprised of 152 food questions, which include nine to ten options for frequency of intake and three selections for portion size (32). Selected food items also include additional questions to assess seasonal variations and variations in the preparation of foods in meals (e.g. fat added to potatoes). The C-DHQ II data was analyzed using DietCalc software (version 1.5.0, National Cancer Institute, Applied Research Program, October 2012) and the C-DHQ II nutrient database, which was primarily developed from the Canadian Community Health Survey, Cycle 2.2 (CCHS 2.2), Nutrition (2004) 24-hour dietary recall and nutrient data (34) (35). The database included sex- and portion-size specific nutrient profiles for each food question. The nutrient analysis provided overall daily and food-item specific estimates of weight (g/d), energy (kcal/d), micronutrients, and macronutrients, including carbohydrates (g/d) and dietary fibre (g/d).

The GI and GL values of food items are not available in the C-DHQ II nutrient database, but GL values are present in the US-DHQ II nutrient database. GI values were calculated for food items in the US-DHQII nutrient database by dividing GL by available carbohydrate and multiplying by 100. Computed GI values from the US-DHQ II nutrient database were linked to the C-DHQ II nutrient database using direct and closely related name matches of food items. Food items in the C-DHQ II nutrient database without a matching food item in the US-DHQ II nutrient database were evaluated to determine whether these were in the top 90% of carbohydrate contributing foods in the study population. For foods in the top 90%, GI was estimated as the mean GI value of foods in the International Tables of Glycemic Index and Glycemic Load Values: 2008 (36). For foods in the bottom 10% of carbohydrate contributors, a GI of 0 was imputed for foods containing 0 g of carbohydrate while a GI of 50 was imputed for foods with greater than 0 g of carbohydrate (37).

For this study, the variables of interest were average daily dietary GI and GL, with glucose as the reference food (i.e. GI of glucose = 100). Dietary GI was calculated as the sum of the product of the GI and available carbohydrate of all food items consumed, divided by the total amount of
available carbohydrate of all food items consumed (i.e. calculated by subtracting total dietary fibre from total carbohydrate) (38). Dietary GL was defined as the product of dietary GI and daily total available carbohydrate intake, divided by 100. Dietary GI and GL were categorized as quartiles.

7.3.4 Covariate assessment

Information on demographic and lifestyle factors were collected from the study questionnaire. These factors included age, ethnicity (European or non-European ancestry), alcohol use, and smoking status. Participants’ alcohol use was classified according to whether alcohol was consumed regularly, which was defined as having at least one drink (i.e. alcoholic beverage containing 13.5 g of pure alcohol) per week (39). The four categories for alcohol use were never used, former use, current use of five or fewer drinks per week, and current use of greater than five drinks per week. Participants were classified as non-smokers, former smokers, or current smokers. Physical activity was assessed with the long-form International Physical Activity Questionnaire (IPAQ) (40, 41). The total frequency, duration, and intensity of work, transportation, and leisure physical activities were used to classify participants’ physical activity levels as low, medium, or high.

7.3.5 Statistical Analyses

Demographics, lifestyle factors, dietary intake, and body composition were compared across dietary GI quartiles using linear regression for continuous variables and non-parametric trend test for categorical variables. Separate multivariable linear regression analyses were conducted to examine the associations between dietary GI and GL and each measure of total and abdominal adiposity. Linear trends across dietary GI and GL quartiles were examined using linear contrasts. These associations were examined in a minimally adjusted model, adjusting for age and ethnicity only (Model 1). The associations were also examined after additional adjustment for total energy intake (tertiles) and dietary fibre intake, as well as alcohol use and physical activity levels, which were identified as confounders using the change-in-estimate approach with a cut-off of 10% (Model 2). The nutrient density method for energy adjustment was also examined for the analysis of dietary GL and produced non-significant results, similar to the multivariate method of energy adjustment (not shown). Associations with two-sided P-values <0.05 were considered statistically significant. The interactions between ethnicity and dietary GI
and GL were examined for potential effect modification, but were not statistically significant. All statistical analyses were conducted using Stata 13 (StataCorp, College Station, Texas).

7.4 Results

The mean ± SD dietary GI and GL of this population of postmenopausal women was 55.1 ± 3.7 units/day and 94.7 ± 38.0 units/day, respectively. Characteristics of the study population by dietary GI quartile are presented in Table 7.1. The mean age of the study participants was approximately 62 years, which was consistent across GI quartiles. The majority of the study population was of European ancestry; however, there were significantly more participants of other ethnicities in the highest dietary GI quartile compared to those with lower GI. Alcohol use, smoking status, and physical activity level did not differ significantly among women in the four quartiles of dietary GI. While total energy intake was similar for all levels of dietary GI, women in the lowest quartile of dietary GI had higher percentage of energy intake from protein than women in the other quartiles. Also, dietary fibre intake was lower with higher quartiles of dietary GI. Women in the lowest quartile of dietary GI had significantly lower total body and trunk percentage fat compared to those in the upper three quartiles. However, fat mass in these regions, BMI, and waist circumference were comparable across quartiles of dietary GI.

There were no significant associations between dietary GI and total fat mass, trunk fat mass, android-to-gynoid ratio, BMI, waist circumference, or waist-to-hip ratio in this population of postmenopausal women after adjustments for covariates (Table 7.2). This was observed in the age- and ethnicity-adjusted model, and after additional adjustment for energy intake, dietary fibre intake, alcohol status, and physical activity level. However, the regression coefficients in the fully-adjusted models showed consistent inverse relationships between dietary GI and all measures of adiposity, though not statistically significant. Dietary GL was also not significantly associated with measures of total or abdominal adiposity in the age-and ethnicity-adjusted models or the fully-adjusted models (Table 7.3). While there were no linear trends, the statistically significant quadratic contrasts ($P < 0.05$) provided evidence of curvilinear relationships between dietary GL and total fat mass, trunk fat mass, android-to-gynoid ratio, and waist circumference in the fully-adjusted models (Figure 7.1). For these adiposity measures, there was an increasing trend across the first three quartiles of dietary GL, but adiposity measures were lower in the highest quartile.
7.5 Discussion

In this cross-sectional study of postmenopausal women, dietary GI was not significantly associated with any measures of overall and abdominal adiposity, after adjusting for age, ethnicity, total energy intake, dietary fibre intake, alcohol use, and physical activity level. The linear trends between dietary GL and all measures of total and abdominal adiposity were also non-significant in the adjusted models. These findings were consistent for DXA measurements of adiposity and anthropometric measurements. However, there was evidence of a non-linear trend between dietary GL and total fat mass, trunk fat mass, android-to-gynoid ratio, and waist circumference, which may be due to different characteristics of women in the highest quartile of dietary GL.

Studies on the effect of dietary GI and GL on measures of overall adiposity have reported inconsistent results. The null associations of dietary GI and GL with DXA and anthropometric measures of overall adiposity found in this study were consistent with the findings of Liese et al. (42), who studied adults with normal and impaired glucose tolerance in a cross-sectional study. However, in other cross-sectional studies, inverse associations between dietary GL and BMI have been reported (15, 17). The contrasting findings for dietary GL may be explained by the Mediterranean study population in those studies, since the Mediterranean diet is characterized by low GI foods such as whole-grains, fruits, vegetables, and legumes. Since dietary GL is a measure of both quality and quantity of carbohydrate intake, the high dietary GL in these populations likely reflects greater quantity of carbohydrate intake from fruit, vegetable, and legume sources, while high dietary GL in other populations may reflect high intake of foods with a high GI (i.e. lower carbohydrate quality). Similar to the findings in this study, a prospective study in a Danish population did not find significant associations between dietary GL and change in percentage body fat (18). However, Hare-Bruun et al. (18) did report a positive association between dietary GI and percentage body fat among women only. In contrast, another prospective study in a Danish population found positive associations between dietary GI and GL and change in BMI (16). The difference in results may be attributed to the prospective design of these studies compared to the cross-sectional design of this study, as well as the younger population (i.e. aged 30 to 60 years) versus the population of postmenopausal women in this study.
Fewer studies have examined the relationship of dietary GI and GL with measures of abdominal adiposity. Interestingly, findings from this study were consistent with a cross-sectional study of Italian adults, a Mediterranean population, which found that dietary GI and GL were not significantly associated with waist-to-hip ratio among women or men (15). This is in contrast to the findings from large cohort studies on dietary GI and abdominal adiposity (18–20). These studies found that dietary GI was positively associated with measures of abdominal adiposity (19, 20), but this association was only observed among women in one study (18). The prospective design of these studies allowed the change in abdominal adiposity measures to be examined, which may explain the difference in results. Interestingly, only one cohort study reported a significant positive association between dietary GL and measures of abdominal adiposity among women only (19).

Higher GI and GL are hypothesized to increase adiposity through the increased postprandial insulin levels in response to the higher glucose concentrations. The relative hyperinsulinemia causes greater glucose oxidation and fatty acid formation and decreases the production of glucose and fat oxidation (43–45). In addition, as nutrient absorption in the gastrointestinal tract slows during the middle postprandial period (i.e. two to four hours following intake), the high insulin levels cause blood glucose concentrations to decrease. This leads to increased hunger and subsequent food intake (44, 45). This hypothesis was not confirmed by results of this study, as associations were non-significant. However, findings from this study may be limited by the accuracy of the GI and GL values and overall self-report of past-year dietary intake. We computed GI values using GL values for food items from the US-DHQ II nutrient database. The nutrient profiles of the food items in the C-DHQII and US-DHQII are composed of multiple individual foods. Thus, there may be differences in composition of these food items that would introduce misclassification error. While GI is a property of foods that has been measured for a number of foods reported in the International Tables of Glycemic Index and Glycemic Load Values (36, 46), error could also be introduced for mixed foods where the food GI is calculated from the GI of individual ingredients. This is because the recipes of these foods could differ between Canada and the United States. This would impact the accuracy of GI values because the macronutrient content of mixed foods or mixed meals affect the glycemic response being measured by GI (47) and an individual’s meal intake was not controlled for in the analysis. Overall, the mean dietary GI among postmenopausal women in this study was comparable to that
reported among women in other study populations (17, 20). Although the mean dietary GL in this study population was lower than the estimates of European study populations (17, 20), the dietary GL quartiles were comparable to a population of Canadian women which used the C-DHQ I to estimate dietary GL (48). Error in the estimates of dietary GI and GL would bias the results towards the null. However, dietary GI and GL were categorized in quartiles in order to reduce the impact of dietary GI and GL measurement error on the estimates of the associations with adiposity and examine the relative ranking of dietary GI and GL. The range of dietary GI (39.9 to 66.1) in this study is comparable to other studies and the upper and lower quartiles meet the cut-off to define high and low GI foods. However, this range may be too narrow to detect the effects of dietary GI on adiposity.

Another limitation with dietary intake assessment that should be considered is the potential for measurement error because dietary intake was self-reported. This misclassification would cause an attenuation of the effect estimates. Underreporting dietary intake may also be an issue, particularly among individuals with obesity (49). However, in general, FFQs have been demonstrated to be acceptable for ranking intakes in epidemiologic studies (50). In addition, to minimize the impact of under-reporting, the women completed the diet questionnaire prior to receiving the results of their body composition assessment. Participants with extremely high or low total energy intakes were excluded from the analyses, as these intakes were likely to be implausible. In addition, the analyses were adjusted for total energy intake. Another limitation of this study is its cross-sectional design, which does not provide evidence for a causal association. Individuals with high abdominal adiposity may have already changed their diet to decrease their weight. However, dietary patterns remain relatively stable in adulthood (51, 52) and hence the reported dietary intake likely reflects habitual intake over the longer term.

In conclusion, this study does not provide evidence for associations between dietary GI and GL and total and abdominal adiposity. This study contributes to the evidence because DXA, a direct and objective measure of total and abdominal fat, was examined in conjunction with more commonly used anthropometric measures. However, further research is needed to assess the validity of GI and GL values used with diet questionnaire data in order to improve the quality of evidence from epidemiologic studies. Prospective studies are also needed to investigate the temporal relationship between dietary GI and GL and adiposity.
7.6 References


### Table 7.1 Characteristics of the study population by dietary glycemic index quartile \((N = 357)^{a}\)

<table>
<thead>
<tr>
<th></th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>P-value(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n)</td>
<td>90</td>
<td>89</td>
<td>89</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>Dietary glycemic index (units/d), range</td>
<td>39.9–52.7</td>
<td>52.7–55.1</td>
<td>55.1–57.6</td>
<td>57.6–66.1</td>
<td></td>
</tr>
<tr>
<td>Dietary glycemic index (units/d), median (IQR)</td>
<td>50.8</td>
<td>54.1</td>
<td>56.4</td>
<td>59.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(49.7–51.8)</td>
<td>(53.3–54.5)</td>
<td>(55.8–57.1)</td>
<td>(58.2–60.8)</td>
<td></td>
</tr>
<tr>
<td>Dietary glycemic load (units/d), median (IQR)</td>
<td>75.9</td>
<td>82.7</td>
<td>95.5</td>
<td>107.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(57.7–94.1)</td>
<td>(68.3–105.4)</td>
<td>(73.6–114.9)</td>
<td>(74.2–131.2)</td>
<td></td>
</tr>
<tr>
<td>Age (y)</td>
<td>61.9 ± 3.6</td>
<td>62.3 ± 4.3</td>
<td>61.8 ± 3.9</td>
<td>61.6 ± 4.6</td>
<td>0.46</td>
</tr>
<tr>
<td>Ethnicity, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.04</td>
</tr>
<tr>
<td>European</td>
<td>88.8</td>
<td>89.9</td>
<td>85.4</td>
<td>77.5</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>12.2</td>
<td>10.1</td>
<td>14.6</td>
<td>22.5</td>
<td></td>
</tr>
<tr>
<td>Physical activity level, %</td>
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<td></td>
<td></td>
<td></td>
<td>0.30</td>
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<tr>
<td>Low</td>
<td>31.1</td>
<td>33.7</td>
<td>33.7</td>
<td>41.6</td>
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<tr>
<td>Moderate</td>
<td>51.1</td>
<td>48.3</td>
<td>53.9</td>
<td>40.5</td>
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<tr>
<td>High</td>
<td>14.4</td>
<td>14.6</td>
<td>11.2</td>
<td>15.7</td>
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</tr>
<tr>
<td>Unreliable</td>
<td>3.3</td>
<td>3.4</td>
<td>1.1</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Alcohol use, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.13</td>
</tr>
<tr>
<td>Never</td>
<td>31.1</td>
<td>32.6</td>
<td>39.3</td>
<td>46.1</td>
<td></td>
</tr>
<tr>
<td>Former</td>
<td>7.8</td>
<td>17.9</td>
<td>7.9</td>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td>Current: ≤5 drinks/week(^c)</td>
<td>44.4</td>
<td>24.7</td>
<td>31.5</td>
<td>22.5</td>
<td></td>
</tr>
<tr>
<td>Current: &gt;5 drinks/week(^c)</td>
<td>16.7</td>
<td>24.7</td>
<td>21.4</td>
<td>21.4</td>
<td></td>
</tr>
<tr>
<td>Smoking status, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.93</td>
</tr>
<tr>
<td>Never</td>
<td>53.3</td>
<td>46.1</td>
<td>51.7</td>
<td>53.9</td>
<td></td>
</tr>
<tr>
<td>Former</td>
<td>41.1</td>
<td>47.2</td>
<td>39.3</td>
<td>38.2</td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>5.6</td>
<td>6.7</td>
<td>9.0</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>Dietary intake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy, kcal/d</td>
<td>1,468 ± 496</td>
<td>1,549 ± 544</td>
<td>1,615 ± 550</td>
<td>1,576 ± 572</td>
<td>0.13</td>
</tr>
<tr>
<td>% energy from carbohydrate</td>
<td>50.4 ± 9.3</td>
<td>50.1 ± 9.1</td>
<td>48.2 ± 7.7</td>
<td>50.5 ± 8.8</td>
<td>0.71</td>
</tr>
<tr>
<td>% energy from protein</td>
<td>17.3 ± 3.8</td>
<td>16.5 ± 3.1</td>
<td>16.7 ± 2.5</td>
<td>16.1 ± 3.1</td>
<td>0.02</td>
</tr>
<tr>
<td>% energy from fat</td>
<td>32.8 ± 8.1</td>
<td>33.6 ± 7.5</td>
<td>34.7 ± 5.3</td>
<td>32.9 ± 6.4</td>
<td>0.71</td>
</tr>
<tr>
<td>Dietary fiber (g/d)</td>
<td>22.7 ± 10.7</td>
<td>20.6 ± 9.8</td>
<td>19.7 ± 8.6</td>
<td>18.8 ± 8.1</td>
<td>0.005</td>
</tr>
<tr>
<td>Body fat distribution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body mass index, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.96</td>
</tr>
<tr>
<td>Underweight (&lt;18.5 kg/m(^2))</td>
<td>2.2</td>
<td>1.1</td>
<td>2.3</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Normal weight (18.5–24.9 kg/m(^2))</td>
<td>46.7</td>
<td>42.7</td>
<td>40.5</td>
<td>48.3</td>
<td></td>
</tr>
<tr>
<td>Overweight (25–29.9 kg/m(^2))</td>
<td>31.1</td>
<td>30.3</td>
<td>33.7</td>
<td>29.2</td>
<td></td>
</tr>
<tr>
<td>Obese (≥30 kg/m(^2))</td>
<td>20</td>
<td>25.8</td>
<td>25.8</td>
<td>20.2</td>
<td></td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>86.2 ± 11.8</td>
<td>88.9 ± 11.5</td>
<td>89.0 ± 13.5</td>
<td>88.9 ± 14.3</td>
<td>0.19</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.86 ± 0.07</td>
<td>0.86 ± 0.06</td>
<td>0.86 ± 0.06</td>
<td>0.87 ± 0.07</td>
<td>0.57</td>
</tr>
<tr>
<td>Total body fat mass, kg</td>
<td>27.0 ± 9.5</td>
<td>29.8 ± 8.8</td>
<td>30.0 ± 11.1</td>
<td>29.3 ± 11.0</td>
<td>0.15</td>
</tr>
<tr>
<td>Total body % fat</td>
<td>38.5 ± 6.9</td>
<td>40.9 ± 5.5</td>
<td>40.8 ± 6.5</td>
<td>40.8 ± 6.5</td>
<td>0.03</td>
</tr>
<tr>
<td>Trunk fat mass, kg</td>
<td>12.2 ± 5.0</td>
<td>13.8 ± 5.0</td>
<td>13.8 ± 5.6</td>
<td>13.6 ± 5.6</td>
<td>0.08</td>
</tr>
<tr>
<td>Trunk % fat</td>
<td>36.1 ± 8.4</td>
<td>38.9 ± 6.9</td>
<td>38.8 ± 7.9</td>
<td>38.8 ± 7.9</td>
<td>0.03</td>
</tr>
<tr>
<td>Android:gynoid fat ratio</td>
<td>0.91 ± 0.19</td>
<td>0.94 ± 0.15</td>
<td>0.93 ± 0.16</td>
<td>0.94 ± 0.16</td>
<td>0.24</td>
</tr>
</tbody>
</table>

\(^{a}\)Values are mean ± SD unless specified.

\(^{b}\)Linear regression for continuous variables; non-parametric trend test for categorical variables.

\(^{c}\)A drink contains 13.5 g of pure alcohol.
Table 7.2  Associations between dietary glycemic index quartiles and measures of abdominal adiposity in postmenopausal women (N = 357)

<table>
<thead>
<tr>
<th>Abdominal adiposity</th>
<th>Model 1&lt;sup&gt;b,c&lt;/sup&gt;</th>
<th></th>
<th></th>
<th>P-trend</th>
<th></th>
<th></th>
<th></th>
<th>P-trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total fat mass (kg)</td>
<td>2.82 (−0.17, 5.80)</td>
<td>2.99 (0.00, 5.97)</td>
<td>2.35 (−0.65, 5.35)</td>
<td>0.14</td>
<td>1.96 (−0.98, 4.91)</td>
<td>1.56 (−1.41, 4.52)</td>
<td>0.70 (−2.31, 3.71)</td>
<td>0.73</td>
</tr>
<tr>
<td>Trunk fat mass (kg)</td>
<td>1.64 (0.07, 3.20)</td>
<td>1.61 (0.04, 3.17)</td>
<td>1.51 (−0.06, 3.08)</td>
<td>0.08</td>
<td>1.16 (−0.39, 2.71)</td>
<td>0.88 (−0.67, 2.44)</td>
<td>0.65 (−0.93, 2.23)</td>
<td>0.51</td>
</tr>
<tr>
<td>Android-to-gynoid ratio</td>
<td>0.03 (−0.02, 0.08)</td>
<td>0.02 (−0.03, 0.07)</td>
<td>0.03 (−0.02, 0.07)</td>
<td>0.38</td>
<td>0.02 (−0.03, 0.07)</td>
<td>0.01 (−0.04, 0.06)</td>
<td>0.01 (−0.04, 0.06)</td>
<td>0.77</td>
</tr>
<tr>
<td>Body mass index</td>
<td>1.34 (−0.25, −0.25)</td>
<td>1.47 (−0.12, 3.06)</td>
<td>0.78 (−0.82, 2.37)</td>
<td>0.34</td>
<td>0.87 (−0.71, 2.44)</td>
<td>0.81 (−0.76, 2.39)</td>
<td>−0.04 (−1.64, 1.56)</td>
<td>0.95</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>2.64 (−1.14, 6.42)</td>
<td>2.81 (−0.97, 6.60)</td>
<td>2.73 (−1.07, 6.53)</td>
<td>0.17</td>
<td>1.69 (−2.06, 5.44)</td>
<td>1.29 (−2.49, 5.06)</td>
<td>0.91 (−2.92, 4.74)</td>
<td>0.71</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.0008 (−0.02, 0.02)</td>
<td>−0.002 (−0.02, 0.02)</td>
<td>0.01 (−0.01, 0.02)</td>
<td>0.65</td>
<td>−0.002 (−0.02, 0.02)</td>
<td>−0.005 (−0.02, 0.01)</td>
<td>0.0005 (−0.02, 0.02)</td>
<td>0.96</td>
</tr>
</tbody>
</table>

<sup>a</sup>Range of dietary GI (units/d): Q1 = 39.9–52.7; Q2 = 52.7–55.1; Q3 = 55.1–57.6; Q4 = 57.6–66.1.

<sup>b</sup>Values are β (95% confidence interval), where Q1 is the reference category.

<sup>c</sup>Adjusted for age and ethnicity.

<sup>d</sup>Adjusted for age, ethnicity, total energy intake, dietary fiber intake, alcohol, and physical activity level.

---

Table 7.3  Associations between dietary glycemic load quartiles and measures of abdominal adiposity in postmenopausal women (N = 357)

<table>
<thead>
<tr>
<th>Abdominal adiposity</th>
<th>Model 1&lt;sup&gt;b,c&lt;/sup&gt;</th>
<th></th>
<th></th>
<th>P-trend</th>
<th></th>
<th></th>
<th></th>
<th>P-trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total fat mass (kg)</td>
<td>−0.25 (−3.25, 2.75)</td>
<td>2.07 (−0.93, 5.06)</td>
<td>0.94 (−2.11, 3.99)</td>
<td>0.30</td>
<td>2.03 (−1.25, 5.31)</td>
<td>3.80 (−0.14, 7.73)</td>
<td>0.30 (−4.33, 4.93)</td>
<td>0.94</td>
</tr>
<tr>
<td>Trunk fat mass (kg)</td>
<td>−0.09 (−1.67, 1.48)</td>
<td>1.20 (−0.37, 2.77)</td>
<td>0.31 (−1.28, 1.91)</td>
<td>0.38</td>
<td>1.19 (−0.53, 2.90)</td>
<td>2.34 (0.28, 4.40)</td>
<td>0.33 (−2.10, 2.75)</td>
<td>0.60</td>
</tr>
<tr>
<td>Android-to-gynoid ratio</td>
<td>0.00 (−0.05, 0.05)</td>
<td>0.00 (−0.05, 0.05)</td>
<td>−0.03 (−0.08, 0.02)</td>
<td>0.23</td>
<td>0.02 (−0.03, 0.08)</td>
<td>0.02 (−0.04, 0.09)</td>
<td>−0.03 (−0.11, 0.04)</td>
<td>0.44</td>
</tr>
<tr>
<td>Body mass index</td>
<td>−0.29 (−1.88, −1.88)</td>
<td>0.83 (−0.76, 2.42)</td>
<td>0.74 (−0.88, 2.36)</td>
<td>0.20</td>
<td>0.86 (−0.89, 2.62)</td>
<td>1.80 (−0.30, 3.91)</td>
<td>0.42 (−2.06, 2.90)</td>
<td>0.59</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>−0.42 (−4.21, 3.36)</td>
<td>2.95 (−0.83, 6.73)</td>
<td>0.49 (−3.36, 4.34)</td>
<td>0.43</td>
<td>2.32 (−1.84, 6.48)</td>
<td>5.04 (0.06, 10.0)</td>
<td>−0.11 (−5.98, 5.76)</td>
<td>0.81</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>−0.008 (−0.03, 0.01)</td>
<td>0.001 (−0.02, 0.02)</td>
<td>−0.01 (−0.03, 0.01)</td>
<td>0.31</td>
<td>0.001 (−0.02, 0.02)</td>
<td>0.01 (−0.01, 0.04)</td>
<td>−0.009 (−0.04, 0.02)</td>
<td>0.74</td>
</tr>
</tbody>
</table>

<sup>a</sup>Range of dietary GL (units/d): Q1 = 26.1–67.3; Q2 = 67.8–87.7; Q3 = 87.8–114.5; Q4 = 114.9–236.74.

<sup>b</sup>Values are β (95% confidence interval), where Q1 is the reference category.

<sup>c</sup>Adjusted for age and ethnicity.

<sup>d</sup>Adjusted for age, ethnicity, total energy intake, dietary fiber intake, alcohol, and physical activity level.
Figure 7.1  Least-squares means estimates of (A) total fat mass, (B) trunk fat mass, (C) android-to-gynoid ratio, and (D) waist circumference for dietary glycemic load quartiles ($N = 357$). Linear contrasts were not statistically significant ($P$-trend $> 0.05$), but quadratic contrasts were statistically significant ($P < 0.05$).
Chapter 8
Discussion

8.1 Summary of findings

There is an increasing scientific interest in elucidating the relationships between dietary factors and adiposity, which has led to a growing body of epidemiological research on this topic. However, the evidence to date has been inconclusive, particularly with regard to abdominal adiposity. This thesis contributes to this area of research by examining different measures of carbohydrate quality in order to further elucidate which aspects of carbohydrate intake are potential risk factors for increasing risk of total and abdominal adiposity in postmenopausal women. We found that increased total dietary fibre intake was associated with lower trunk fat mass, but total carbohydrate intake was not associated with trunk fat mass. A more notable finding from this study was that associations with trunk fat mass varied by the food source of carbohydrate and dietary fibre intakes (objective 1). In addition, the two dietary patterns that emerged in this population of postmenopausal women were significantly associated with dual-energy X-ray absorptiometry (DXA) and anthropometric measures of total adiposity (total fat mass and body mass index, BMI) and abdominal adiposity (trunk fat mass, android fat mass, android-to-gynoid ratio, waist circumference, and waist-to-hip ratio). Greater adherence to the Western dietary pattern (high intake of meat, potatoes, processed meat, sweets, pasta and pizza, jams, syrups and honey, mayonnaise, sweet baked products) was associated with increased total adiposity and abdominal adiposity. In contrast, greater adherence to the Prudent dietary pattern (high intake of vegetables, legumes, fruits, tomatoes, vegetable oil, soups, rice, grains and pasta, breakfast cereals, and fish and seafood) was associated with reduced total adiposity and abdominal adiposity (objective 2). Finally, there was no evidence to show that dietary glycemic index (GI) or dietary glycemic load (GL) were associated with any of the DXA and anthropometric measures of total adiposity and abdominal adiposity in this study (objective 3).

All of the dietary factors (carbohydrate, dietary fibre, dietary patterns, dietary GI, and dietary GL) investigated in the thesis capture different aspects of carbohydrate nutrition, particularly carbohydrate quality. Dietary fibre is classified as a type of carbohydrate of high quality because fibre intake may positively influence health through various physiological mechanisms, including increased release of gut hormones, reduced digestion of other macronutrients, or
reduced glycemic response (1). The finding of an inverse association between total dietary fibre intake and trunk fat mass, in contrast to the null association between total carbohydrate intake and trunk fat mass, illustrates that the type and quality of carbohydrate are likely to be important risk factors in the etiology of abdominal adiposity. The results for dietary fibre with abdominal fat are consistent with findings from other epidemiological research (2–5) and correspond with the physiologic responses elicited by dietary fibre intake, which are hypothesized to lower adiposity. However, the varied associations with abdominal adiposity by source of carbohydrate and dietary fibre intake found in this study suggest that the distinction between dietary fibre and other types of carbohydrate is not the sole characteristic of carbohydrates that affects abdominal adiposity.

A novel finding of this study was that carbohydrate and dietary fibre intakes from potatoes were positively associated with trunk fat mass, regardless of the method of energy adjustment. While a positive association for carbohydrate from refined-grain products plus potatoes has been reported (6), dietary fibre specifically from potatoes has not been investigated in relation to abdominal adiposity. Some studies have found an inverse association between cereal sources of dietary fibre and abdominal adiposity (2, 7). Grain sources of dietary fibre were inversely associated with trunk fat mass in this study. The contrasting results among food sources in this study suggest that the type of dietary fibre may be another factor in abdominal adiposity. Potatoes are a source of soluble and insoluble fibre, while whole grains are a source of insoluble fibre. Soluble and insoluble fibre have different mechanisms of action, which may explain the different effects of dietary fibre food sources on abdominal adiposity. While soluble fibre increases viscosity and slows digestion, insoluble fibre increases bulk and transit time through the gastrointestinal tract (8).

The findings from the investigation of dietary patterns in this study support the contrasting associations for potato and grain sources of carbohydrate and dietary fibre intakes. Greater intake of potatoes was a characteristic of the Western dietary pattern, which was also found to be positively associated with abdominal adiposity, in addition to total adiposity. Potato intake in the Western pattern was related to the intake of other carbohydrate sources with added sugars, which also points to the role of the quality of carbohydrates. However, greater potato intake was also related to greater meat intake, which could also indicate a contributing role for types of fat intake in adiposity. Greater intake of grains and cereals was a characteristic of the Prudent dietary
pattern, which was inversely associated with abdominal adiposity and total adiposity in this study. Consumption of grains and cereal products in the Prudent dietary pattern was correlated with greater intake of vegetables, legumes, and fruit, which are other important sources of dietary fibre. The carbohydrate sources in each dietary pattern reflect the quality of carbohydrates. However, the dietary patterns also highlight other nutrients which may influence adiposity. The dietary patterns show that the complexity of diet and interactions among foods and nutrients may be of greater relevance in adiposity than dietary components considered individually.

There are other properties of carbohydrates which contribute to carbohydrate quality and may affect abdominal adiposity. GI classifies the quality of carbohydrate foods according to the glycemic response elicited by the available carbohydrate in the food relative to glucose or white bread. Most potatoes have a high GI (GI ≥ 70), whereas the GI of grain products range from low (GI ≤ 55) to high (9). Thus, the variable glycemic responses elicited by these two food sources may explain the contrasting findings in this study. However, the null findings of dietary GI and dietary GL in relation to abdominal adiposity in this study do not allow conclusions to be made regarding this hypothesis. This could mean that carbohydrates may act through another physiological mechanism to affect adiposity or that we could not detect a relationship in this study. Measurement error in dietary GI and dietary GL is a factor that may have limited our ability to detect an association. There may also be measurement error in carbohydrate intake, dietary fibre intake, and dietary pattern classification due to the method of dietary assessment. The significant findings for carbohydrate intake, dietary fibre intake, and dietary patterns may be attenuated by measurement error in this study and the true effect sizes are not known. Overall, the findings from this thesis research suggest that cumulative effects of the nature of carbohydrates and other dietary factors are associated with total and abdominal adiposity, and further investigation is warranted.

8.2 Methodological considerations

The following section addresses a number of methodological considerations which must be taken into account when interpreting the findings of this observational study.
8.2.1 Study design

This study utilized a cross-sectional design to investigate the associations of interest. However, a limitation of this study design is that the temporality between the dietary factors and adiposity cannot be established. Therefore, inferences about the causality of the associations cannot be made directly. Diet, however, has been shown to be relatively stable during adulthood (10, 11). As such, the usual dietary intake assessed using the past-year C-DHQ II was expected to be representative of an individual’s diet over a period of time prior to the study. Participants in this study were recruited through the Ontario Breast Screening Program (OBSP), advertisements, and word-of-mouth, which resulted in a study population of volunteers. This has implications for the generalizability of the study’s findings to other populations. Specifically, this study population was predominantly European, which may have limited the diversity of dietary intake. However, their diet is likely similar to populations in many Western countries. Therefore, the results of this study may only be generalizable to postmenopausal women from these Western countries. Another consideration related to the volunteer study population is that these individuals may be more health conscious than the general population, which could introduce bias. However, the distribution of BMI (12) and the proportion of never smokers (13) in this study population was comparable to the Canadian population, which provides some indication that the volunteer population were not significantly different from the target population of postmenopausal women.

8.2.2 Dietary factors assessment

A strength of the study was the use of a dietary assessment instrument that underwent extensive evaluation to be adapted specifically for Canadian populations. This relates to both food representation and the nutrient database. However, similar to other food frequency questionnaires (FFQs) and nutrient databases, a limitation is that the list of foods and nutrients are not exhaustive. As such, this study could not examine whole- and refined-grain products in detail or different types of fibre (soluble and insoluble). There is also the potential for misclassification error for GI and GL estimates since the values were determined for larger classes of food items used in the C-DHQ II and US-DHQ II rather than the individual foods that constitute these food items. In addition, dietary intake in this study was self-reported, which results in the potential for random and systematic measurement error. Underreporting of dietary intake is a potential issue, particularly among individuals with obesity. This would cause the associations between the dietary factors of interest and adiposity to be attenuated. However,
participants with extremely low or high energy intakes were excluded from the analyses to minimize the impact of mis-reporting on the study’s findings. Individuals also tend to overestimate fruit and vegetable intake, which are significant sources of carbohydrate (7). This misclassification is likely to be non-differential and would attenuate the results of the study.

### 8.2.3 Adiposity assessment

One of the strengths of this study was the use of DXA measures of total and abdominal adiposity because it provides a direct measure of body fat. As described in Chapter 4 (section 4.5.1), DXA is a precise method for measuring fat mass or percent body fat. In addition, DXA is relatively inexpensive in comparison to other imaging methods for measuring body fat, such as computed tomography (CT) and magnetic resonance imaging (MRI), which could translate to application in clinical settings for assessing body composition. Although DXA measures of trunk fat mass and android fat mass have a good correlation with visceral adipose tissue (VAT), a limitation of DXA is that it is unable to directly measure subcutaneous adipose tissue (SAT) and VAT. This may have affected the ability to distinguish the effects of dietary patterns, dietary GI, and dietary GL on abdominal adiposity versus total adiposity. This is especially relevant as VAT has been established as the biologically relevant fat depot in a number of obesity-related diseases. Some researchers have developed algorithms and defined regions of interest using DXA software in order to provide more accurate estimates of visceral adiposity (14, 15). In addition, newer versions of the Hologic DXA system and software are capable of estimating VAT area (16). This work will have a significant impact on future research examining abdominal adiposity.

### 8.2.4 Confounding

The use of different methods of energy adjustment in the statistical analyses of carbohydrate intake, dietary fibre intake, and dietary GL was a strength of this study. This is because the method of energy adjustment affects the interpretation of the results relating to intake of energy-yielding nutrients. The use of the substitution model in addition the multivariate method of energy adjustment for the analysis of carbohydrate and dietary fibre intakes, provided additional information about the interactions among the sources of carbohydrate and other macronutrients.

We also accounted for a number of other confounders, identified as strong determinants of the adiposity outcomes, in the statistical analyses. One of the confounding variables adjusted for in the analyses was physical activity level. Participants in our study reported high levels of
physical activity, which was largely accounted for by high levels of reported household physical activity. We addressed this issue by excluding household physical activity from the summary categorization of physical activity. Misclassification of physical activity may still be present, but is likely to be non-differential and may have biased our results towards the null. However, residual confounding could still impact the findings from this study. Reverse causation, in particular, may be an issue in this study due to the nature of the outcome. Individuals with increased adiposity may have modified their diet because of a desire to improve health. Similarly, individuals may have an obesity-related disease which could confound the associations between the dietary factors of interest and adiposity because the condition could cause changes in diet and body composition. A limitation of the study was that comorbidities, such as diabetes, cardiovascular disease, and non-breast cancers, were not queried during the screening process or on the study questionnaire. Thus, we were unable to account for any health conditions in the analyses, which may have impacted the results of the study. Socioeconomic status was another factor which was not assessed in the study and may be a confounder. Individuals of lower socioeconomic status are more likely to choose foods which have lower costs per calorie, but also have lower quality and nutritional value (17). Furthermore, another potential confounding variable which we did not account for in the analyses was sleeping habits, as it was not queried in the original study. It has been found that individuals with short sleep duration (i.e. ≤6 hours) have greater change in abdominal adiposity compared to those with a longer duration of sleep, independent of change in total adiposity (18). In addition, sleep deprivation has been shown to be related to increased consumption of high-energy foods (18). Thus, sleeping habits needs to be considered in future examination of the relationships between dietary factors and abdominal adiposity.

8.3 Future research directions

As described previously, the cross-sectional design of this study does not allow for the temporal sequence between dietary factors and adiposity to be established. As there are feasibility issues with conducting randomised controlled trials (RCTs) to examine the effects of dietary factors on adiposity, future research should use a prospective design in order to determine whether the associations we found may be causal. Presently, there are a few well-designed, large cohort studies with a focus on diet and nutrition, including the European Prospective Investigation into Cancer and Nutrition (EPIC), the Nurses’ Health Study (NHS), and the Nurses’ Health Study II
(NHS II), which have used validated FFQs and anthropometric measures of adiposity. While the EPIC only assessed dietary intake at baseline, the NHS and NHS II assessed dietary intake every four years (19) and would be useful for investigating the temporal relationship between carbohydrate quality-related dietary factors and adiposity. Repeated measures of dietary intake would provide valuable information about the cumulative intake of dietary factors as well as any changes in dietary intake over time. Furthermore, women in the NHS and NHS II were aged 30 to 55 years and 25 to 42 years, respectively, at the time of recruitment (20), which would allow an investigation of the relevant exposure period for adiposity in postmenopausal women. This is an important consideration since sex hormones and menopausal status have been identified as determinants of abdominal adiposity and dietary intake during premenopausal, perimenopausal, and postmenopausal periods could be evaluated in these cohorts. These cohort studies would also have information about co-morbidities which could be examined as potential confounders of the diet-adiposity associations of interest. Utilizing data from these existing cohorts would be a cost-effective method for further examination of the associations examined in this thesis research. It would, however, be beneficial for future prospective studies to use imaging methods of adiposity assessment among a sub-cohort in order to understand the influence of overall adiposity on the relationships between dietary factors and abdominal adipose tissue accumulation.

As epidemiological research on the relationships between dietary factors and abdominal adiposity advances, it is important to improve the assessment of diet and abdominal adiposity. While validation studies of the US-DHQ I have been conducted, validation studies of the C-DHQ II would be valuable. Information from these validation studies would allow for calibration of the dietary data and would improve estimates of the associations between dietary exposures and adiposity outcomes (21). Similarly, better measurements of abdominal VAT for large epidemiological studies would improve estimates. As shown by the findings for dietary patterns, dietary GI, and dietary GL in this study, it is difficult to differentiate the effects of dietary factors on abdominal adiposity versus total adiposity. Specific measures of abdominal adipose tissue could help clarify these relationships. Supplemental sensitivity analyses were conducted as a preliminary investigation of these effects (Appendix G). The final regression analyses for the dietary factors of interest and abdominal adiposity measures were stratified by BMI category, where the two strata were underweight or normal weight (BMI ≤24.9) and
overweight or obese (BMI ≥25.0). Total dietary fibre (Table G.1), the Western dietary pattern (Table G.4), and the Prudent dietary pattern (Table G.4) were significantly associated with measures of abdominal adiposity (trunk fat mass and/or waist circumference) among overweight or obese women, but not among underweight or normal weight women. In contrast, the effects of potato sources of carbohydrates (Table G.2) and dietary fibre (Table G.3) on trunk fat mass were only present among underweight or normal weight women. The results of the sensitivity analyses suggest that the effects of these dietary factors on abdominal adiposity may depend on an individual’s overall adiposity. Since the sample size for the sensitivity analyses was limited, further investigation is needed to elucidate the relationships among dietary factors, abdominal adiposity, and overall adiposity.

Future research examining diet-adiposity relationships must continue to utilize different methods to account for complex interactions among dietary factors, as shown in the findings of this study. One approach would be greater emphasis on dietary patterns, which could be defined using foods or nutrients. Alternatively, statistical approaches, such as substitution models, could provide information about how exchanging dietary components affect adiposity outcomes. Furthermore, there was a suggestion of a non-linear association between dietary GL and adiposity in this study. Thus, future research should also evaluate non-linear associations, including potential threshold effects (21).

Finally, a focus of future research on dietary determinants of adiposity should be gene-diet interactions. Over the past decade, research examining the associations of interactions between various dietary factors and genetic variants with obesity has emerged (22). While numerous genetic variants associated with obesity have been identified, these only account for a small amount of the variation in overall obesity and the unexplained variance may be due to interactions of genetic variants with environmental factors, such as diet and other lifestyle factors (22). Likewise, gene-diet interactions need to be explored specifically in relation to abdominal adiposity. Future research on gene-diet interactions may be of particular relevance to understanding the role of carbohydrate-related dietary factors because there is also evidence that genetic variants are associated with dietary preferences relating to foods and macronutrient intake (22). Developments in this field will significantly improve our understanding of the etiology of abdominal adipose tissue accumulation and have implications for nutrition practices.
8.4 Conclusions

This thesis research adds valuable information to our understanding of the role of the nature of carbohydrate intake in abdominal adiposity. Examining macronutrients (carbohydrate and dietary fibre), dietary patterns, and carbohydrate-related indices allowed for a more comprehensive investigation of this relationship. We found that increased total dietary fibre intake was associated with reduced abdominal adiposity, although the associations varied among specific food sources of dietary fibre intake. In addition, there were distinct differences between the carbohydrate food groups which characterized the Western dietary pattern compared to the Prudent dietary pattern. These differences in the quality of carbohydrate food groups were reflected in the positive and inverse associations with abdominal adiposity found for the Western and Prudent dietary patterns, respectively. However, we did not detect an association between dietary GI and dietary GL, which are indices of carbohydrate quality, and abdominal adiposity. Altogether, the findings from this study suggest that the quality of carbohydrate intake is an important factor in abdominal adiposity. This contributes to the emerging research on carbohydrate-related dietary factors and abdominal adiposity, but additional studies, addressing some of the methodological issues outlined previously, are necessary to draw conclusions about the effect of carbohydrate quality on the accumulation of abdominal adipose tissue.

The finding of the potential role of carbohydrate quality in the etiology of abdominal adipose tissue accumulation is significant because it furthers our knowledge and understanding of determinants of abdominal adiposity. In addition to the epidemiological evidence, plausible biological mechanisms in which high-quality carbohydrates lead to reduced insulin response and reduced abdominal adiposity have been hypothesized. Thus, identifying modifiable dietary factors associated with adiposity has substantial public health implications because of the potential to reduce the prevalence rates of overall obesity and abdominal obesity, as well as the subsequent health risks associated with increased adipose tissue. Knowledge about the role of carbohydrate quality in abdominal adiposity could inform changes to dietary guidelines and recommendations. In addition, this could lead to changes in food production to include more high-quality carbohydrates. Understanding the relationship between carbohydrate quality and abdominal adiposity could also inform clinical practice. Furthermore, future research on gene-diet interactions could also be applied to the practice of precision nutrition to tailor an individual’s diet based on their genetic susceptibility.
In summary, this thesis research suggests that carbohydrate quality may be associated with abdominal adiposity. However, additional research is required to further elucidate the relationship between carbohydrate intake and abdominal adiposity. Research in this area has the potential to inform both public health and clinical nutrition practices, with the ultimate aim of reducing abdominal obesity and associated health risks.
8.5 References


12. Statistics Canada. Table 13–10–0794–01 Measured adult body mass index (BMI) (World Health Organization classification), by age group and sex, Canada and provinces, Canadian Community Health Survey - Nutrition [Internet]. 2018 [cited 2018 Jun 25]. Available from: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310079401&pickMembers%5B0%5D=1.1&pickMembers%5B1%5D=2.9&pickMembers%5B2%5D=3.3&pickMembers%5B3%5D=5.5.


Appendix A
Study Questionnaire

Body Composition Study Research Questionnaire

Study ID: ___________________ Date/time: _______________________

A. Background

1. How old are you? _______ years old

2. What is your birth date? ________________________ (Day/Month/Year)

3. What is your ethnic background? (Which most closely describes the part of the world you or your ancestors came from?) You can pick as many as apply:

○ British
○ Northern European
○ Southern European
○ Eastern European
○ North-East Asian
○ South-East Asian
○ South Asian
○ Middle Eastern
○ African
○ First Nations
○ Latin American
○ Caribbean
○ Other (please specify) ________________________________

B. Menstrual/reproductive history

4. At what age did you have your first menstrual period? _______ years old

   OR ○ Never Started

5a. At what age did you have your last menstrual period? _______ years old

5b. What was the reason you stopped having periods?

   ○ Stopped naturally
   ○ Stopped because of surgery
   ○ Other reason: ________________________________

6a. Have you ever been pregnant?
If YES, proceed to questions 6b to 6i, if NO, proceed to question 7:

6b. How many pregnancies have you had? _____

6c. How many times have you given birth? _____

6d. How old were you when you first gave birth? _____ years old

6e. How old were you when you last gave birth? _____ years old

6f. Have you ever breastfed a child for one month or more?
   ☐ YES ☐ NO

6g. If YES, for how many births? _____

7a. Have you ever used hormonal contraceptives such as birth control pills?
   ☐ YES ☐ NO

7b. If YES, at what age(s)?
   _____ to _____ years old; _____ to _____ years old

8a. Have you ever used hormones for menopause?
   ☐ YES ☐ NO

   If YES, proceed to questions 8b,c:

8b. What did you take? ________________________________

8c. At what age(s)? _____ to _____ years old; _____ to _____ years old

9a. Have you ever taken hormones for any other reason?
   ☐ YES ☐ NO

   If YES, proceed to questions 9b,c:

9b. What did you take? ________________________________

9c. At what age(s)? _____ to _____ years old; _____ to _____ years old

C. Breast cancer family history

10. Did your mother ever have breast cancer?
    ☐ YES ☐ NO ☐ Don’t Know
11. How many full-sisters do you have (i.e. sisters who share the same biological mother and father as you)? ____

   If >0, Did any of them ever have breast cancer?
   ☐ YES ☐ NO ☐ Don’t Know

   If YES, How many? ____

12. Is there anyone else in your family who has had breast cancer?
   ☐ YES ☐ NO ☐ Don’t Know

   If YES, who? (Please specify mother or father’s side)
   _____________________________________________________________________

D. Alcohol/smoking

13a. Did you ever drink alcohol regularly (at least once per week)?
   ☐ YES ☐ NO

   b. If YES, at what age did you start drinking alcohol regularly? ____

14a. Did you ever stop drinking alcohol?
   ☐ YES ☐ NO

   b. If YES, at what age did you stop drinking? ____

15. How many drinks, on average per week, do/did you drink in the following ages?
   (Types of alcohol examples: beer, wine, cocktails, mixed drinks or spirits)
   a. Teens and 20’s: ______
   b. 30’s and 40’s: ______
   c. 50’s (or 50’s and 60’s): ______

16a. Are you currently drinking regularly (at least once per week)?
   ☐ YES ☐ NO

   b. If YES, how many drinks per week or per day do you currently consume?
   _______ drinks per week/day

17a. Did you ever smoke cigarettes at least once per week?
   ☐ YES ☐ NO

   b. If YES, at what age did you start smoking? _____

18a. Did you ever quit smoking?
b. If YES, at what age did you last quit smoking? 

19a. About how many cigarettes, on average per day, do/did you smoke in the following ages?

- Teens and 20's: _________ cigarettes per week/day
- 30's and 40's: _________ cigarettes per week/day
- 50's (or 50's and 60's): _________ cigarettes per week/day

20a. Are you currently smoking?  

- YES  
- NO  

b. If YES, how many cigarettes per week or per day do you currently smoke?  

_______ cigarettes per week/day

E. Body size and shapes

21. What is/was your approximate weight at the following ages?

a. Teens and 20's: _________ lbs/kg
b. 30's and 40's: _________ lbs/kg
c. 50's (or 50's and 60's): _________ lbs/kg

22. How tall were you in your 20's? _________ cm or ___ ft ___ inches

22. I am going to show you some pictures of different body shapes, please pick the one that you feel suits you the best at the following ages:

20's: _________
30's and 40's: _________
50's (or 50's and 60's): _________

Thank you!
Appendix B
International Physical Activity Questionnaire

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE
(November 2002)

LONG LAST 7 DAYS TELEPHONE FORMAT

For use with Young and Middle-aged Adults (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health-related physical activity.

Background on IPAQ
The development of an international measure for physical activity started in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ
Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation
Translation from English is encouraged to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

Data Entry and Coding
Attached to the response categories for each question are suggested variable names and valid ranges to assist in data management and interviewer training. We recommend that the actual response provided by each respondent is recorded. For example, “120 minutes” is recorded in the minutes response space. “Two hours” should be recorded as “2” in the hours column. A response of “one and a half hours” should be recorded as either “1” in hour column and “30” in minutes column.

Further Developments of IPAQ
International collaboration on IPAQ is on-going and an International Physical Activity Prevalence Study is in progress. For further information see the IPAQ website.

More Information
Long Last 7 Days Telephone IPAQ

READ: I am going to ask you about the time you spent being physically active in the last 7 days. Please answer each question even if you do not consider yourself to be an active person. Think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

READ: The first questions are about your work. This includes paid jobs, farming, volunteer work, course work and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. I will ask you about these later.

1. Do you currently have a job or do any unpaid work outside your home?
   [WORK: Yes=1, No=0, 8, 9]
   ___ Yes
   ___ No [Skip to PART 2]
   8. Don’t Know/Not Sure [Skip to PART 2]
   9. Refused [Skip to PART 2]

   [Interviewer clarification: This also includes credit and non-credit classes or course work. It also includes volunteer work and time spent looking for work. It does not includes unpaid house or yard work, nor caring for dependents, this will be asked in a later section.]

READ: The following questions are about all the physical activity you did as part of your paid or unpaid work. This does not include traveling to and from work.

READ: First, think about all the vigorous activities which take hard physical effort that you did as part of your work. Vigorous activities make you breathe much harder than normal. These may include things like heavy lifting, digging, heavy construction work, or climbing up stairs. Think about only those vigorous physical activities that you did for at least 10 minutes at a time.

2. During the last 7 days, on how many days did you do vigorous physical activities as part of your work? [OVDAY: Range 0-7, 8, 9]
   ___ Days per week [If respondent answers 0, skip to Question 4]
   8. Don’t Know/Not Sure [Skip to Question 4]
   9. Refused [Skip to Question 4]

   [Interviewer clarification: Think about only those physical activities that you did for at least 10 minutes at a time.]
[Interviewer clarification: Work includes paid and unpaid work as well as course work. Include all jobs and volunteer work.]

3. How much time did you usually spend on one of those days doing vigorous physical activities as part of your work?
   ___ ___ Hours per day [OVDHRS; Range 0-16]
   ___ ___ ___ Minutes per day [OVDMIN; Range 0-960, 998, 999]
   998. Don’t Know/Not Sure
   999. Refused

[Interviewer clarification: Think about only those physical activities you did for at least 10 minutes at a time.]

[Interviewer probe: An average time per day is being sought. If the respondent can’t answer because the pattern of time spent varies widely from day to day, or includes time spent doing a variety of paid and unpaid work, ask: “What is the total amount of time you spent over the last 7 days doing vigorous physical activities as part of your work?”]
   ___ ___ Hours per week [OIVHWRS; Range 0-112]
   ___ ___ ___ ___ Minutes per week [OIVWMIN; Range 0-6720, 9998, 9999]
   9998. Don’t Know/Not Sure
   9999. Refused

READ: Now think about activities which take moderate physical effort that you did as part of your work. Moderate physical activities make you breathe somewhat harder than normal and may include activities like carrying light loads. Do not include walking. Again, think about only those moderate physical activities that you did for at least 10 minutes at a time.

4. During the last 7 days, on how many days did you do moderate physical activities as part of your work? [OMDAY; Range 0-7, 8, 9]
   ___ Days per week [If respondent answers 0, skip to Question 6]
   8. Don’t Know/Not Sure [Skip to Question 6]
   9. Refused [Skip to Question 6]

[Interviewer clarification: Think about only those physical activities that you did for at least 10 minutes at a time.]

[Interviewer clarification: Work includes paid and unpaid work as well as course work. Include all jobs.]

5. How much time did you usually spend on one of those days doing moderate physical activities as part of your work?
   ___ ___ Hours per day [OMDHR; Range 0-16]
   ___ ___ ___ Minutes per day [OMDMIN; Range 0-960, 998, 999]
998. Don’t Know/Not Sure
999. Refused

[Interviewer clarification: Think about only those physical activities you did for at least 10 minutes at a time.]

[Interviewer probe: An average time per day is being sought. If the respondent can’t answer because the pattern of time spent varies widely from day to day, or includes time spent doing a variety of paid and unpaid work, ask: “What is the total amount of time you spent over the last 7 days doing moderate physical activities as part of your work?”

___ ___ Hours per week [OMWHRS; Range 0-112]
___ ___ ___ ___ Minutes per week [OMWMIN; Range 0-6720, 9998, 9999]
9998. Don’t Know/Not Sure
9999. Refused

READ: Now think about the time you spend walking for at least 10 minutes at a time as part of your work. Please do not count any walking you did to travel to or from work.

6. During the last 7 days, on how many days did you walk as part of your work?
[OWDAY; Range 0-7, 8, 9]
___ ___ Days per week [If respondent answers 0, skip to PART 2]
8. Don’t Know/Not Sure [Skip to PART 2]
9. Refused [Skip to PART 2]

[Interviewer clarification: Think about only the walking that you did for at least 10 minutes at a time.]

[Interviewer clarification: Include all jobs.]

7. How much time did you usually spend on one of those days walking as part of your work?
___ ___ Hours per day [OWDHR; Range 0-16]
___ ___ ___ ___ Minutes per day [OWDMIN; Range 0-960, 998, 998]
998. Don’t Know/Not Sure
999. Refused

[Interviewer clarification: Think about only the walking you did for at least 10 minutes at a time.]

[Interviewer probe: An average time per day is being sought. If the respondent can’t answer because the pattern of time spent varies widely from day to day, or includes

LONG LAST 7 DAYS TELEPHONE version of the IPAQ. Revised October 2002.
time spent doing a variety of paid and unpaid work, ask: “What is the total amount of
time you spent walking over the last 7 days as part of your work?”

<table>
<thead>
<tr>
<th>Hours per week</th>
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<tr>
<td>9998.</td>
<td>Don’t Know/Not Sure</td>
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<td>9999.</td>
<td>Refused</td>
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**PART 2: TRANSPORTATION PHYSICAL ACTIVITY**

**READ:** Now, think about how you traveled from place to place, including to places like
work, stores, movies and so on.

8. **During the last 7 days,** on how many days did you travel in a motor vehicle like a
train, bus, car or tram? [TMDAY; Range 0-7, 8, 9]
   - Days per week [If respondent answer 0, skip to Question 10]
   - Don’t Know/Not Sure [Skip to Question 10]
   - Refused [Skip to Question 10]

9. How much time did you usually spend on one of those days traveling in a car, bus,
train or other kind of motor vehicle?
   - Hours per day [TMDHRS; Range 0-16]
   - Minutes per day [TMDMIN; Range 0-960, 998, 999]
   - Don’t Know/Not Sure
   - Refused

[Interviewer probe: An average time per day is being sought. If the respondent can’t
answer because the pattern of time spent varies widely from day to day, ask: “What
is the total amount of time you spent over the last 7 days traveling in a motor
vehicle?”

<table>
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<tr>
<th>Hours per week</th>
<th>Minutes per week</th>
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<tr>
<td>9998.</td>
<td>Don’t Know/Not Sure</td>
</tr>
<tr>
<td>9999.</td>
<td>Refused</td>
</tr>
</tbody>
</table>

**READ:** Now think only about the bicycling you did to travel to and from work, to do
errands, or to go from place to place. Only include bicycling that you did for at least
10 minutes at a time.

10. **During the last 7 days,** on how many days did you bicycle to go from place to
place? [TBDAY; Range 0-7, 8, 9]
    - Days per week [If respondent answers 0, skip to Question 12]
    - Don’t Know/Not Sure [Skip to Question 12]
    - Refused [Skip to Question 12]

LONG LAST 7 DAYS TELEPHONE version of the IPAQ. Revised October 2002.
[Interviewer clarification: Think only about the bicycling that you did for at least 10 minutes at a time.]

11. How much time did you usually spend on one of those days to bicycle from place to place?

   ___ ___ Hours per day [TBCHRS; Range 0-16]
   ___ ___ ___ Minutes per day [TBDMIN; Range 0-960, 998, 999]

998. Don’t Know/Not Sure
999. Refused

[Interviewer clarification: Think about only the bicycling that you did for at least 10 minutes at a time.]

[Interviewer probe: An average time per day is being sought. If the respondent can’t answer because the pattern of time spent varies widely from day to day, ask: "What is the total amount of time you spent bicycling over the last 7 days to travel from place to place?"]

   ___ ___ Hours per week [TBWHRXS; Range 0-112]
   ___ ___ ___ ___ Minutes per week [TBWMIN; Range 0-6720, 9980, 9999]

9998. Don’t Know/Not Sure
9999. Refused

READ: Now think only about the walking you did to travel to and from work, to do errands or to go from place to place. Only include walking that you did for at least 10 minutes at a time.

12. During the last 7 days, on how many days did you walk to go from place to place?

   [TWDAY; Range 0-7, 8, 9]

   ___ Days per week [If respondent answers 0, skip to PART 3]

8. Don’t Know/Not Sure [Skip to PART 3]
9. Refused [Skip to PART 3]

[Interviewer clarification: Think only about the walking that you did for at least 10 minutes at a time.]

13. How much time did you usually spend on one of those days walking from place to place?

   ___ ___ Hours per day [TWCHRS; Range 0-16]
   ___ ___ ___ Minutes per day [TWDMIN; Range 0-960, 996, 999]

998. Don’t Know/Not Sure
999. Refused

LONG LAST 7 DAYS TELEPHONE version of the IPAQ. Revised October 2002.
[Interviewer clarification: Think about only the walking that you did for at least 10 minutes at a time.]

[Interviewer probe: An average time per day is being sought. If the respondent can’t answer because the pattern of time spent varies widely from day to day, ask: "What is the total amount of time you spent over the last 7 days walking from place to place?"]

<table>
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<th>Hours per week</th>
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<tr>
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*PART 3: HOUSEWORK, HOUSE MAINTENANCE AND CARING FOR FAMILY*

READ: Now think about the physical activities you have done in the last 7 days in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

READ: First think about vigorous activities which take hard physical effort that you did in the garden or yard. Vigorous activities make you breathe much harder than normal and may include heavy lifting, chopping wood, shoveling snow, or digging. Again, think about only those vigorous physical activities that you did for at least 10 minutes at a time.

14. During the last 7 days, on how many days did you do vigorous physical activities in the garden or yard? [GVDAY; Range 0-7, 0, 9]

<table>
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<th>Days per week</th>
</tr>
</thead>
<tbody>
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<td>8. Don’t Know/Not Sure [Skip to Question 16]</td>
</tr>
<tr>
<td>9. Refused [Skip to Question 16]</td>
</tr>
</tbody>
</table>

[Interviewer clarification: Think about only those physical activities that you did for at least 10 minutes at a time.]

15. How much time did you usually spend on one of those days doing vigorous physical activities in the garden or yard?

<table>
<thead>
<tr>
<th>Hours per day</th>
<th>Minutes per day</th>
</tr>
</thead>
<tbody>
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<td>998.</td>
<td>Don’t Know/Not Sure</td>
</tr>
<tr>
<td>999.</td>
<td>Refused</td>
</tr>
</tbody>
</table>

[Interviewer clarification: Think about only those physical activities that you did for at least 10 minutes at a time.]

LONG LAST 7 DAYS TELEPHONE version of the IPAQ. Revised October 2002.
[Interviewer probe: An average time per day is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, ask: "What is the total amount of time you spent over the last 7 days doing vigorous physical activities in the garden or yard?"

____  ____  Hours per week [GVWHR5; Range 0-112]
____  ____  ____  Minutes per week [GVWMIN; Range 0-8720, 9998, 9999]
9998.  Don't Know/Not Sure
9999.  Refused

READ: Now think about activities which take moderate physical effort that you did in the garden or yard. Moderate physical activities make you breathe somewhat harder than normal and may include carrying light loads, sweeping, washing windows, and raking. Again, include only those moderate physical activities that you did for at least 10 minutes at a time.

16.  During the last 7 days, on how many days did you do moderate activities in the garden or yard? [GMDAY; Range 0-7, 8, 9]
____  ____  Days per week [If respondent answers 0, skip to Question 18]
8.  Don't Know/Not Sure [Skip to Question 18]
9.  Refused [Skip to Question 18]

[Interviewer clarification: Think about only those physical activities that you did for at least 10 minutes at a time.]

17.  How much time did you usually spend on one of those days doing moderate physical activities in the garden or yard?
____  ____  Hours per day [GMDHR5; Range 0-16]
____  ____  ____  Minutes per day [GMDHR5; Range 0-960, 998, 999]
998.  Don't Know/Not Sure
999.  Refused

[Interviewer clarification: Think about only those physical activities that you did for at least 10 minutes at a time.]

[Interviewer probe: An average time per day is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, ask: "What is the total amount of time you spent over the last 7 days doing moderate physical activities in the garden or yard?"

____  ____  Hours per week [GMWHR5; Range 0-112]
____  ____  ____  Minutes per week [GMWMIN; Range 0-8720, 9998, 9999]
9998.  Don't Know/Not Sure
9999.  Refused

LONG LAST 7 DAYS TELEPHONE version of the IPAQ. Revised October 2002.
READ: Now think about activities which take at least moderate physical effort that you did inside your home. Examples include carrying light loads, washing windows, scrubbing floors, and sweeping. Include only those moderate physical activities that you did for at least 10 minutes at a time.

[Interviewer clarification: Moderate activities make you breathe somewhat harder than normal.]

18. During the last 7 days, on how many days did you do moderate activities inside your home? [HMDAY; Range 0-7, 8, 9]
   _____ Days per week [If respondent answers 0, skip to PART 4]
   8. Don't Know/Not Sure [Skip to PART 4]
   9. Refused [Skip to PART 4]

[Interviewer clarification: Think about only those physical activities that you did for at least 10 minutes at a time.]

[Interviewer clarification: During the last 7 days, on how many days did you do activities that take at least moderate effort inside your home?]

19. How much time did you usually spend on one of those days doing moderate physical activities inside your home?
   _____ _____ Hours per day [HMDHRS; Range 0-16]
   _____ _____ Minutes per day [HMDMIN; Range 0-960, 998, 999]
   998. Don't Know/Not Sure
   999. Refused

[Interviewer clarification: Think about only those physical activities that you did for at least 10 minutes at a time.]

[Interviewer probe: An average time per day is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, ask: "What is the total amount of time you spent over the last 7 days doing moderate physical activities inside your home?"

   _____ _____ Hours per week [HMWHR; Range 0-112]
   _____ _____ Minutes per week [HMWMIN; Range 0-6720, 9998, 9999]
   9998. Don't Know/Not Sure
   9999. Refused

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

READ: Now, think about all the physical activities that you did in the last 7 days solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

LONG LAST 7 DAYS TELEPHONE version of the IPAQ. Revised October 2002.
20. Not counting any walking you have already mentioned, during the last 7 days, on how many days did you walk for at least 10 minutes at a time in your leisure time? [LWDAY; Range 0-7, 8, 9]
   _____ Days per week [If respondent answers 0, skip to Question 22]
   8. Don’t Know/Not Sure [Skip to Question 22]
   9. Refused [Skip to Question 22]

[Interviewer clarification: Think about only the walking that you did for at least 10 minutes at a time.]

21. How much time did you usually spend on one of those days walking in your leisure time?
   _____ _____ Hours per day [LWDRS; Range 0-16]
   _____ _____ Minutes per day [LWDRMIN; Range 0-999, 999, 9999]
   998. Don’t Know/Not Sure
   999. Refused

[Interviewer clarification: Think about only the walking that you did for at least 10 minutes at a time.]

[Interviewer probe: An average time per day is being sought. If the respondent can’t answer because the pattern of time spent varies widely from day to day, ask: “What is the total amount of time you spent over the last 7 days walking in your leisure time?”
   _____ _____ Hours per week [LWDRWS; Range 0-112]
   _____ _____ _____ Minutes per week [LWDRWMIN; Range 0-6720, 9998, 99999]
   99998. Don’t Know/Not Sure
   99999. Refused

READ: Now think about other physical activities you did in your leisure time for at least 10 minutes at a time.

READ: First, think about vigorous activities which take hard physical effort that you did in your leisure time. Examples include aerobics, running, fast bicycling, or fast swimming.

[Interviewer clarification: Vigorous activities make you breathe much harder than normal.]

22. During the last 7 days, on how many days did you do vigorous physical activities in your leisure time? [LVDAY; Range 0-7, 8, 9]
   _____ Days per week [If respondent answers 0, skip to Question 24]
   8. Don’t Know/Not Sure [Skip to Question 24]
9. Refused [Skip to Question 24]

[Interviewer clarification: Think about only those vigorous physical activities that you did for at least 10 minutes at a time.]

23. How much time did you usually spend on one of those days doing vigorous physical activities in your leisure time?
   ______ Hours per day [LMDHRS; Range 0-16]
   ______ Minutes per day [LMDMIN; Range 0-960, 998, 999]
   998. Don't Know/Not Sure
   999. Refused

[Interviewer clarification: Think about only those physical activities that you did for at least 10 minutes at a time.]

[Interviewer probe: An average time per day is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, ask: “What is the total amount of time you spent over the last 7 days doing vigorous physical activities in your leisure time?”
   ______ Hours per week [LWMDHRS; Range 0-112]
   ______ Minutes per week [LWMDMIN; Range 0-6720, 9998, 9999]
   9998. Don't Know/Not Sure
   9999. Refused

READ: Now think about activities which take moderate physical effort that you did in your leisure time. Examples include bicycling at a regular pace, swimming at a regular pace, and doubles tennis. Again, include only those moderate activities that you did for at least 10 minutes at a time.

[Interviewer clarification: Moderate physical activities make you breathe somewhat harder than normal.]

24. During the last 7 days, on how many days did you do moderate physical activities in your leisure time? [LMDAY; Range 0-7, 8, 9]
   _____ Days per week [If respondent answers 0, skip to PART 5]
   8. Don't Know/Not Sure [Skip to PART 5]
   9. Refused [Skip to PART 5]

[Interviewer clarification: Think about only those physical activities that you did for at least 10 minutes at a time.]

23. How much time did you usually spend on one of those days doing moderate physical activities in your leisure time?
   _____ _____ Hours per day [LMDHRS; Range 0-16]
Minutes per day [LMOMIN, Range 0-960, 998, 999]
998. Don't Know/Not Sure
999. Refused

[Interviewer clarification: Think about only those physical activities that you did for at least 10 minutes at a time.]

[Interviewer probe: An average time per day is being sought. If the respondent can’t answer because the pattern of time spent varies widely from day to day, ask: “What is the total amount of time you spent over the last 7 days doing moderate physical activities in your leisure time?”

Hours per week [LMWHRS; Range 0-112]
Minutes per week [LMWMIN; Range 0-8720, 998, 999]
9998. Don’t Know/Not Sure
9999. Refused

PART 5: TIME SPENT SITTING

READ: The last question is about the time that you spent sitting during the last 7 days. Include time at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the last 7 days, how much time did you usually spend sitting on a weekday?

Hours per day [SDHRS; Range 0-16]
Minutes per day [SDMIN; Range 0-960, 998, 999]
998. Don’t Know/Not Sure
999. Refused

[Interviewer clarification: Include time spent lying down (awake) as well as sitting.]

[Interviewer probe: An average time per day is being sought. If the respondent can’t answer because the pattern of time spent sitting varies widely from day to day, ask: "How much time in total did you spend sitting on Wednesday?

Hours on Wednesday [SWHRS; Range 0-16]
Minutes per Wednesday [SWMIN; Range 0-960, 998, 999]
9998. Don’t Know/Not Sure
9999. Refused

27. During the last 7 days, how much time did you usually spend sitting on a weekend day?

Hours per day [SEHRS; Range 0-16]

LONG LAST 7 DAYS TELEPHONE version of the IPAQ. Revised October 2002.
Minutes per day [SEMIN; Range 0-990, 996, 999]

998.  Don’t Know/Not Sure
999.  Refused

[Interviewer clarification: Include time spent lying down (awake) as well as sitting.]

[Interviewer probe: An average time per day is being sought. If the respondent can’t answer because the pattern of time spent sitting varies widely from day to day, ask: “How much time in total did you spend sitting on Saturday?”

Hours on Saturday [SSHRS; Range 0-16]

Minutes per Saturday [SEMIN; Range 0-990, 996, 999]

9998.  Don’t Know/Not Sure
9999.  Refused
Appendix C
Canadian Diet History Questionnaire II

GENERAL INSTRUCTIONS

- Answer each question as best you can. Estimate if you are not sure. A guess is better than leaving a blank.
- Use only a black ball-point pen. Do not use a pencil or felt-tip pen. Do not fold, staple, or tear the pages.
- Put an X in the box next to your answer.
- If you make any changes, cross out the incorrect answer and put an X in the box next to the correct answer. Also draw a circle around the correct answer.
- If you mark NEVER, NO, or DON’T KNOW for a question, please follow any arrows or instructions that direct you to the next question.

BEFORE TURNING THE PAGE, PLEASE COMPLETE THE FOLLOWING QUESTIONS.

Today's date: __/__/20__

In what month were you born?
☐ Jan  ☐ Jul  ☐ Nov
☐ Feb  ☐ Aug  ☐ Dec
☐ Mar  ☐ Sep  ☐ Jan
☐ Apr  ☐ Oct  ☐ Feb
☐ May  ☐ Nov  ☐ Mar
☐ Jun  ☐ Dec  ☐ Apr

In what year were you born? __/___/19__

Are you male or female?
☐ Male  ☐ Female

BAR CODE LABEL OR SUBJECT ID HERE
1. Over the past 12 months, how often did you drink tomato juice?
   - □ NEVER (GO TO QUESTION 2)
   - □ 1 time per month or less
   - □ 2-3 times per month
   - □ 1-2 times per week
   - □ 3-4 times per week
   - □ 5-6 times per week

1a. Each time you drank tomato juice, how much did you usually drink?
   - □ Less than ¼ cup (6 ounces)
   - □ ¼ to 1½ cups (6 to 10 ounces)
   - □ More than 1½ cups (10 ounces)

2. Over the past 12 months, how often did you drink other vegetable juice? (Please do not include tomato juice.)
   - □ NEVER (GO TO QUESTION 3)
   - □ 1 time per month or less
   - □ 2-3 times per month
   - □ 1-2 times per week
   - □ 3-4 times per week
   - □ 5-6 times per week

2a. Each time you drank other vegetable juice, how much did you usually drink?
   - □ Less than ¼ cup (4 ounces)
   - □ ¼ to 1½ cups (4 to 10 ounces)
   - □ More than 1½ cups (10 ounces)

3. Over the past 12 months, how often did you drink 100% orange juice or grapefruit juice?
   - □ NEVER (GO TO QUESTION 4)
   - □ 1 time per month or less
   - □ 2-3 times per month
   - □ 1-2 times per week
   - □ 3-4 times per week
   - □ 5-6 times per week

3a. Each time you drank 100% orange juice or grapefruit juice, how much did you usually drink?
   - □ Less than ¼ cup (6 ounces)
   - □ ¼ to 1½ cups (6 to 10 ounces)
   - □ More than 1½ cups (10 ounces)

3b. How often was the orange juice you drank calcium-fortified?
   - □ Almost never or never
   - □ About ¼ of the time
   - □ About ½ of the time
   - □ About ¾ of the time
   - □ Almost always or always

4. Over the past 12 months, how often did you drink other 100% fruit juice or 100% fruit juice mixtures (such as apple, grape, pineapple, or others)?
   - □ NEVER (GO TO QUESTION 5)
   - □ 1 time per month or less
   - □ 2-3 times per month
   - □ 1-2 times per week
   - □ 3-4 times per week
   - □ 5-6 times per week

4a. Each time you drank other 100% fruit juice or 100% fruit juice mixtures, how much did you usually drink?
   - □ Less than ¼ cup (6 ounces)
   - □ ¼ to 1½ cups (6 to 12 ounces)
   - □ More than 1½ cups (12 ounces)

5. How often did you drink other fruit drinks (such as Fruté, Frutopia, Five Alive, Sunny D, or Kool-Aid, diet or regular)?
   - □ NEVER (GO TO QUESTION 6)
   - □ 1 time per month or less
   - □ 2-3 times per month
   - □ 1-2 times per week
   - □ 3-4 times per week
   - □ 5-6 times per week

Question 4 appears in the next column

Question 6 appears on the next page
Over the past 12 months...

5a. Each time you drank other fruit drinks, how much did you usually drink?
- Less than 1 cup (8 ounces)
- 1 to 2 cups (8 to 16 ounces)
- More than 2 cups (16 ounces)

5b. How often were your other fruit drinks diet or low calorie?
- Almost never or never
- About 1/4 of the time
- About 1/2 of the time
- About 3/4 of the time
- Almost always or always

6. How often did you drink milk or milk substitutes as a beverage (NOT in coffee, NOT in cereal)? (Please do not include chocolate milk, hot chocolate, and milk in milkshakes or meal replacement beverages.)
- NEVER (GO TO QUESTION 7)
- 1 time per month or less
- 2-3 times per month
- 1-2 times per week
- 3-4 times per week
- 5-6 times per week

6a. Each time you drank milk or milk substitute as a beverage, how much did you usually drink?
- Less than 1 cup (8 ounces)
- 1 to 1 1/2 cups (8 to 12 ounces)
- More than 1 1/2 cups (12 ounces)

6b. What kind of milk or milk substitute did you usually drink?
- Whole milk
- 2% fat milk
- 1% fat milk
- Skim, nonfat, or 0.5% fat milk
- Soy milk
- Rice milk
- Almond milk
- Other

7. How often did you drink chocolate milk (including hot chocolate)?
- NEVER (GO TO QUESTION 8)
- 1 time per month or less
- 2-3 times per month
- 1-2 times per week
- 3-4 times per week
- 5-6 times per week

7a. Each time you drank chocolate milk, how much did you usually drink?
- Less than 1 cup (8 ounces)
- 1 to 1 1/4 cups (8 to 12 ounces)
- More than 1 1/4 cups (12 ounces)

7b. How often was the chocolate milk you drank reduced-fat or fat-free?
- Almost never or never
- About 1/4 of the time
- About 1/2 of the time
- About 3/4 of the time
- Almost always or always

8. How often did you drink milkshakes?
- NEVER (GO TO QUESTION 9)
- 1 time per month or less
- 2-3 times per month
- 1-2 times per week
- 3-4 times per week
- 5-6 times per week
day

8a. Each time you drank milkshakes, how much did you usually drink?
- Less than 1 cup (less than 250mL)
- 1 to 2 cups (250 to 500 mL)
- More than 2 cups (more than 500 mL)

9. How often did you drink meal replacement or high-protein beverages (such as Boost, Breakfast Anytime, Ensure, Slimfast or others)?
- NEVER (GO TO QUESTION 10)
- 1 time per month or less
- 2-3 times per month
- 1-2 times per week
- 3-4 times per week
- 5-6 times per week
day

9a. Each time you drank meal replacement or high-protein beverages, how much did you usually drink?
- Less than 1 cup (8 ounces)
- 1 to 1 1/4 cups (8 to 10 ounces)
- More than 1 1/4 cups (10 ounces)
Over the past 12 months...

10. How often did you drink soft drinks or pop?
   - NEVER (GO TO QUESTION 11)
   - 1 time per month or less
   - 2-3 times per month
   - 1-2 times per week
   - 3-4 times per week
   - 5-6 times per week

10a. Each time you drank soft drinks or pop, how much did you usually drink?
   - Less than 10 ounces or less than 1 can or bottle
   - 10 to 18 ounces or 1 can or bottle
   - More than 18 ounces or more than 1 can or bottle

10b. How often were your soft drinks or pop diet or calorie-free?
   - Almost never or never
   - About 1/3 of the time
   - About 1/2 of the time
   - Almost always or always

10c. How often were your soft drinks or pop caffeine-free?
   - Almost never or never
   - About 1/3 of the time
   - About 1/2 of the time
   - Almost always or always

11. Over the past 12 months, did you drink sports drinks (such as PowerAde or Gatorade)?
   - NO (GO TO QUESTION 12)
   - YES

11a. How often did you drink sports drinks IN THE SUMMER?
   - NEVER
   - 1 time per month or less
   - 2-3 times per month
   - 1-2 times per week
   - 3-4 times per week
   - 5-6 times per week

11b. How often did you drink sports drinks DURING THE REST OF THE YEAR?
   - NEVER
   - 1 time per month or less
   - 2-3 times per month
   - 1-2 times per week
   - 3-4 times per week
   - 5-6 times per week

11c. Each time you drank sports drinks, how much did you usually drink?
   - Less than 12 ounces or less than 1 bottle
   - 12 to 24 ounces or 1 to 2 bottles
   - More than 24 ounces or more than 2 bottles

12. How often did you drink energy drinks (such as Red Bull, Rock Star, Full Throttle, or Monster)?
   - NEVER (GO TO QUESTION 13)
   - 1 time per month or less
   - 2-3 times per month
   - 1-2 times per week
   - 3-4 times per week
   - 5-6 times per week

12a. Each time you drank energy drinks, how much did you usually drink?
   - Less than 8 ounces or less than 1 cup
   - 8 to 16 ounces or 1 to 2 cups
   - More than 16 ounces or more than 2 cups

13. How often did you drink beer?
   - NEVER (GO TO QUESTION 14)
   - 1 time per month or less
   - 2-3 times per month
   - 1-2 times per week
   - 3-4 times per week
   - 5-6 times per week

13a. Each time you drank beer, how much did you usually drink?
   - Less than 1 regular size can or bottle (355 mL)
   - 1 to 3 regular size cans or bottles
   - More than 3 regular size cans or bottles
Over the past 12 months...

14. How often did you drink water (including tap, bottled, carbonated, flavoured and vitamin added water)?
   - NEVER (GO TO QUESTION 15)
   - 1 time per month or less 1 time per day
   - 2-3 times per month 2-3 times per day
   - 1-2 times per week 4-5 times per day
   - 3-4 times per week 6 or more times per day
   - 5-6 times per week

14a. Each time you drank water, how much did you usually drink?
   - Less than 1 cup or less than ½ bottle (less than 250 mL)
   - 1 to 4 cups or ½ bottle to 2 bottles (250 mL to 1 litre)
   - More than 4 cups or more than 2 bottles (more than 1 litre)

14b. How often was the water you drank tap water?
   - Almost never or never
   - About ¼ of the time
   - About ½ of the time
   - About ¾ of the time
   - Almost always or always

14c. How often was the water you drank bottled, sweetened water (with low or no-calorie sweetener, including carbonated water)?
   - Almost never or never
   - About ¼ of the time
   - About ½ of the time
   - About ¾ of the time
   - Almost always or always

14d. How often was the bottled sweetened water you drank with added vitamins and minerals (such as Aquafina Plus, Vitaminwater or others)?
   - Almost never or never
   - About ¼ of the time
   - About ½ of the time
   - About ¾ of the time
   - Almost always or always

15. How often did you drink wine?
   - NEVER (GO TO QUESTION 16)
   - 1 time per month or less 1 time per day
   - 2-3 times per month 2-3 times per day
   - 1-2 times per week 4-5 times per day
   - 3-4 times per week 6 or more times per day
   - 5-6 times per week

15a. Each time you drank wine, how much did you usually drink?
   - Less than 5 ounces or less than 1 glass
   - 5 to 12 ounces or 1 to 2 glasses
   - More than 12 ounces or more than 2 glasses

15b. How often was the wine you drank red wine?
   - Almost never or never
   - About ¼ of the time
   - About ½ of the time
   - About ¾ of the time
   - Almost always or always

16. How often did you drink liquor or mixed drinks?
   - NEVER (GO TO QUESTION 17)
   - 1 time per month or less 1 time per day
   - 2-3 times per month 2-3 times per day
   - 1-2 times per week 4-5 times per day
   - 3-4 times per week 6 or more times per day
   - 5-6 times per week

16a. Each time you drank liquor or mixed drinks, how much did you usually drink?
   - Less than 1 shot of liquor
   - 1 to 3 shots of liquor
   - More than 3 shots of liquor
Over the past 12 months...

17. Did you eat oatmeal, Cream of Wheat, Red River, or other cooked cereal?

☐ NO (GO TO QUESTION 18)
☐ YES

17a. How often did you eat oatmeal, Cream of Wheat, Red River, or other cooked cereal IN THE WINTER?

☐ NEVER
☐ 1-6 times per winter
☐ 7-11 times per winter
☐ 1 time per month
☐ 2-3 times per month
☐ 1 time per week

17b. How often did you eat oatmeal, Cream of Wheat, Red River, or other cooked cereal DURING THE REST OF THE YEAR?

☐ NEVER
☐ 1-6 times per year
☐ 7-11 times per year
☐ 1 time per month
☐ 2-3 times per month
☐ 1 time per week

17c. Each time you ate oatmeal, Cream of Wheat, Red River, or other cooked cereal, how much did you usually eat?

☐ Less than ¼ cup
☐ ¼ to 1¼ cups
☐ More than 1¼ cups

17d. How often was butter or margarine added to your oatmeal, Cream of Wheat, Red River, or other cooked cereal?

☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

17e. Was milk added to your oatmeal, Cream of Wheat, Red River, or other cooked cereal?

☐ NO (GO TO QUESTION 18)
☐ YES

17f. What kind of milk was usually added?

☐ Whole milk
☐ 2% milk
☐ 1% milk
☐ Skim, nonfat, or 0.5% milk
☐ Soy milk
☐ Rice milk
☐ Almond milk
☐ Other

17g. Each time milk was added to your oatmeal, Cream of Wheat, Red River, or other cooked cereal, how much was usually added?

☐ Less than ⅓ cup
☐ ⅓ to 1 cup
☐ More than 1 cup

18. How often did you eat cold cereal?

☐ NEVER (GO TO QUESTION 19)

18a. Each time you ate cold cereal, how much did you usually eat?

☐ Less than 1 cup
☐ 1 to 2½ cups
☐ More than 2½ cups

18b. How often was the cold cereal you ate Vector or PC Force Active?

☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ Almost always or always

18c. How often was the cold cereal you ate All Bran, Fibre 1, Fibre First, 100% Bran, or All-Bran Buds?

☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ Almost always or always
Over the past 12 months...

18d. How often was the cold cereal you ate some other bran or fibre cereal (such as Cheerios, Shredded Wheat, Raisin Bran, Bran Flakes, Mini-Wheats, Shreddies, Honey Bunches of Oats, Oatmeal Crisp or others)?

☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

18e. How often was the cold cereal you ate any other type of cold cereal (such as Corn Flakes, Rice Krispies, Frosted Flakes, Special K, Froot Loops, Cap'n Crunch, Honey Nut Cheerios, Honeycomb, or others)?

☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

18f. Was milk added to your cold cereal?

☐ NO (GO TO QUESTION 19)
☐ YES

18g. What kind of milk was usually added?

☐ Whole milk
☐ 2% fat milk
☐ 1% fat milk
☐ Skim, nonfat, or 0.5% fat milk
☐ Soy milk
☐ Rice milk
☐ Almond milk
☐ Other

18h. Each time milk was added to your cold cereal, how much was usually added?

☐ Less than ½ cup
☐ ½ to 1 cup
☐ More than 1 cup

19. How often did you eat applesauce?

☐ NEVER (GO TO QUESTION 20)

☐ 1-6 times per year
☐ 7-11 times per year
☐ 1 time per month
☐ 2-3 times per month
☐ 1 time per week
☐ 2 or more times per week

19a. Each time you ate applesauce, how much did you usually eat?

☐ Less than ½ cup
☐ ½ to ½ cup
☐ More than ½ cup

20. How often did you eat apples?

☐ NEVER (GO TO QUESTION 21)

☐ 1-6 times per year
☐ 7-11 times per year
☐ 1 time per month
☐ 2-3 times per month
☐ 1 time per week

20a. Each time you ate apples, how many did you usually eat?

☐ Less than 1 apple
☐ 1 apple
☐ More than 1 apple

21. How often did you eat pears (fresh, canned, or frozen)?

☐ NEVER (GO TO QUESTION 22)

☐ 1-6 times per year
☐ 7-11 times per year
☐ 1 time per month
☐ 2-3 times per month
☐ 1 time per week

21a. Each time you ate pears, how many did you usually eat?

☐ Less than 1 pear
☐ 1 pear
☐ More than 1 pear

22. How often did you eat bananas?

☐ NEVER (GO TO QUESTION 23)

☐ 1-6 times per year
☐ 7-11 times per year
☐ 1 time per month
☐ 2-3 times per month
☐ 1 time per week

Question 20 appears in the next column.
Over the past 12 months...

22a. Each time you ate bananas, how many did you usually eat?
- Less than 1 banana
- 1 banana
- More than 1 banana

23. How often did you eat dried fruit (such as prunes or raisins)? (Please do not include dried apricots)
- NEVER (GO TO QUESTION 24)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week

23a. Each time you ate dried fruit, how much did you usually eat?
- Less than 2 tablespoons
- 2 to 5 tablespoons
- More than 5 tablespoons

24. Over the past 12 months, did you eat peaches, nectarines, or plums?
- NO (GO TO QUESTION 25)
- YES

24a. How often did you eat fresh peaches, nectarines, or plums WHEN IN SEASON?
- NEVER
- 1-6 times per season
- 7-11 times per season
- 1 time per month
- 2-3 times per month
- 1 time per week

24b. How often did you eat peaches, nectarines, or plums (fresh, canned, or frozen) DURING THE REST OF THE YEAR?
- NEVER
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week

24c. Each time you ate peaches, nectarines, or plums, how much did you usually eat?
- Less than 1 fruit or less than 1/8 cup
- 1 to 2 fruits or 1/2 to 1/4 cup
- More than 2 fruits or more than 1/4 cup

25. How often did you eat grapes?
- NEVER (GO TO QUESTION 26)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week

25a. Each time you ate grapes, how much did you usually eat?
- Less than 1/8 cup or less than 10 grapes
- 1/2 to 1 cup or 10 to 30 grapes
- More than 1 cup or more than 30 grapes

26. Over the past 12 months, did you eat cantaloupe?
- NO (GO TO QUESTION 27)
- YES

26a. How often did you eat fresh cantaloupe WHEN IN SEASON?
- NEVER
- 1-6 times per season
- 7-11 times per season
- 1 time per month
- 2-3 times per month
- 1 time per week

26b. How often did you eat cantaloupe (fresh or frozen) DURING THE REST OF THE YEAR?
- NEVER
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
Over the past 12 months...

26c. Each time you ate cantaloupe, how much did you usually eat?
- Less than ½ melon or less than ½ cup
- ½ melon or ¾ to 1 cup
- More than ½ melon or more than 1 cup

27. Over the past 12 months, did you eat melon, other than cantaloupe (such as watermelon or honeydew)?
- NO (GO TO QUESTION 28)
- YES

27a. How often did you eat fresh melon, other than cantaloupe, WHEN IN SEASON?
- NEVER
- 1-6 times per season
- 7-11 times per season
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

27b. How often did you eat melon other than cantaloupe (fresh or frozen) DURING THE REST OF THE YEAR?
- NEVER
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

27c. Each time you ate melon other than cantaloupe, how much did you usually eat?
- Less than ½ cup or 1 small wedge
- ½ to 2 cups or 1 medium wedge
- More than 2 cups or 1 large wedge

28. Over the past 12 months, did you eat strawberries?
- NO (GO TO QUESTION 29)
- YES

28a. How often did you eat fresh strawberries WHEN IN SEASON?
- NEVER
- 1-6 times per season
- 7-11 times per season
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

28b. How often did you eat strawberries (fresh or frozen) DURING THE REST OF THE YEAR?
- NEVER
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

28c. Each time you ate strawberries, how much did you usually eat?
- Less than ½ cup or less than 3 berries
- ¼ to ½ cup or 3 to 9 berries
- More than ½ cup or more than 9 berries

29. Over the past 12 months, did you eat blueberries, raspberries, saskatoon berries or blackberries?
- NO (GO TO QUESTION 30)
- YES

29a. How often did you eat blueberries, raspberries, saskatoon berries or blackberries WHEN IN SEASON?
- NEVER
- 1-6 times per season
- 7-11 times per season
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day
Over the past 12 months...

33. How often did you eat other kinds of fruit?
   - NEVER (GO TO QUESTION 34)
   - 1-8 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   
   33a. Each time you ate other kinds of fruit, how much did you usually eat?
   - Less than 1/4 cup
   - 1/4 to 3/4 cup
   - More than 3/4 cup

34. How often did you eat COOKED greens (such as spinach, turnip greens, collard, mustard greens, chard, or kale)?
   - NEVER (GO TO QUESTION 36)
   - 1-8 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   
   34a. Each time you ate COOKED greens, how much did you usually eat?
   - Less than 1/2 cup
   - 1/2 to 1 cup
   - More than 1 cup

35. How often did you eat RAW greens (such as spinach, chard, or kale)? (We will ask about lettuce later.)
   - NEVER (GO TO QUESTION 36)
   - 1-8 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   
   35a. Each time you ate RAW greens, how much did you usually eat?
   - Less than 3/4 cups
   - 1 1/2 to 3 cups
   - More than 3 cups

36. How often did you eat coleslaw?
   - NEVER (GO TO QUESTION 37)
   - 1-8 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   
   36a. Each time you ate coleslaw, how much did you usually eat?
   - Less than 1/4 cup
   - 1/4 to 1/2 cup
   - More than 1/2 cup

37. How often did you eat sauerkraut or cabbage (other than coleslaw)?
   - NEVER (GO TO QUESTION 38)
   - 1-8 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   
   37a. Each time you ate sauerkraut or cabbage, how much did you usually eat?
   - Less than 1/2 cup
   - 1/2 to 1 cup
   - More than 1 cup

38. How often did you eat carrots (fresh, canned, or frozen)?
   - NEVER (GO TO QUESTION 39)
   - 1-8 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   
   38a. Each time you ate carrots, how much did you usually eat?
   - Less than 1/4 cup or less than 2 baby carrots
   - 1/4 to 1/2 cup or 2 to 5 baby carrots
   - More than 1/2 cup or more than 5 baby carrots
Over the past 12 months...

39. How often did you eat string beans or green beans (fresh, canned, or frozen)?
   □ NEVER (GO TO QUESTION 40)
   □ 1-6 times per year
   □ 7-11 times per year
   □ 1 time per month
   □ 2-3 times per month
   □ 1 time per week
   □ 2 or more times per day

39a. Each time you ate string beans or green beans, how much did you usually eat?
   □ Less than ½ cup
   □ ½ to 1 cup
   □ More than 1 cup

40. How often did you eat peas (fresh, canned, or frozen)?
   □ NEVER (GO TO QUESTION 41)
   □ 1-6 times per year
   □ 7-11 times per year
   □ 1 time per month
   □ 2-3 times per month
   □ 1 time per week
   □ 2 or more times per day

40a. Each time you ate peas, how much did you usually eat?
   □ Less than ½ cup
   □ ½ to ¾ cup
   □ More than ¾ cup

41. Over the past 12 months, did you eat corn?
   □ NO (GO TO QUESTION 42)
   □ YES

41a. How often did you eat fresh corn WHEN IN SEASON?
   □ NEVER
   □ 1-6 times per season
   □ 7-11 times per season
   □ 1 time per month
   □ 2-3 times per month
   □ 1 time per week
   □ 2 or more times per day

41b. How often did you eat corn (fresh, canned, or frozen) DURING THE REST OF THE YEAR?
   □ NEVER
   □ 1-6 times per year
   □ 7-11 times per year
   □ 1 time per month
   □ 2-3 times per month
   □ 1 time per week
   □ 2 or more times per day

41c. Each time you ate corn, how much did you usually eat?
   □ Less than 1 ear or less than ½ cup
   □ 1 ear or ½ to 1 cup
   □ More than 1 ear or more than 1 cup

42. How often did you eat broccoli (fresh or frozen)?
   □ NEVER (GO TO QUESTION 43)
   □ 1-6 times per year
   □ 7-11 times per year
   □ 1 time per month
   □ 2-3 times per month
   □ 1 time per week
   □ 2 or more times per day

42a. Each time you ate broccoli, how much did you usually eat?
   □ Less than ½ cup
   □ ½ to 1 cup
   □ More than 1 cup

43. How often did you eat cauliflower (fresh or frozen)?
   □ NEVER (GO TO QUESTION 44)
   □ 1-6 times per year
   □ 7-11 times per year
   □ 1 time per month
   □ 2-3 times per month
   □ 1 time per week
   □ 2 or more times per day

43a. Each time you ate cauliflower, how much did you usually eat?
   □ Less than ½ cup
   □ ½ to ¾ cup
   □ More than ¾ cup
Over the past 12 months...

44. How often did you eat Brussels sprouts (fresh or frozen)?
   - □ NEVER (GO TO QUESTION 45)
   - □ 1-6 times per year
   - □ 7-11 times per year
   - □ 1 time per month
   - □ 2-3 times per month
   - □ 1 time per week
   - □ 2 or more times per day
   - □ 44a. Each time you ate Brussels sprouts, how much did you usually eat?
     - □ Less than ½ cup (2 or less Brussels sprouts)
     - □ ½ to ¾ cup (3 or 4 Brussels sprouts)
     - □ More than ¾ cup (more than 4 Brussels sprouts)

45. How often did you eat asparagus (fresh or frozen)?
   - □ NEVER (GO TO QUESTION 46)
   - □ 1-6 times per year
   - □ 7-11 times per year
   - □ 1 time per month
   - □ 2-3 times per month
   - □ 1 time per week
   - □ 2 or more times per day
   - □ 45a. Each time you ate asparagus, how much did you usually eat?
     - □ Less than ¼ cup or less than 4 spears
     - □ ¼ to ½ cup or 4 to 7 spears
     - □ More than ½ cup or more than 7 spears

46. How often did you eat winter squash (such as pumpkin, butternut, or acorn)?
   - □ NEVER (GO TO QUESTION 47)
   - □ 1-6 times per year
   - □ 7-11 times per year
   - □ 1 time per month
   - □ 2-3 times per month
   - □ 1 time per week
   - □ 2 or more times per day
   - □ 46a. Each time you ate winter squash, how much did you usually eat?
     - □ Less than ½ cup
     - □ ½ to ¾ cup
     - □ More than ¾ cup

47. How often did you eat mixed vegetables (such as vegetable stir fry, frozen or canned mixed vegetables)?
   - □ NEVER (GO TO QUESTION 48)
   - □ 1-6 times per year
   - □ 7-11 times per year
   - □ 1 time per month
   - □ 2-3 times per month
   - □ 1 time per week
   - □ 2 or more times per day
   - □ 47a. Each time you ate mixed vegetables, how much did you usually eat?
     - □ Less than ½ cup
     - □ ½ to 1 cup
     - □ More than 1 cup

48. How often did you eat onions?
   - □ NEVER (GO TO QUESTION 49)
   - □ 1-6 times per year
   - □ 7-11 times per year
   - □ 1 time per month
   - □ 2-3 times per month
   - □ 1 time per week
   - □ 2 or more times per day
   - □ 48a. Each time you ate onions, how much did you usually eat?
     - □ Less than 1 slice or less than 1 tablespoon
     - □ 1 slice or 1 to 4 tablespoons
     - □ More than 1 slice or more than 4 tablespoons

49. Now think about all the cooked vegetables you ate in the past 12 months and how they were prepared. How often were your vegetables COOKED WITH some sort of fat, including oil spray? (Please do not include potatoes.)
   - □ NEVER (GO TO QUESTION 50)
   - □ 1-6 times per year
   - □ 7-11 times per year
   - □ 1 time per month
   - □ 2-3 times per month
   - □ 1 time per week
   - □ 2 or more times per day
Over the past 12 months...

49a. Which fats were usually added to your vegetables DURING COOKING? (Please do not include potatoes. Mark all that apply.)

- Margarine
- Corn oil
- Butter
- Canola or rapeseed oil
- (including light) Oil spray, such as Pamm or others
- (including light) Other kinds of oils
- Lard, fatback, or bacon fat None of the above
- Olive oil

50. Now, thinking again about all the cooked vegetables you ate in the past 12 months, how often was some sort of fat, sauce, or dressing added AFTER COOKING OR AT THE TABLE? (Please do not include potatoes.)

- NEVER (GO TO QUESTION 51)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1-2 times per week
- 3-4 times per week
- 5-6 times per week
- 2 times per day
- 3 or more times per day

50a. Which fats, sauces, or dressings were usually added AFTER COOKING OR AT THE TABLE? (Please do not include potatoes. Mark all that apply.)

- Margarine
- Salad dressing
- Butter
- Cheese sauce
- (including light) White sauce
- Lard, fatback, or Other bacon fat
- Vegetable oil

50b. If margarine, butter, lard, fatback, or bacon fat was added to your cooked vegetables AFTER COOKING OR AT THE TABLE, how much did you usually add?

- Did not usually add these
- Less than 1 teaspoon
- 1 to 3 teaspoons
- More than 3 teaspoons

50c. If salad dressing, vegetable oil, cheese sauce, or white sauce was added to your cooked vegetables AFTER COOKING OR AT THE TABLE, how much did you usually add?

- Did not usually add these
- Less than 1 teaspoon
- 1 to 3 teaspoons
- More than 3 teaspoons

51. How often did you eat sweet peppers (green, red, or yellow)?

- NEVER (GO TO QUESTION 52)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 3-4 times per week
- 5-6 times per week
- 1 time per day
- 2 or more times per day

51a. Each time you ate sweet peppers, how much did you usually eat?

- Less than ¼ pepper
- ¼ to ½ pepper
- More than ½ pepper

52. Over the past 12 months, did you eat fresh tomatoes (including those in salads)?

- NO. (GO TO QUESTION 53)
- YES

52a. How often did you eat fresh tomatoes (including those in salads) WHEN IN SEASON?

- NEVER
- 1-6 times per season
- 7-11 times per season
- 1 time per month
- 2-3 times per month
- 1 time per week
- 3-4 times per week
- 5-6 times per week
- 1 time per day
- 2 or more times per day

52b. How often did you eat fresh tomatoes (including those in salads) DURING THE REST OF THE YEAR?

- NEVER
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 3-4 times per week
- 5-6 times per week
- 1 time per day
- 2 or more times per day

52c. Each time you ate fresh tomatoes, how much did you usually eat?

- Less than ¼ tomato
- ¼ to ½ tomato
- More than ½ tomato

Question 51 appears in the next column

Question 52 appears on the next page
### Over the past 12 months...

53. How often did you eat **lettuce salads** (with or without other vegetables)?

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<th>Description</th>
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<td>1 time per week</td>
<td>10976</td>
<td>2 or more times per day</td>
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53a. Each time you ate **lettuce salads**, how much did you usually eat?

- Less than ¼ cup
- ¼ to ½ cup
- More than ½ cup

53b. How often did the lettuce salads you ate include **dark green lettuce**?

- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

54. How often did you eat **salad dressing** (including low-fat) on salads?

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</table>

54a. Each time you ate **salad dressing on salads**, how much did you usually eat?

- Less than 2 tablespoons
- 2 to 4 tablespoons
- More than 4 tablespoons

55. How often did you eat **sweet potatoes** or **yams**?

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<td>2 or more times per day</td>
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55a. Each time you ate **sweet potatoes** or **yams**, how much did you usually eat?

- 1 small potato or less than ¼ cup
- 1 medium potato or ¼ to ½ cup
- 1 large potato or more than ¼ cup

56. How often did you eat **French fries, home fries, hash browned potatoes, or tater tots**?

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<td>2 or more times per day</td>
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56a. Each time you ate **French fries, home fries, hash browned potatoes, or tater tots**, how much did you usually eat?

- Less than 10 fries or less than ¼ cup
- 10 to 25 fries or ¼ to ½ cup
- More than 25 fries or more than 1 cup

56b. Each time you ate **French fries, home fries, hash browned potatoes, or tater tots**, how often was it **poutine (with gravy and cheese)**?

- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

57. How often did you eat **potato salad**?

<table>
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<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
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<tr>
<td>1-6 times per year</td>
<td>10976</td>
<td>2 times per week</td>
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<tr>
<td>7-11 times per year</td>
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<td>5-6 times per week</td>
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<td>2-3 times per month</td>
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<tr>
<td>1 time per week</td>
<td>10976</td>
<td>2 or more times per day</td>
</tr>
</tbody>
</table>

57a. Each time you ate **potato salad**, how much did you usually eat?

- Less than ½ cup
- ¼ to 1 cup
- More than 1 cup

58. How often did you eat **baked, boiled, or mashed potatoes**?

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage</th>
<th>Description</th>
</tr>
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<td>1 time per week</td>
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<td>2 or more times per day</td>
</tr>
</tbody>
</table>

58a. Each time you ate **baked, boiled, or mashed potatoes**, how much did you usually eat?

- 1 small potato or less than ¼ cup
- 1 medium potato or ¼ to ½ cup
- 1 large potato or more than ¼ cup
Over the past 12 months...

58a. Each time you ate baked, boiled, or mashed potatoes, how much did you usually eat?
- □ 1 small potato or less than ½ cup
- □ 1 medium potato or ½ to 1 cup
- □ 1 large potato or more than 1 cup

58b. How often was sour cream (including low-fat) added to your potatoes, EITHER IN COOKING OR AT THE TABLE?
- □ Almost never or never (GO TO QUESTION 56d)
- □ About ¼ of the time
- □ About ½ of the time
- □ About ¾ of the time
- □ Almost always or always

58c. Each time sour cream was added to your potatoes, how much was usually added?
- □ Less than 1 tablespoon
- □ 1 to 3 tablespoons
- □ More than 3 tablespoons

58d. How often was margarine (including light) added to your potatoes, EITHER IN COOKING OR AT THE TABLE?
- □ Almost never or never
- □ About ¼ of the time
- □ About ½ of the time
- □ About ¾ of the time
- □ Almost always or always

58e. How often was butter (including light) added to your potatoes, EITHER IN COOKING OR AT THE TABLE?
- □ Almost never or never
- □ About ¼ of the time
- □ About ½ of the time
- □ About ¾ of the time
- □ Almost always or always

58f. Each time margarine or butter was added to your potatoes, how much was usually added?
- □ Never added
- □ Less than 1 teaspoon
- □ 1 to 3 teaspoons
- □ More than 3 teaspoons

58g. How often was cheese or cheese sauce added to your potatoes, EITHER IN COOKING OR AT THE TABLE?
- □ Almost never or never (GO TO QUESTION 59)
- □ About ¼ of the time
- □ About ½ of the time
- □ About ¾ of the time
- □ Almost always or always

58h. Each time cheese or cheese sauce was added to your potatoes, how much was usually added?
- □ Less than 1 tablespoon
- □ 1 to 3 tablespoons
- □ More than 3 tablespoons

59. How often did you eat salsa?
- □ NEVER (GO TO QUESTION 60)
- □ 1-6 times per year
- □ 7-11 times per year
- □ 1 time per month
- □ 2-3 times per month
- □ 1 time per week
- □ 2 more times per week

59a. Each time you ate salsa, how much did you usually eat?
- □ Less than 1 tablespoon
- □ 1 to 5 tablespoons
- □ More than 5 tablespoons

60. How often did you eat ketchup?
- □ NEVER (GO TO QUESTION 61)
- □ 1-6 times per year
- □ 7-11 times per year
- □ 1 time per month
- □ 2-3 times per month
- □ 1 time per week
- □ 2 more times per week

60a. Each time you ate ketchup, how much did you usually eat?
- □ Less than 1 teaspoon
- □ 1 to 6 teaspoons
- □ More than 6 teaspoons

61. How often did you eat stuffing, dressing, or dumplings?
- □ NEVER (GO TO QUESTION 62)
- □ 1-6 times per year
- □ 7-11 times per year
- □ 1 time per month
- □ 2-3 times per month
- □ 1 time per week
- □ 2 more times per week

61a. Each time you ate stuffing, dressing, or dumplings, how much did you usually eat?
- □ Less than ¼ cup
- □ ½ to 1 cup
- □ More than 1 cup
Over the past 12 months...

62. How often did you eat chili?
   - NEVER (GO TO QUESTION 63)
   - 1-8 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   - 2 times per week
   - 3-4 times per week
   - 6-8 times per week
   - 1 time per day
   - 2 or more times per day

62a. Each time you ate chili, how much did you usually eat?
   - Less than ½ cup
   - ½ to 1 ½ cups
   - More than 1 ½ cups

63. How often did you eat Mexican foods (such as tacos, tostadas, burritos, tamales, fajitas, enchiladas, quesadillas, and chimichangas)?
   - NEVER (GO TO QUESTION 64)
   - 1-8 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   - 2 times per week
   - 3-4 times per week
   - 5-6 times per week
   - 1 time per day
   - 2 or more times per day

63a. Each time you ate Mexican foods, how much did you usually eat?
   - Less than 1 taco, burrito, etc.
   - 1 to 2 tacos, burritos, etc.
   - More than 2 tacos, burritos, etc.

64. How often did you eat baked beans? (Please include canned, ready-made or homemade.)
   - NEVER (GO TO QUESTION 65)
   - 1-8 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   - 2 times per week
   - 3-4 times per week
   - 5-6 times per week
   - 1 time per day
   - 2 or more times per day

64a. Each time you ate baked beans, how much did you usually eat?
   - Less than ½ cup
   - ½ to 1 cup
   - More than 1 cup

65. How often did you eat other cooked dried beans (such as pinto, kidney, black-eyed peas, lima, lentils, soybeans, or refried beans)? (Please do not include bean, pea or lentil soups or chili.)
   - NEVER (GO TO QUESTION 66)
   - 1-6 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   - 2 times per week
   - 3-4 times per week
   - 5-6 times per week
   - 1 time per day
   - 2 or more times per day

65a. Each time you ate other beans, how much did you usually eat?
   - Less than ½ cup
   - ½ to 1 cup
   - More than 1 cup

65b. How often were the other beans you ate refried beans, beans prepared with any type of fat, or with meat added?
   - Almost never or never
   - About ¼ of the time
   - About ½ of the time
   - Almost always or always

66. How often did you eat other kinds of vegetables?
   - NEVER (GO TO QUESTION 67)
   - 1-8 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   - 2 times per week
   - 3-4 times per week
   - 5-6 times per week
   - 1 time per day
   - 2 or more times per day

66a. Each time you ate other kinds of vegetables, how much did you usually eat?
   - Less than ¼ cup
   - ¼ to ½ cup
   - More than ½ cup

67. How often did you eat rice or other cooked grains (such as bulgur, cracked wheat, or millet)?
   - NEVER (GO TO QUESTION 68)
   - 1-6 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   - 2 times per week
   - 3-4 times per week
   - 5-6 times per week
   - 1 time per day
   - 2 or more times per day

Question 65 appears in the next column

Question 66 appears on the next page
Over the past 12 months...

67a. Each time you ate rice or other cooked grains, how much did you usually eat?

- Less than ½ cup
- ½ to 1½ cups
- More than 1½ cups

67b. How often was butter, margarine, or oil added to your rice or other cooked grains IN COOKING OR AT THE TABLE?

- Almost never or never
- About ¼ of the time
- About ½ of the time
- Almost always or always

68. How often did you eat pancakes, waffles, or French toast?

- NEVER (GO TO QUESTION 69)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

68a. Each time you ate pancakes, waffles, or French toast, how much did you usually eat?

- Less than 1 medium piece
- 1 to 3 medium pieces
- More than 3 medium pieces

68b. How often was margarine (including light) added to your pancakes, waffles, or French toast AFTER COOKING OR AT THE TABLE?

- Almost never or never
- About ¼ of the time
- About ½ of the time
- Almost always or always

68c. How often was butter (including light) added to your pancakes, waffles, or French toast AFTER COOKING OR AT THE TABLE?

- Almost never or never
- About ¼ of the time
- About ½ of the time
- Almost always or always

68d. Each time margarine or butter was added to your pancakes, waffles, or French toast, how much was usually added?

- Never added
- Less than 1 teaspoon
- 1 to 3 teaspoons
- More than 3 teaspoons

68e. How often was syrup added to your pancakes, waffles, or French toast?

- Almost never or never (GO TO QUESTION 69)
- About ¼ of the time
- About ½ of the time
- Almost always or always

68f. Each time syrup was added to your pancakes, waffles, or French toast, how much was usually added?

- Less than 1 tablespoon
- 1 to 4 tablespoons
- More than 4 tablespoons

69. How often did you eat lasagna, stuffed shells, stuffed manicotti, ravioli, or tortellini? (Please do not include spaghetti or other pasta.)

- NEVER (GO TO QUESTION 70)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

69a. Each time you ate lasagna, stuffed shells, stuffed manicotti, ravioli, or tortellini, how much did you usually eat?

- Less than 1 cup
- 1 to 2 cups
- More than 2 cups

70. How often did you eat macaroni and cheese?

- NEVER (GO TO QUESTION 71)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

70a. Each time you ate macaroni and cheese, how much did you usually eat?

- Less than 1 cup
- 1 to 1½ cups
- More than 1½ cups
Over the past 12 months...

71. How often did you eat pasta salad or macaroni salad?
   - NEVER (GO TO QUESTION 72)
   - 1-6 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   - 2 or more times per day

71a. Each time you ate pasta salad or macaroni salad, how much did you usually eat?
   - Less than ½ cup
   - ½ to 1 cup
   - More than 1 cup

72. Other than the pastas listed in Questions 69, 70, and 71, how often did you eat pasta, spaghetti, or other noodles?
   - NEVER (GO TO QUESTION 73)
   - 1-6 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   - 2 or more times per day

72a. Each time you ate pasta, spaghetti, or other noodles, how much did you usually eat?
   - Less than 1 cup
   - 1 to 3 cups
   - More than 3 cups

72b. How often did you eat your pasta, spaghetti, or other noodles with tomato sauce or spaghetti sauce made WITH meat?
   - Almost never or never
   - About ¼ of the time
   - About ½ of the time
   - About ¾ of the time
   - Almost always or always

72c. How often did you eat your pasta, spaghetti, or other noodles with tomato sauce or spaghetti sauce made WITHOUT meat?
   - Almost never or never
   - About ¼ of the time
   - About ½ of the time
   - About ¾ of the time
   - Almost always or always

72d. How often did you eat your pasta, spaghetti, or other noodles with margarine, butter, oil, or cream sauce?
   - Almost never or never
   - About ¼ of the time
   - About ½ of the time
   - About ¾ of the time
   - Almost always or always

73. How often did you eat bagels or English muffins?
   - NEVER (GO TO INTRODUCTION TO QUESTION 74)
   - 1-6 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week
   - 2 or more times per day

73a. How often were the bagels or English muffins you ate whole wheat?
   - Almost never or never
   - About ¼ of the time
   - About ½ of the time
   - About ¾ of the time
   - Almost always or always

73b. Each time you ate bagels or English muffins, how many did you usually eat?
   - Less than 1 bagel or English muffin
   - 1 bagel or English muffin
   - More than 1 bagel or English muffin

73c. How often was margarine (including light) added to your bagels or English muffins?
   - Almost never or never
   - About ¼ of the time
   - About ½ of the time
   - About ¾ of the time
   - Almost always or always

73d. How often was butter (including light) added to your bagels or English muffins?
   - Almost never or never
   - About ¼ of the time
   - About ½ of the time
   - About ¾ of the time
   - Almost always or always

73e. Each time margarine or butter was added to your bagels or English muffins, how much was usually added?
   - Never added
   - Less than 1 teaspoon
   - 1 to 2 teaspoons
   - More than 2 teaspoons

Question 73 appears in the next column

Introduction to Question 74 appears on the next page
Over the past 12 months...

73f. How often was cream cheese (including low-fat) spread on your bagels or English muffins?

☐ Almost never or never
☐ (GO TO INTRODUCTION TO QUESTION 74)
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

73g. Each time cream cheese was added to your bagels or English muffins, how much was usually added?

☐ Less than 1 tablespoon
☐ 1 to 2 tablespoons
☐ More than 2 tablespoons

The next questions ask about your intake of breads other than bagels or English muffins. First, we will ask about bread you ate as part of sandwiches only. Then we will ask about all other bread you ate.

74. How often did you eat breads, rolls or flatbread (such as pita, roti and tortillas) as part of sandwiches (including burger and hot dog rolls)?

☐ NEVER (GO TO QUESTION 75)
☐ 1-6 times per year
☐ 7-11 times per year
☐ 1 time per month
☐ 2-3 times per month
☐ 1 time per week
☐ 2 times per week
☐ 3-4 times per week
☐ 5-6 times per week
☐ 1 time per day
☐ 2 or more times per day

74a. Each time you ate breads, rolls or flatbreads as part of sandwiches, how many did you usually eat?

☐ 1 slice or ½ roll or flatbread
☐ 2 slices or 1 roll or flatbread
☐ More than 2 slices or more than 1 roll or flatbread

74b. How often were the breads, rolls or flatbread that you used for your sandwiches white (including burger and hot dog rolls)?

☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

74c. How often was mayonnaise or mayonnaise-type dressing (including low-fat) added to the breads, rolls or flatbread used for your sandwiches or wraps?

☐ Almost never or never (GO TO QUESTION 74e)
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

74d. Each time mayonnaise or mayonnaise-type dressing was added to the breads, rolls or flatbread used for your sandwiches or wraps, how much was usually added?

☐ Less than 1 teaspoon
☐ 1 to 3 teaspoons
☐ More than 3 teaspoons

74e. How often was margarine (including light) added to the breads, rolls or flatbread used for your sandwiches or wraps?

☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

74f. How often was butter (including low-fat) added to the breads, rolls or flatbread used for your sandwiches or wraps?

☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

74g. Each time margarine or butter was added to the breads, rolls or flatbread used for your sandwiches or wraps, how much was usually added?

☐ Never added
☐ Less than 1 teaspoon
☐ 1 to 2 teaspoons
☐ More than 2 teaspoons

75. How often did you eat breads, dinner rolls or flatbreads, not as part of sandwiches?

☐ NEVER (GO TO QUESTION 76)
☐ 1-6 times per year
☐ 7-11 times per year
☐ 1 time per month
☐ 2-3 times per month
☐ 1 time per week
☐ 2 times per week
☐ 3-4 times per week
☐ 5-6 times per week
☐ 1 time per day
☐ 2 or more times per day

Question 75 appears in the next column

Question 76 appears on the next page
75a. Each time you ate breads, dinner rolls or flatbreads, NOT AS PART OF SANDWICHES, how much did you usually eat?
- 1 slice or 1 dinner roll or ½ flatbread
- 2 slices or 2 dinner rolls or 1 flatbread
- More than 2 slices or 2 dinner rolls or 1 flatbread

75b. How often were the breads, rolls or flatbreads you ate white?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

75c. How often was margarine (including light) added to your breads, rolls or flatbreads?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

75d. How often was butter (including light) added to your breads, rolls or flatbreads?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

75e. Each time margarine or butter was added to your breads, rolls or flatbreads, how much was usually added?
- Never added
- Less than 1 teaspoon
- 1 to 2 teaspoons
- More than 2 teaspoons

75f. How often was cream cheese (including low-fat) added to your breads, rolls or flatbreads?
- Almost never or never (GO TO QUESTION 76)
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

75g. Each time cream cheese was added to your breads, rolls or flatbreads, how much was usually added?
- Less than 1 tablespoon
- 1 to 2 tablespoons
- More than 2 tablespoons

76. How often did you eat jam, jelly, or honey on bagels, muffins, bread, rolls, or crackers?
- NEVER (GO TO QUESTION 77)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2-3 times per week
- 1 time per day
- 2 or more times per day

76a. Each time you ate jam, jelly, or honey, how much did you usually eat?
- Less than 1 teaspoon
- 1 to 3 teaspoons
- More than 3 teaspoons

77. How often did you eat peanut butter or other nut butter?
- NEVER (GO TO QUESTION 78)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2-3 times per week
- 1 time per day
- 2 or more times per day

77a. Each time you ate peanut butter or other nut butter, how much did you usually eat?
- Less than 1 tablespoon
- 1 to 2 tablespoons
- More than 2 tablespoons

78. How often did you eat roast beef or steak IN SANDWICHES?
- NEVER (GO TO QUESTION 79)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2-3 times per week
- 1 time per day
- 2 or more times per day

Question 76 appears in the next column

Question 79 appears on the next page
Over the past 12 months...

78a. Each time you ate roast beef or steak IN SANDWICHES, how much did you usually eat?
- [ ] Less than 1 slice or less than 2 ounces
- [ ] 1 to 2 slices or 2 to 4 ounces
- [ ] More than 2 slices or more than 4 ounces

79. How often did you eat turkey or chicken COLD CUTS (such as loaf, luncheon meat, turkey ham, turkey salami, or turkey pastrami)? (We will ask about other turkey or chicken later.)
- [ ] NEVER (GO TO QUESTION 80)
- [ ] 1-6 times per year
- [ ] 7-11 times per year
- [ ] 1 time per month
- [ ] 2-3 times per month
- [ ] 1 time per week
- [ ] 2 or more times per week

79a. Each time you ate turkey or chicken COLD CUTS, how much did you usually eat?
- [ ] Less than 1 slice
- [ ] 1 to 3 slices
- [ ] More than 3 slices

80. How often did you eat luncheon or deli-style ham? (We will ask about other ham later.)
- [ ] NEVER (GO TO QUESTION 81)
- [ ] 1-6 times per year
- [ ] 7-11 times per year
- [ ] 1 time per month
- [ ] 2-3 times per month
- [ ] 1 time per week
- [ ] 2 or more times per week

80a. Each time you ate luncheon or deli-style ham, how much did you usually eat?
- [ ] Less than 1 slice
- [ ] 1 to 3 slices
- [ ] More than 3 slices

80b. How often was the luncheon or deli-style ham you ate light, low-fat, or fat-free?
- [ ] Almost never or never
- [ ] About ¼ of the time
- [ ] About ½ of the time
- [ ] Almost always or always

81. How often did you eat other cold cuts or luncheon meats (such as bologna, salami, comed beef, pastrami, or others, including low-fat)? (Please do not include ham, turkey, or chicken cold cuts.)
- [ ] NEVER (GO TO QUESTION 82)
- [ ] 1-6 times per year
- [ ] 7-11 times per year
- [ ] 1 time per month
- [ ] 2-3 times per month
- [ ] 1 time per week
- [ ] 2 or more times per week

81a. Each time you ate other cold cuts or luncheon meats, how much did you usually eat?
- [ ] Less than 1 slice
- [ ] 1 to 3 slices
- [ ] More than 3 slices

81b. How often were the other cold cuts or luncheon meats you ate light, low-fat, or fat-free? (Please do not include ham, turkey, or chicken cold cuts.)
- [ ] Almost never or never
- [ ] About ¼ of the time
- [ ] About ½ of the time
- [ ] Almost always or always

82. How often did you eat canned tuna (including in salads, sandwiches, or casseroles)?
- [ ] NEVER (GO TO QUESTION 83)
- [ ] 1-6 times per year
- [ ] 7-11 times per year
- [ ] 1 time per month
- [ ] 2-3 times per month
- [ ] 1 time per week
- [ ] 2 or more times per week

82a. Each time you ate canned tuna, how much did you usually eat?
- [ ] Less than ¼ cup or less than 2 ounces
- [ ] ¼ to ½ cup or 2 to 3 ounces
- [ ] More than ½ cup or more than 3 ounces

82b. How often was the canned tuna you ate water-packed?
- [ ] Almost never or never
- [ ] About ¼ of the time
- [ ] About ½ of the time
- [ ] Almost always or always
Over the past 12 months...

82c. How often was the canned tuna you ate prepared with mayonnaise or other dressing (including low-fat)?
- Almost never or never
- About 1/4 of the time
- About 1/2 of the time
- About 3/4 of the time
- Almost always or always

83. How often did you eat GROUND chicken or turkey? (We will ask about other chicken and turkey later.)
- NEVER (GO TO QUESTION 84)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

83a. Each time you ate GROUND chicken or turkey, how much did you usually eat?
- Less than 2 ounces or less than 1/2 cup
- 2 to 4 ounces or 1/2 to 1 cup
- More than 4 ounces or more than 1 cup

84. How often did you eat beef hamburgers or cheeseburgers from a FAST FOOD or OTHER RESTAURANT?
- NEVER (GO TO QUESTION 85)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

84a. Each time you ate beef hamburgers or cheeseburgers from a FAST FOOD or OTHER RESTAURANT, what size did you usually eat?
- Small hamburger (such as a regular Burger King or McDonald's Hamburger)
- Medium (such as McDonald's or Burger King Double Burger or Cheeseburger)
- Large (such as Burger King Whopper or Double Whopper or a McDonald's Double Quarter Pounder)

84b. Each time you ate beef hamburgers or cheeseburgers from a FAST FOOD or OTHER RESTAURANT, how much did you usually eat?
- Less than 1 burger
- 1 burger
- More than 1 burger

84c. How often did you have cheeseburgers rather than hamburgers from a FAST FOOD or OTHER RESTAURANT?
- Almost never or never
- About 1/4 of the time
- About 1/2 of the time
- About 3/4 of the time
- Almost always or always

85. How often did you eat beef hamburgers or cheeseburgers that were NOT from a FAST FOOD or OTHER RESTAURANT?
- NEVER (GO TO QUESTION 86)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

85a. Each time you ate beef hamburgers or cheeseburgers that were NOT from a FAST FOOD or OTHER RESTAURANT, how much did you usually eat?
- Less than 1 patty or less than 2 ounces
- 1 patty or 2 to 4 ounces
- More than 1 patty or more than 4 ounces

85b. How often were these beef hamburgers or cheeseburgers made with lean or extra lean ground beef?
- Almost never or never
- About 1/4 of the time
- About 1/2 of the time
- About 3/4 of the time
- Almost always or always

86. How often did you eat ground beef in mixtures (such as meatballs, casseroles, chili, or meatloaf)?
- NEVER (GO TO QUESTION 87)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day
Over the past 12 months...

86a. Each time you ate ground beef in mixtures, how much did you usually eat?
- Less than 3 ounces or less than ½ cup
- 3 to 8 ounces or ½ to 1 cup
- More than 8 ounces or more than 1 cup

87. How often did you eat hot dogs, wiens or frankfurters? (Please do not include sausages or vegetarian hot dogs)
- NEVER (GO TO QUESTION 88)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week

87a. Each time you ate hot dogs, wiens, or frankfurters, how many did you usually eat?
- Less than 1 hot dog
- 1 to 2 hot dogs
- More than 2 hot dogs

87b. How often were the hot dogs, wiens, or frankfurters you ate light or low-fat?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

88. How often did you eat beef mixtures (such as beef stew, beef curry, beef pot pie, beef and noodles, or beef and vegetables)?
- NEVER (GO TO QUESTION 89)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week

88a. Each time you ate beef mixtures, how much did you usually eat?
- Less than 1 cup
- 1 to 2 cups
- More than 2 cups

89. How often did you eat roast beef or pot roast? (Please do not include roast beef or pot roast in sandwiches)
- NEVER (GO TO QUESTION 90)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week

89a. Each time you ate roast beef or pot roast, how much did you usually eat?
- Less than 2 ounces
- 2 to 5 ounces
- More than 5 ounces

90. How often did you eat steak (beef)? (Please do not include steak in sandwiches)
- NEVER (GO TO QUESTION 91)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week

90a. Each time you ate steak (beef), how much did you usually eat?
- Less than 3 ounces
- 3 to 7 ounces
- More than 7 ounces

90b. How often was the steak you ate lean steak?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

91. How often did you eat pork or beef spareribs?
- NEVER (GO TO QUESTION 92)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week

91a. Each time you ate pork or beef spareribs, how much did you usually eat?
- Less than 1 cup
- 1 to 2 cups
- More than 2 cups
Over the past 12 months...

91a. Each time you ate pork or beef spareribs, how much did you usually eat?
- Less than 4 ribs
- 4 to 12 ribs
- More than 12 ribs

92. How often did you eat roast turkey, turkey cutlets, or turkey nuggets (including in sandwiches)?
- NEVER (GO TO QUESTION 93)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

92a. Each time you ate roast turkey, turkey cutlets, or turkey nuggets, how much did you usually eat? (Please note: 4 to 8 turkey nuggets = .3 ounces.)
- Less than 2 ounces
- 2 to 4 ounces
- More than 4 ounces

93. How often did you eat chicken mixtures (such as salads, sandwiches, casseroles, chicken curries, stews, or other mixtures)?
- NEVER (GO TO QUESTION 94)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

93a. Each time you ate chicken mixtures, how much did you usually eat?
- Less than ½ cup
- ¼ to ½ cups
- More than 1½ cups

94. How often did you eat baked, broiled, roasted, stewed, or fried chicken (including nuggets)? (Please do not include chicken in mixtures.)
- NEVER (GO TO QUESTION 96)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

94a. Each time you ate baked, broiled, roasted, stewed, or fried chicken (including nuggets), how much did you usually eat?
- Less than 2 drumsticks or wings, less than 1 breast or thigh, or less than 4 nuggets
- 2 drumsticks or wings, 1 breast or thigh, or 4 to 8 nuggets
- More than 2 drumsticks or wings, more than 1 breast or thigh, or more than 8 nuggets

94b. How often was the chicken you ate fried chicken (including deep fried) or chicken nuggets?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

94c. How often was the chicken you ate WHITE meat?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

94d. How often did you eat chicken WITH skin?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

95. How often did you eat baked ham or ham steak?
- NEVER (GO TO QUESTION 96)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

Question 94 appears in the next column

Question 96 appears on the next page
Over the past 12 months...

95a. Each time you ate baked ham or ham steak, how much did you usually eat?
- Less than 1 ounce
- 1 to 3 ounces
- More than 3 ounces

96. How often did you eat pork (including chops, roasts, and in mixed dishes)? (Please do not include ham, ham steak, or sausage.)
- NEVER (GO TO QUESTION 97)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week

96a. Each time you ate pork, how much did you usually eat?
- Less than 2 ounces or less than 1 chop
- 2 to 5 ounces or 1 chop
- More than 5 ounces or more than 1 chop

97. How often did you eat gravy on meat, chicken, potatoes, rice, etc.?
- NEVER (GO TO QUESTION 98)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week

97a. Each time you ate gravy on meat, chicken, potatoes, rice, etc., how much did you usually eat?
- Less than ¼ cup
- ¼ to ½ cup
- More than ½ cup

98. How often did you eat liver (all kinds) or liverwurst?
- NEVER (GO TO QUESTION 99)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week

98a. Each time you ate liver or liverwurst, how much did you usually eat?
- Less than 1 ounce
- 1 to 4 ounces
- More than 4 ounces

99. How often did you eat bacon (including low-fat)?
- NEVER (GO TO QUESTION 100)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week

99a. Each time you ate bacon, how much did you usually eat?
- Fewer than 2 slices
- 2 to 3 slices
- More than 3 slices

99b. How often was the bacon you ate light, low-fat, or lean?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- Almost always or always

100. How often did you eat sausage (including low-fat)?
- NEVER (GO TO QUESTION 101)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week

100a. Each time you ate sausage, how much did you usually eat?
- Less than 1 patty or 2 links
- 1 to 3 patties or 2 to 5 links
- More than 3 patties or 5 links

100b. How often was the sausage you ate light, low-fat, or lean?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- Almost always or always
Over the past 12 months...

106a. Which of the following fats were regularly used to prepare your meat, poultry, or fish? *(Mark all that apply.)*
- Margarine (including light)
- Butter (including light)
- Lard, fatback, or bacon fat
- Olive oil
- Corn oil
- Canola or rapeseed oil
- Oil spray, such as Pam or others
- Other kinds of oils
- None of the above

107. Thinking about the meat you ate, how often was it cooked by broiling, grilling, barbecuing or pan-frying? *(Do not include poultry or fish.)*
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 times per week
- 3-4 times per week
- 5-8 times per week
- 1 time per day
- 2 or more times per day

107a. Each time you ate meat cooked by broiling, grilling, barbecuing or pan-frying, what was the outside appearance of the meat?
- Light brown
- Medium brown
- Heavily browned or blackened

107b. Each time you ate meat cooked by broiling, grilling, barbecuing or pan-frying, what was the inside appearance of the meat?
- Red (rare)
- Pink (medium)
- Brown (well-done)

108. How often did you eat tofu?
- NEVER (GO TO QUESTION 109)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 times per week
- 3-4 times per week
- 5-6 times per week
- 1 time per day
- 2 or more times per day

108a. Each time you ate tofu, how much did you usually eat?
- Less than ¼ cup or less than 2 ounces
- ¼ to ½ cup or 2 to 4 ounces
- More than ½ cup or more than 4 ounces

109. How often did you eat soy burgers or soy meat-substitutes?
- NEVER (GO TO QUESTION 110)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 times per week
- 3-4 times per week
- 5-6 times per week
- 1 time per day
- 2 or more times per day

109a. Each time you ate soy burgers or soy meat-substitutes, how much did you usually eat?
- Less than ¼ cup or less than 2 ounces
- ¼ to ½ cup or 2 to 4 ounces
- More than ½ cup or more than 4 ounces

110. Over the past 12 months, did you eat soups?
- NO (GO TO QUESTION 111)
- YES

110a. How often did you eat soup IN THE WINTER?
- NEVER
- 1-6 times per winter
- 7-11 times per winter
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 times per week
- 3-4 times per week
- 5-6 times per week
- 1 time per day
- 2 or more times per day

110b. How often did you eat soup DURING THE REST OF THE YEAR?
- NEVER
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 times per week
- 3-4 times per week
- 5-6 times per week
- 1 time per day
- 2 or more times per day

110c. Each time you ate soup, how much did you usually eat?
- Less than 1 cup
- 1 to 2 cups
- More than 2 cups

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Question 111 appears on the next page
Over the past 12 months...

110d. How often were the soups you ate bean, pea or lentil soups?
- Almost never or never
- About 1/4 of the time
- About 1/2 of the time
- About 3/4 of the time
- Almost always or always

110e. How often were the soups you ate cream soups (including chowders)?
- Almost never or never
- About 1/4 of the time
- About 1/2 of the time
- About 3/4 of the time
- Almost always or always

110f. How often were the soups you ate tomato or vegetable soups (not cream soups)?
- Almost never or never
- About 1/4 of the time
- About 1/2 of the time
- About 3/4 of the time
- Almost always or always

110g. How often were the soups you ate broth soups (including chicken) with or without noodles or rice?
- Almost never or never
- About 1/4 of the time
- About 1/2 of the time
- About 3/4 of the time
- Almost always or always

111. How often did you eat pizza?
- NEVER (GO TO QUESTION 112)
  - 1-6 times per year
  - 7-11 times per year
  - 1 time per month
  - 2-3 times per month
  - 1 time per week

111a. Each time you ate pizza, how much did you usually eat?
- Less than 1 slice or less than 1 mini pizza
- 1 to 3 slices or 1 mini pizza
- More than 3 slices or more than 1 mini pizza

111b. How often did you eat pizza with pepperoni, sausage, or other meat?
- Almost never or never
- About 1/4 of the time
- About 1/2 of the time
- About 3/4 of the time
- Almost always or always

112. How often did you eat crackers?
- NEVER (GO TO QUESTION 113)
  - 1-6 times per year
  - 7-11 times per year
  - 1 time per month
  - 2-3 times per month
  - 1 time per week

112a. Each time you ate crackers, how many did you usually eat?
- Fewer than 4 crackers
- 4 to 10 crackers
- More than 10 crackers

113. How often did you eat corn bread or corn muffins?
- NEVER (GO TO QUESTION 114)
  - 1-6 times per year
  - 7-11 times per year
  - 1 time per month
  - 2-3 times per month
  - 1 time per week

113a. Each time you ate corn bread or corn muffins, how much did you usually eat?
- Less than 1 piece or muffin
- 1 to 2 pieces or muffins
- More than 2 pieces or muffins

114. How often did you eat baking powder biscuits, including scones or tea biscuits?
- NEVER (GO TO QUESTION 115)
  - 1-6 times per year
  - 7-11 times per year
  - 1 time per month
  - 2-3 times per month
  - 1 time per week

114a. Each time you ate baking powder biscuits including scones or tea biscuits, how many did you usually eat?
- Fewer than 1 biscuit
- 1 to 2 biscuits
- More than 2 biscuits
Over the past 12 months...

115. How often did you eat potato chips (including low-fat, baked, or low-salt)?
   ☐ NEVER (GO TO QUESTION 116)
   ☐ 1-6 times per year
   ☐ 7-11 times per year
   ☐ 1 time per month
   ☐ 2-3 times per month
   ☐ 1 time per week
   ☐ 2 or more times per day

115a. Each time you ate potato chips, how much did you usually eat?
   ☐ Fewer than 10 chips or less than 1 cup
   ☐ 10 to 25 chips or 1 to 2 cups
   ☐ More than 25 chips or more than 2 cups

116. How often did you eat corn chips or tortilla chips (including low-fat, baked, or low-salt)?
   ☐ NEVER (GO TO QUESTION 117)
   ☐ 1-6 times per year
   ☐ 7-11 times per year
   ☐ 1 time per month
   ☐ 2-3 times per month
   ☐ 1 time per week
   ☐ 2 or more times per day

116a. Each time you ate corn chips, how much did you usually eat?
   ☐ Fewer than 10 chips or less than 1 cup
   ☐ 10 to 25 chips or 1 to 1 ½ cups
   ☐ More than 25 chips or more than 1 ½ cups

117. How often did you eat popcorn (including low-fat)?
   ☐ NEVER (GO TO QUESTION 118)
   ☐ 1-6 times per year
   ☐ 7-11 times per year
   ☐ 1 time per month
   ☐ 2-3 times per month
   ☐ 1 time per week
   ☐ 2 or more times per day

117a. Each time you ate popcorn, how much did you usually eat?
   ☐ Less than 2 cups, popped
   ☐ 2 to 6 cups, popped
   ☐ More than 5 cups, popped

118. How often did you eat pretzels?
   ☐ NEVER (GO TO QUESTION 119)
   ☐ 1-6 times per year
   ☐ 7-11 times per year
   ☐ 1 time per month
   ☐ 2-3 times per month
   ☐ 1 time per week
   ☐ 2 or more times per day

118a. Each time you ate pretzels, how many did you usually eat?
   ☐ Fewer than 5 average twists
   ☐ 5 to 20 average twists
   ☐ More than 20 average twists

119. How often did you eat peanuts, walnuts, almonds, or other nuts?
   ☐ NEVER (GO TO QUESTION 120)
   ☐ 1-6 times per year
   ☐ 7-11 times per year
   ☐ 1 time per month
   ☐ 2-3 times per month
   ☐ 1 time per week
   ☐ 2 or more times per day

119a. Each time you ate peanuts, walnuts, almonds, or other nuts, how much did you usually eat?
   ☐ Less than ¼ cup
   ☐ ¼ to ½ cup
   ☐ More than ½ cup

119b. How often were the nuts you ate peanuts?
   ☐ Almost never or never
   ☐ About ¼ of the time
   ☐ About ½ of the time
   ☐ About ¾ of the time
   ☐ Almost always or always

120. How often did you eat flaxseeds?
   ☐ NEVER (GO TO QUESTION 121)
   ☐ 1-6 times per year
   ☐ 7-11 times per year
   ☐ 1 time per month
   ☐ 2-3 times per month
   ☐ 1 time per week
   ☐ 2 or more times per day

120a. Each time you ate flaxseeds, how much did you usually eat?
   ☐ Less than 1 tablespoon
   ☐ 1 to 2 tablespoons
   ☐ More than 2 tablespoons

Question 110 appears in the next column

Question 121 appears on the next page
Over the past 12 months...

121. How often did you eat other seeds, like sunflower or pumpkin seeds?
- NEVER (GO TO QUESTION 122)
  - 1-6 times per year
  - 7-11 times per year
  - 1 time per month
  - 2-3 times per month
  - 1 time per week
  - 2 or more times per day

121a. Each time you ate other seeds, like sunflower or pumpkin seeds, how much did you usually eat?
- Less than ½ cup
- ¼ to ½ cup
- More than ½ cup

122. How often did you eat energy or high-protein bars, (such as Power Bars, Vector, Clif, Luna, Isoflex or others)?
- NEVER (GO TO QUESTION 123)
  - 1-6 times per year
  - 7-11 times per year
  - 1 time per month
  - 2-3 times per month
  - 1 time per week
  - 2 or more times per day

122a. Each time you ate energy or high-protein bars, how much did you usually eat?
- Less than 1 bar
- 1 bar
- More than 1 bar

123. How often did you eat yogurt (NOT including frozen yogurt)?
- NEVER (GO TO QUESTION 124)
  - 1-6 times per year
  - 7-11 times per year
  - 1 time per month
  - 2-3 times per month
  - 1 time per week
  - 2 or more times per day

123a. Each time you ate yogurt, how much did you usually eat?
- Less than ½ cup or less than 1 container
- ¼ to 1 cup or 1 container
- More than 1 cup or more than 1 container

123b. How often was the yogurt you ate low-fat or fat-free?
- Almost never or never
- About ⅛ of the time
- About ⅜ of the time
- Almost always or always

124. How often did you eat cottage cheese (including low-fat)?
- NEVER (GO TO QUESTION 125)
  - 1-6 times per year
  - 7-11 times per year
  - 1 time per month
  - 2-3 times per month
  - 1 time per week
  - 2 or more times per day

124a. Each time you ate cottage cheese, how much did you usually eat?
- Less than ½ cup
- ¼ to 1 cup
- More than 1 cup

125. How often did you eat cheese (including low-fat; including on cheeseburgers or in sandwiches or subs, NOT including cream cheese)?
- NEVER (GO TO QUESTION 126)
  - 1-6 times per year
  - 7-11 times per year
  - 1 time per month
  - 2-3 times per month
  - 1 time per week
  - 2 or more times per day

125a. Each time you ate cheese, how much did you usually eat?
- Less than ½ ounce or less than 1 slice
- ⅛ to ⅛ ounce or 1 slice
- More than ⅜ ounce or more than 1 slice

125b. How often was the cheese you ate low-fat?
- Almost never or never
- About ⅛ of the time
- About ⅜ of the time
- Almost always or always

Question 124 appears in the next column

Question 126 appears on the next page
Over the past 12 months...

126. How often did you eat frozen yogurt, sorbet, or ices (including low-fat or fat-free)?
   - NEVER (GO TO QUESTION 127)
   - 1-6 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week

126a. Each time you ate frozen yogurt, sorbet, or ices, how much did you usually eat?
   - Less than ½ cup or less than 1 scoop
   - ½ to 1 cup or 1 to 2 scoops
   - More than 1 cup or more than 2 scoops

127. How often did you eat ice cream or ice cream bars (including low-fat or fat-free)?
   - NEVER (GO TO QUESTION 128)
   - 1-6 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week

127a. Each time you ate ice cream or ice cream bars, how much did you usually eat?
   - Less than ½ cup or less than 1 scoop
   - ½ to 1½ cups or 1 to 2 scoops
   - More than 1½ cups or more than 2 scoops

127b. How often was the ice cream you ate light, low-fat, or fat-free?
   - Almost never or never
   - About ¼ of the time
   - About ½ of the time
   - About ¾ of the time
   - Almost always or always

128. How often did you eat cake (including low-fat or fat-free)?
   - NEVER (GO TO QUESTION 129)
   - 1-6 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week

128a. Each time you ate cake, how much did you usually eat?
   - Less than 1 medium piece
   - 1 medium piece
   - More than 1 medium piece

129. How often did you eat cookies or brownies (including low-fat or fat-free)?
   - NEVER (GO TO QUESTION 130)
   - 1-6 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week

129a. Each time you ate cookies or brownies, how much did you usually eat?
   - Less than 2 cookies or 1 small brownie
   - 2 to 4 cookies or 1 medium brownie
   - More than 4 cookies or 1 large brownie

130. How often did you eat doughnuts, sweet rolls, Danish, or pop-tarts?
   - NEVER (GO TO QUESTION 131)
   - 1-6 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week

130a. Each time you ate doughnuts, sweet rolls, Danish, or pop-tarts, how much did you usually eat?
   - Less than 1 piece
   - 1 to 2 pieces
   - More than 2 pieces

131. How often did you eat sweet muffins or dessert breads (such as banana bread, blueberry muffins or lemon loaf, including low-fat or fat-free)?
   - NEVER (GO TO QUESTION 132)
   - 1-6 times per year
   - 7-11 times per year
   - 1 time per month
   - 2-3 times per month
   - 1 time per week

Question 129 appears in the next column

Question 132 appears on the next page
Over the past 12 months...

131a. Each time you ate sweet muffins or dessert breads, how much did you usually eat?
- Less than 1 medium piece
- 1 medium piece
- More than 1 medium piece

132. How often did you eat fruit crisp, cobbler, or strudel?
- NEVER (GO TO QUESTION 133)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

132a. Each time you ate fruit crisp, cobbler, or strudel, how much did you usually eat?
- Less than ½ cup
- ½ to 1 cup
- More than 1 cup

133. How often did you eat pie?
- NEVER (GO TO QUESTION 134)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

133a. Each time you ate pie, how much did you usually eat?
- Less than ¼ of a pie
- About ¼ of a pie
- More than ¼ of a pie

The next four questions ask about the kinds of pie you ate. Please read all four questions before answering.

133b. How often were the pies you ate fruit pie (such as apple, blueberry, others)?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

133c. How often were the pies you ate cream, pudding, custard, or meringue pie?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

133d. How often were the pies you ate pumpkin or sweet potato pie?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

133e. How often were the pies you ate pecan pie?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

134. How often did you eat chocolate candy?
- NEVER (GO TO QUESTION 135)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

134a. Each time you ate chocolate candy, how much did you usually eat?
- Less than 1 average bar or less than 1 ounce
- 1 average bar or 1 to 2 ounces
- More than 1 average bar or more than 2 ounces

135. How often did you eat other candy?
- NEVER (GO TO QUESTION 136)
- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 or more times per day

135a. Each time you ate other candy, how much did you usually eat?
- Fewer than 2 pieces
- 2 to 9 pieces
- More than 9 pieces
Over the past 12 months...

136. How often did you eat eggs, egg whites, or egg substitutes (NOT counting eggs in baked goods and desserts)? (Please include eggs in salads, quiche, soufflés, and sandwiches.)

☐ NEVER (GO TO QUESTION 137)
☐ 1-6 times per year
☐ 7-11 times per year
☐ 1 time per month
☐ 2-3 times per month
☐ 1 time per week
☐ 2 or more times per day

136a. Each time you ate eggs, how many did you usually eat?
☐ 1 egg
☐ 2 eggs
☐ 3 or more eggs

136b. How often were the eggs you ate egg substitutes or egg whites only?
☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

136c. How often were the eggs you ate regular whole eggs?
☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

136d. How often were the eggs you ate cooked in oil, butter, or margarine?
☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

136e. How often were the eggs you ate part of egg salad?
☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

137. How many cups of coffee, caffeinated or decaffeinated, did you drink (please do not include coffee drinks such as Latte, Mocha, Cappuccino, or Frappuccino)?

☐ NONE (GO TO QUESTION 139)
☐ Less than 1 cup per month
☐ 1-3 cups per month
☐ 1 cup per week
☐ 2-4 cups per week
☐ 6 or more cups per day

137a. How often was the coffee you drank decaffeinated?
☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

138. How often did you drink coffee drinks, such as Latte, Mocha, Cappuccino, Frappuccino (including caffeinated or decaffeinated, hot or cold)?

☐ NEVER (GO TO QUESTION 139)
☐ 1 cup per day
☐ 2-3 cups per day
☐ 4-5 cups per day
☐ 6 or more times per day

138a. Each time you drank coffee drinks, how much did you usually drink?
☐ Less than 8 ounces (250 mL)
☐ 8 to 16 ounces (250 to 500 mL)
☐ More than 16 ounces (more than 500 mL)

138b. How often were the coffee drinks you drank decaffeinated?
☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always
Over the past 12 months...

139. How many glasses, cans, or bottles of **COLD or ICED tea**, caffeinated or decaffeinated, did you drink?

- [ ] NONE (GO TO QUESTION 140)
- [ ] Less than 1 glass, can or bottle per month
- [ ] 1-3 glasses, cans or bottles per month
- [ ] 1 glass, can or bottle per week
- [ ] 2-4 glasses, cans or bottles per week
- [ ] 5-6 glasses, cans or bottles per week
- [ ] 1 glass, can or bottle per day
- [ ] 2-3 glasses, cans or bottles per day
- [ ] 4-5 glasses, cans or bottles per day
- [ ] 6 or more glasses, cans or bottles per day

139a. How often was the cold or iced tea you drank **decaffeinated or herbal**?

- [ ] Almost never or never
- [ ] About ¼ of the time
- [ ] About ½ of the time
- [ ] About ¾ of the time
- [ ] Almost always or always

139b. How often was the cold or iced tea you drank **presweetened with sugar or artificial sweeteners** (such as Splenda, Equal, Sweet’N Low or others)?

- [ ] Almost never or never (GO TO QUESTION 140)
- [ ] About ¼ of the time
- [ ] About ½ of the time
- [ ] About ¾ of the time
- [ ] Almost always or always

139c. What kind of **sweetener** was added to your presweetened cold or iced tea most of the time?

- [ ] Sugar or honey
- [ ] Artificial sweeteners (such as Splenda, Equal, Sweet’N Low or others)

140. How many cups of **HOT tea**, caffeinated or decaffeinated (including herbal), did you drink?

- [ ] NONE (GO TO QUESTION 141)
- [ ] Less than 1 cup per month
- [ ] 1-3 cups per month
- [ ] 1 cup per week
- [ ] 2-4 cups per week
- [ ] 5-6 cups per week
- [ ] 1 cup per day
- [ ] 2-3 cups per day
- [ ] 4-5 cups per day
- [ ] 6 or more cups per day

140a. How often was the hot tea you drank **herbal**?

- [ ] Almost never or never
- [ ] About ¼ of the time
- [ ] About ½ of the time
- [ ] About ¾ of the time
- [ ] Almost always or always

140b. How often was the hot tea you drank **green tea**?

- [ ] Almost never or never
- [ ] About ¼ of the time
- [ ] About ½ of the time
- [ ] About ¾ of the time
- [ ] Almost always or always

140c. How often was the hot black tea and/or the green tea you drank **decaffeinated**?

- [ ] Almost never or never
- [ ] About ¼ of the time
- [ ] About ½ of the time
- [ ] About ¾ of the time
- [ ] Almost always or always

141. Over the past 12 months, did you add **sugar, honey or other sweeteners** to your tea or coffee (hot or iced)?

- [ ] NO (GO TO QUESTION 142)
- [ ] YES

141a. How often did you add **sugar** or **honey** to your coffee or tea (hot or iced)?

- [ ] Almost never or never (GO TO QUESTION 141c)
- [ ] About ¼ of the time
- [ ] About ½ of the time
- [ ] About ¾ of the time
- [ ] Almost always or always
Over the past 12 months...

141b. Each time sugar or honey was added to your coffee or tea, how much was usually added?
- Less than 1 teaspoon
- 1 to 3 teaspoons
- More than 3 teaspoons

141c. How often did you add artificial sweetener (such as Splenda, Equal, SweetN Low or others) to your coffee or tea?
- Almost never or never (GO TO QUESTION 142)
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

141d. What kind of artificial sweetener did you usually use?
- Equal, NaturaSweet or aspartame
- SweetN Low or cyclamate
- Splenda or sucralose
- Hermesetas or saccharine
- Herbal sweeteners like Stevia

141e. Each time artificial sweetener was added to your coffee or tea, how much was usually added?
- Less than 1 packet or less than 1 teaspoon
- 1 packet or 1 teaspoon
- More than 1 packet or more than 1 teaspoon

142. Over the past 12 months, did you add whiteners (such as cream, milk, or non-dairy creamer) to your tea or coffee?
- NO (GO TO QUESTION 143)
- YES

142a. How often was non-dairy creamer added to your coffee or tea?
- Almost never or never (GO TO QUESTION 142d)
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

142d. Each time non-dairy creamer was added to your coffee or tea, how much was usually used?
- Less than 1 teaspoon
- 1 to 3 teaspoons
- More than 3 teaspoons

142c. What kind of non-dairy creamer did you usually use?
- Regular powdered
- Low-fat or fat-free powdered
- Regular liquid
- Low-fat or fat-free liquid

142d. How often was cream or half and half added to your coffee or tea?
- Almost never or never (GO TO QUESTION 142f)
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

142e. Each time cream or half and half was added to your coffee or tea, how much was usually added?
- Less than 1 tablespoon
- 1 to 2 tablespoons
- More than 2 tablespoons

142f. How often was milk added to your coffee or tea?
- Almost never or never (GO TO QUESTION 143)
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

142g. Each time milk was added to your coffee or tea, how much was usually added?
- Less than 1 tablespoon
- 1 to 3 tablespoons
- More than 3 tablespoons

142h. What kind of milk was usually added to your coffee or tea?
- Whole milk
- 2% milk
- 1% milk
- Skim, nonfat, or 0.5% fat milk
- Evaporated or condensed (canned) milk
- Soy milk
- Rice milk
- Almond milk
- Other
217

Over the past 12 months...

143. How often was sugar or honey added to foods you ate? (For example on cereal, fruit or yogurt. Please do not include sugar in coffee, tea, other beverages, or baked goods.)

☐ NEVER (GO TO INTRODUCTION TO QUESTION 144)
☐ 1-8 times per year
☐ 7-11 times per year
☐ 1 time per month
☐ 2-3 times per month
☐ 1 time per week
☐ 2 or more times per week

143a. Each time sugar or honey was added to foods you ate, how much was usually added?

☐ Less than 1 teaspoon
☐ 1 to 3 teaspoons
☐ More than 3 teaspoons

The following questions are about the kinds of margarine, mayonnaise, sour cream, cream cheese, and salad dressing that you ate. If possible, please check the labels of these foods to help you answer.

144. Over the past 12 months, did you eat margarine?

☐ NO (GO TO QUESTION 145)
☐ YES

144a. How often was the margarine you ate light or low-fat (stick or tub)?

☐ Almost never or never
☐ About ⅛ of the time
☐ About ¼ of the time
☐ About ½ of the time
☐ Almost always or always

145. Over the past 12 months, did you eat butter?

☐ NO (GO TO QUESTION 146)
☐ YES

145a. How often was the butter you ate light or low-fat?

☐ Almost never or never
☐ About ⅛ of the time
☐ About ¼ of the time
☐ About ½ of the time
☐ Almost always or always

146. Over the past 12 months, did you eat mayonnaise or mayonnaise-type dressing?

☐ NO (GO TO QUESTION 147)
☐ YES

146a. How often was the mayonnaise you ate light, low-fat or fat-free?

☐ Almost never or never
☐ About ⅛ of the time
☐ About ¼ of the time
☐ About ½ of the time
☐ Almost always or always

147. Over the past 12 months, did you eat sour cream?

☐ NO (GO TO QUESTION 148)
☐ YES

147a. How often was the sour cream you ate light, low-fat, or fat-free?

☐ Almost never or never
☐ About ⅛ of the time
☐ About ¼ of the time
☐ About ½ of the time
☐ Almost always or always

148. Over the past 12 months, did you eat cream cheese?

☐ NO (GO TO QUESTION 149)
☐ YES

148a. How often was the cream cheese you ate light, low-fat, or fat-free?

☐ Almost never or never
☐ About ⅛ of the time
☐ About ¼ of the time
☐ About ½ of the time
☐ Almost always or always
Over the past 12 months...

149. Did you eat salad dressing?
   - NO (GO TO INTRODUCTION TO QUESTION 150)
   - YES

   149a. How often was the salad dressing you ate light, low-fat or fat-free?
   - Almost never or never
   - About ¼ of the time
   - About ½ of the time
   - About ¾ of the time
   - Almost always or always

The following two questions ask you to summarize your usual intake of vegetables and fruits. Please do not include salads, potatoes, or juices.

150. Over the past 12 months, how many servings of vegetables (not including salad or potatoes) did you eat per week or per day?
   - Less than 1 per week
   - 1-2 per week
   - 3-4 per week
   - 5-6 per week
   - 1 per day

151. Over the past 12 months, how many servings of fruit (not including juices) did you eat per week or per day?
   - Less than 1 per week
   - 1-2 per week
   - 3-4 per week
   - 5-6 per week
   - 1 per day

152. Over the past month, which of the following foods did you eat AT LEAST THREE TIMES? (Mark all that apply.)
   - Avocado, guacamole
   - Beef jerky
   - Cheesecake
   - Chocolate, fudge, or butterscotch toppings or syrups
   - Chow mein noodles
   - Croissants
   - Dark chocolate
   - Dried apricots
   - Dried curcumin, turmeric
   - Dried oregano, rosemary, thyme
   - Egg rolls
   - Fresh basil, cilantro, or parsley
   - Granola bars
   - Hot peppers
   - Jell-O, gelatin
   - Mangoes
   - Olives
   - Pickles or pickled vegetables or fruit
   - Plantains
   - Pork neck bones, hock, head, feet
   - Pudding or custard
   - Sushi
   - Veal, venison, lamb
   - Whipped cream, regular
   - Whipped cream, substitute
   - NONE

153. For ALL of the past 12 months, have you followed any type of vegetarian diet?
   - NO (GO TO INTRODUCTION TO QUESTION 154)
   - YES

153a. Which of the following foods did you TOTALLY EXCLUDE from your diet? (Mark all that apply.)
   - Meat (beef, pork, lamb, etc.)
   - Poultry (chicken, turkey, duck)
   - Fish and shellfish
   - Eggs
   - Dairy products (milk, cheese, etc.)

Introduction to Question 154 appears on the next page
The next questions are about your use of vitamin pills or other supplements.

154. Over the past 12 months, did you take any *multivitamins*, such as One-a-Day-, Centrum-, or Prenatal-type multivitamins (as pills, liquids, or packets)?
- NO (GO TO INTRODUCTION TO QUESTION 156)
- YES

155. How often did you take *One-a-Day-, Centrum- or Prenatal-type* multivitamins?
- Less than 1 day per month
- 1-3 days per month
- 1-3 days per week
- 4-6 days per week
- Every day

155a. Did your *multivitamin* usually contain minerals (such as iron, zinc, etc.)?
- NO
- YES
- Don't know

155b. Was your *multivitamin* usually a *Prenatal-type*?
- NO
- YES
- Don't know

155c. For how many years have you taken *multivitamins*?
- Less than 1 year
- 1-4 years
- 5-9 years
- 10 or more years

155d. Over the past 12 months, did you take any *vitamins, minerals, or other herbal supplements* other than your multivitamin?
- NO
- YES (GO TO INTRODUCTION TO QUESTION 156)

Thank you *very much* for completing this questionnaire! Because we want to be able to use all the information you have provided, we would greatly appreciate it if you would please take a moment to review each page making sure that you:

- Did not skip any pages and
- Crossed out the incorrect answer and circled the correct answer if you made any changes.

These last questions are about the vitamins, minerals, or herbal supplements you took that are NOT part of a One-a-Day-, Centrum- or Prenatal-type of multivitamin.

Over the past 12 months...

156. How often did you take *Antacids that contain Calcium such as Tums or Rolaid*?
- NEVER (GO TO QUESTION 157)
- Less than 1 day per month
- 1-3 days per month
- 1-3 days per week
- 4-6 days per week
- Every day

156a. When you took *Antacids that contain Calcium such as Tums or Rolaid*, about how many tablets or lozenges did you take in one day?
- Less than 1
- 1
- 2
- 3
- 4 or more
- Don't know

156b. Was your antacid usually "extra strength"?
- NO
- YES
- Don't know

156c. For how many years have you taken *Antacids that contain Calcium such as Tums or Rolaid*?
- Less than 1 year
- 1-4 years
- 5-9 years
- 10 or more years

156d. Over the past 12 months, did you take any *Calcium* (with or without Vitamin D) *(NOT as part of a multivitamin in Question 155 or antacid in Question 156)*?
- NEVER (GO TO QUESTION 158)
- Less than 1 day per month
- 1-3 days per month
- 1-3 days per week
- 4-6 days per week
- Every day
Over the past 12 months...

157a. When you took Calcium, about how much elemental calcium did you take in one day? (If possible, please check the label for elemental calcium.)
- Less than 500 mg
- 500-599 mg
- 600-999 mg
- 1,000 mg or more
- Don't know

157b. Did your Calcium usually contain Vitamin D?
- NO
- YES
- Don't know

157c. Did your Calcium usually contain Magnesium?
- NO
- YES
- Don't know

157d. Did your Calcium usually contain Zinc?
- NO
- YES
- Don't know

157e. For how many years have you taken Calcium?
- Less than 1 year
- 1-4 years
- 5-9 years
- 10 or more years

158a. When you took Vitamin D, about how much did you take in one day?
- Less than 400 IU
- 400-799 IU
- 800-999 IU
- 1,000 IU or more
- Don't know

158b. For how many years have you taken Vitamin D?
- Less than 1 year
- 1-4 years
- 5-9 years
- 10 or more years

159. How often did you take Iron (NOT as part of a multivitamin in Question 155)?
- NEVER (GO TO QUESTION 160)
- Less than 1 day per month
- 1-3 days per month
- 1-3 days per week
- 4-6 days per week
- Every day

159a. For how many years have you taken Iron?
- Less than 1 year
- 1-4 years
- 5-9 years
- 10 or more years

160. How often did you take folic acid (NOT as part of a multivitamin in Question 155)?
- NEVER (GO TO QUESTION 161)
- Less than 1 day per month
- 1-3 days per month
- 1-3 days per week
- 4-6 days per week
- Every day

160a. When you took folic acid, about how much did you take in one day?
- Less than 0.4 mg
- 0.4-0.9 mg
- 1.0 mg
- More than 1.0 mg
- Don't know

160b. For how many years have you taken folic acid?
- Less than 1 year
- 1-4 years
- 5-9 years
- 10 or more years
Over the past 12 months...

161. How often did you take Vitamin C (NOT as part of a multivitamin in Question 155)?
   - NEVER (GO TO QUESTION 162)
   - Less than 1 day per month
   - 1-3 days per month
   - 1-5 days per week
   - 4-6 days per week
   - Every day

161a. When you took Vitamin C, about how much did you take in one day?
   - Less than 500 mg
   - 500-999 mg
   - 1,000-1,499 mg
   - 1,500-1,999 mg
   - 2,000 mg or more
   - Don’t know

161b. How many years have you taken Vitamin C?
   - Less than 1 year
   - 1-4 years
   - 5-9 years
   - 10 or more years

162. How often did you take Vitamin E (NOT as part of a multivitamin in Question 155)?
   - NEVER (GO TO INTRODUCTION TO QUESTION 163)
   - Less than 1 day per month
   - 1-3 days per month
   - 1-5 days per week
   - 4-6 days per week
   - Every day

162a. When you took Vitamin E, about how much did you take in one day?
   - Less than 400 IU
   - 400-799 IU
   - 800-999 IU
   - 1,000 IU or more
   - Don’t know

162b. How many years have you taken Vitamin E?
   - Less than 1 year
   - 1-4 years
   - 5-9 years
   - 10 or more years

The last two questions ask you about other supplements you took more than once per week.

163. Please mark any of the following single supplements you took more than once per week (NOT as part of a multivitamin in Question 155):
   - B-6
   - B-complex
   - B-12
   - Beta-carotene
   - Magnesium
   - Occu-vite/Eye health
   - Potassium
   - Selenium
   - Vitamin A
   - Zinc

164. Please mark any of the following herbal, botanical, or other supplements you took more than once per week:
   - Chordroitin
   - Coenzyme Q-10
   - Echinacea
   - Energy supplements
   - Fish oil/Omega-3’s
   - Flaxseed oil
   - Garlic
   - Ginger
   - Ginkgo biloba
   - Ginseng
   - Glucosamine
   - Peppermint
   - Probiotics
   - Red clover
   - Saw palmetto
   - Soy supplement
   - Sports supplements
   - St. John’s wort
   - Other

Thank you very much for completing this questionnaire! Because we want to be able to use all the information you have provided, we would greatly appreciate it if you would please take a moment to review each page making sure that you:

- Did not skip any pages and
- Crossed out the incorrect answer and circled the correct answer if you made any changes.
Appendix D
Research Ethics Approval

PROTOCOL REFERENCE #: 30113

April 4, 2014

Dr. Julia Knight
DALLA LANA SCHOOL OF PUBLIC HEALTH
FACULTY OF MEDICINE

Miss Felicia Leung
DALLA LANA SCHOOL OF PUBLIC HEALTH
FACULTY OF MEDICINE

Dear Dr. Knight and Miss Felicia Leung,

Re: Administrative Approval of your research protocol entitled, "Dietary factors and abdominal adiposity among postmenopausal women"

We are writing to advise you that the Office of Research Ethics (ORE) has granted administrative approval to the above-named research protocol. The level of approval is based on the following role(s) of the University of Toronto (University), as you have identified with your submission and administered under the terms and conditions of the affiliation agreement between the University and the associated TAHSN hospital:

- Graduate Student research - hospital-based only
- Storage or analysis of De-identified Personal Information (data)

This approval does not substitute for ethics approval, which has been obtained from your hospital Research Ethics Board (REB). Please note that you do not need to submit Annual Renewals, Study Completion Reports or Amendments to the ORE unless the involvement of the University changes so that ethics review is required. Please contact the ORE to determine whether a particular change to the University’s involvement requires ethics review.

Best wishes for the successful completion of your research.

Yours sincerely,

Dario Kuzmanovic
REB Manager

OFFICE OF RESEARCH ETHICS
McMaster Building, 13 Queen’s Park Crescent West, 2nd Floor, Toronto, ON M5S 3G8 Canada
Tel: +1 416 946-3273 • Fax: +1 416 946-5763 • ethics.review@utoronto.ca • http://www.research.utoronto.ca/for-researchers/administrators/ethics/
Appendix E
Assigning Glycemic Index Values to the Canadian Diet History Questionnaire II – Supplemental Data

**Table E.1** Modified food group matches with measures to assess match quality for women’s medium portion size

<table>
<thead>
<tr>
<th>C-DHQ II food group</th>
<th>US-DHQ II food group</th>
<th>Energy per 100 g</th>
<th>Carbohydrate per 100 g</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ratio</td>
<td>Difference</td>
</tr>
<tr>
<td>Veal/venison/lamb dishes</td>
<td>Beef stews/pot pies/ mixtures</td>
<td>0.9</td>
<td>0.4</td>
</tr>
<tr>
<td>Sushi</td>
<td>Rice, NFA</td>
<td>1.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Poutine</td>
<td>Potatoes, fried</td>
<td>0.7</td>
<td>22.3</td>
</tr>
</tbody>
</table>

Abbreviations: C-DHQ II, Canadian Diet History Questionnaire II; NFA, no fat added; US-DHQ II, United States Diet History Questionnaire II.

**Table E.2** Canadian Diet History Questionnaire II food group glycemic index values calculated from International Tables of Glycemic Index and Glycemic Load Values: 2008

<table>
<thead>
<tr>
<th>C-DHQ II food group</th>
<th>Number of studies for normal glucose tolerance</th>
<th>Mean GI (glucose reference)</th>
<th>Mean GI (bread reference)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tortillas/taco shells, plain</td>
<td>4</td>
<td>42.3</td>
<td>60.3</td>
</tr>
<tr>
<td>Frozen meals</td>
<td>6</td>
<td>46.2</td>
<td>66.5</td>
</tr>
</tbody>
</table>

Abbreviations: C-DHQ II, Canadian Diet History Questionnaire II; GI, glycemic index; GL, glycemic load.

Appendix F
Principal Components Analysis Supplemental Results
Table F.1 Component loadings from principal components analysis, using weight (g/d) adjusted for energy intake (kcal) as the input variable, for two dietary patterns among postmenopausal women (N = 357)

<table>
<thead>
<tr>
<th>Food grouping</th>
<th>Component 1</th>
<th>Component 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweets</td>
<td>0.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.08</td>
</tr>
<tr>
<td>Baked products, sweet</td>
<td>0.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.06</td>
</tr>
<tr>
<td>Jams, syrups, honey</td>
<td>0.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.00</td>
</tr>
<tr>
<td>Snack foods</td>
<td>0.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.03</td>
</tr>
<tr>
<td>Artificial sweeteners</td>
<td>0.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.04</td>
</tr>
<tr>
<td>Dairy products, regular/high-fat</td>
<td>0.21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.04</td>
</tr>
<tr>
<td>Oil, vegetable</td>
<td>-0.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.03</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>-0.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.12</td>
</tr>
<tr>
<td>Legumes</td>
<td>-0.24&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.06</td>
</tr>
<tr>
<td>Vegetables</td>
<td>-0.37&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.13</td>
</tr>
<tr>
<td>Meat</td>
<td>-0.02</td>
<td>0.39&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Potatoes</td>
<td>-0.08</td>
<td>0.38&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Butter</td>
<td>0.03</td>
<td>0.25&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Meat, processed</td>
<td>0.07</td>
<td>0.24&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Beer</td>
<td>-0.04</td>
<td>0.23&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Wine</td>
<td>-0.05</td>
<td>0.21&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Breakfast cereals</td>
<td>-0.06</td>
<td>-0.23&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fruits</td>
<td>-0.15</td>
<td>-0.30&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nuts and seeds</td>
<td>0.02</td>
<td>-0.33&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Baked products, other</td>
<td>0.16</td>
<td>0.00</td>
</tr>
<tr>
<td>Sweetened beverages, diet</td>
<td>0.16</td>
<td>0.05</td>
</tr>
<tr>
<td>Mayonnaise</td>
<td>0.15</td>
<td>0.13</td>
</tr>
<tr>
<td>Dairy products, low-fat</td>
<td>0.09</td>
<td>0.01</td>
</tr>
<tr>
<td>Margarine</td>
<td>0.09</td>
<td>0.11</td>
</tr>
<tr>
<td>Baked products, bread whole-grain</td>
<td>0.07</td>
<td>0.13</td>
</tr>
<tr>
<td>Mixed dishes, pasta/pizza</td>
<td>0.07</td>
<td>0.09</td>
</tr>
<tr>
<td>Eggs</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>Tea</td>
<td>0.07</td>
<td>0.00</td>
</tr>
<tr>
<td>Coffee</td>
<td>0.06</td>
<td>0.09</td>
</tr>
<tr>
<td>Baked products, bread white</td>
<td>0.04</td>
<td>0.07</td>
</tr>
<tr>
<td>Mixed dishes</td>
<td>0.00</td>
<td>0.11</td>
</tr>
<tr>
<td>Sweetened beverages, regular</td>
<td>0.00</td>
<td>-0.05</td>
</tr>
<tr>
<td>Meal replacement</td>
<td>-0.01</td>
<td>-0.10</td>
</tr>
<tr>
<td>Liquor</td>
<td>-0.02</td>
<td>0.13</td>
</tr>
<tr>
<td>Fruit juice</td>
<td>-0.02</td>
<td>0.00</td>
</tr>
<tr>
<td>Sauces, high-fat</td>
<td>-0.03</td>
<td>0.08</td>
</tr>
<tr>
<td>Poultry</td>
<td>-0.07</td>
<td>0.12</td>
</tr>
<tr>
<td>Non-dairy products</td>
<td>-0.07</td>
<td>-0.14</td>
</tr>
<tr>
<td>Fish and seafood</td>
<td>-0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>Salad dressing</td>
<td>-0.11</td>
<td>0.07</td>
</tr>
<tr>
<td>Soups</td>
<td>-0.14</td>
<td>0.08</td>
</tr>
<tr>
<td>Rice, grains, pasta</td>
<td>-0.18</td>
<td>0.01</td>
</tr>
<tr>
<td>Oil, olive</td>
<td>-0.18</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Variance explained (%)

|                | 7.9 | 5.4 |

<sup>a</sup>Component loadings ≥|0.200|. 
Table F.2 Component loadings from principal components analysis, using percentage of energy intake (%) as the input variable, for two dietary patterns among postmenopausal women (N = 357)

<table>
<thead>
<tr>
<th>Food grouping</th>
<th>Component 1</th>
<th>Component 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat</td>
<td>0.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.18</td>
</tr>
<tr>
<td>Potatoes</td>
<td>0.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.03</td>
</tr>
<tr>
<td>Meat, processed</td>
<td>0.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.05</td>
</tr>
<tr>
<td>Butter</td>
<td>0.21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.10</td>
</tr>
<tr>
<td>Nuts and seeds</td>
<td>−0.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.07</td>
</tr>
<tr>
<td>Legumes</td>
<td>−0.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>−0.04</td>
</tr>
<tr>
<td>Fruits</td>
<td>−0.33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>−0.12</td>
</tr>
<tr>
<td>Vegetables</td>
<td>−0.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.00</td>
</tr>
<tr>
<td>Mixed dishes</td>
<td>0.10</td>
<td>0.26&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fish and seafood</td>
<td>−0.03</td>
<td>0.23&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Wine</td>
<td>0.13</td>
<td>0.21&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Margarine</td>
<td>0.18</td>
<td>−0.21&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Tea</td>
<td>0.11</td>
<td>−0.23&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Artificial sweeteners</td>
<td>0.13</td>
<td>−0.26&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Breakfast cereals</td>
<td>−0.04</td>
<td>−0.27&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Jams, syrups, honey</td>
<td>0.18</td>
<td>−0.32&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Dairy products, low-fat</td>
<td>0.09</td>
<td>−0.37&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mixed dishes, pasta/pizza</td>
<td>0.17</td>
<td>−0.09</td>
</tr>
<tr>
<td>Baked products, sweet</td>
<td>0.17</td>
<td>−0.07</td>
</tr>
<tr>
<td>Snack foods</td>
<td>0.16</td>
<td>0.03</td>
</tr>
<tr>
<td>Mayonnaise</td>
<td>0.16</td>
<td>0.16</td>
</tr>
<tr>
<td>Baked products, bread whole-grain</td>
<td>0.14</td>
<td>0.02</td>
</tr>
<tr>
<td>Baked products, other</td>
<td>0.11</td>
<td>0.17</td>
</tr>
<tr>
<td>Sweets</td>
<td>0.10</td>
<td>0.02</td>
</tr>
<tr>
<td>Sweetened beverages, diet</td>
<td>0.10</td>
<td>−0.12</td>
</tr>
<tr>
<td>Dairy products, regular/high-fat</td>
<td>0.10</td>
<td>−0.01</td>
</tr>
<tr>
<td>Beer</td>
<td>0.09</td>
<td>0.08</td>
</tr>
<tr>
<td>Baked products, bread white</td>
<td>0.09</td>
<td>−0.16</td>
</tr>
<tr>
<td>Liquor</td>
<td>0.08</td>
<td>0.01</td>
</tr>
<tr>
<td>Sauces, high-fat</td>
<td>0.06</td>
<td>0.00</td>
</tr>
<tr>
<td>Poultry</td>
<td>0.06</td>
<td>0.20</td>
</tr>
<tr>
<td>Eggs</td>
<td>0.05</td>
<td>0.16</td>
</tr>
<tr>
<td>Coffee</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>Sweetened beverages, regular</td>
<td>−0.01</td>
<td>0.17</td>
</tr>
<tr>
<td>Fruit juice</td>
<td>−0.04</td>
<td>−0.02</td>
</tr>
<tr>
<td>Salad dressing</td>
<td>−0.04</td>
<td>0.17</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>−0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>Meal replacement</td>
<td>−0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>Oil, olive</td>
<td>−0.07</td>
<td>0.19</td>
</tr>
<tr>
<td>Soups</td>
<td>−0.10</td>
<td>−0.12</td>
</tr>
<tr>
<td>Oil, vegetable</td>
<td>−0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>Rice, grains, pasta</td>
<td>−0.14</td>
<td>0.01</td>
</tr>
<tr>
<td>Non-dairy products</td>
<td>−0.16</td>
<td>−0.03</td>
</tr>
<tr>
<td>Variance explained (%)</td>
<td>7.3</td>
<td>4.8</td>
</tr>
</tbody>
</table>

<sup>a</sup> Component loadings ≥|0.200|. 
### Supplemental Sensitivity Analyses

**Table G.1** Associations of total carbohydrate and total dietary fibre intake with trunk fat mass (kg) in postmenopausal women by body mass index category

<table>
<thead>
<tr>
<th></th>
<th>Body mass index ≤24.9 (n = 161)</th>
<th></th>
<th>Body mass index ≥25.0 (n = 187)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β (95% CI)</td>
<td>P-value</td>
<td>β (95% CI)</td>
<td>P-value</td>
</tr>
<tr>
<td>Total carbohydrate, g/d</td>
<td>-0.01 ( -0.03, 0.00004)</td>
<td>0.05</td>
<td>-0.01 ( -0.04, 0.008)</td>
<td>0.22</td>
</tr>
<tr>
<td>Total dietary fibre, g/d</td>
<td>-0.01 ( -0.07, 0.05)</td>
<td>0.74</td>
<td>-0.12 ( -0.22, -0.02)</td>
<td>0.016</td>
</tr>
</tbody>
</table>

*β (95% CI) is the association for each 1-g/d increase in nutrient intake. Adjusted for total carbohydrate intake or total dietary fibre intake (mutually adjusted), total energy intake, age, ethnicity, physical activity level, and alcohol use.*
Table G.2 Associations between carbohydrate intake from eight food sources and trunk fat mass (kg) in postmenopausal women, with and without adjustment for total dietary fibre intake (g/d) by body mass index category

<table>
<thead>
<tr>
<th></th>
<th>Body mass index ≤24.9 (n = 161)</th>
<th>Body mass index ≥25.0 (n = 187)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unadjusted for dietary fibre intake</td>
<td>Adjusted for dietary fibre intake</td>
</tr>
<tr>
<td></td>
<td>β (95% CI) P-value</td>
<td>β (95% CI) P-value</td>
</tr>
<tr>
<td>Carbohydrate intake, g/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grains</td>
<td>-0.029 (-0.055, -0.004) 0.02</td>
<td>-0.029 (-0.055, -0.004) 0.02</td>
</tr>
<tr>
<td>Breakfast cereals &amp; baked products</td>
<td>0.004 (-0.020, 0.028) 0.75</td>
<td>0.005 (-0.020, 0.029) 0.71</td>
</tr>
<tr>
<td>Fruit</td>
<td>-0.009 (-0.024, 0.006) 0.26</td>
<td>-0.007 (-0.025, 0.010) 0.42</td>
</tr>
<tr>
<td>Vegetables</td>
<td>0.007 (-0.026, 0.041) 0.66</td>
<td>0.014 (-0.037, 0.065) 0.59</td>
</tr>
<tr>
<td>Potatoes</td>
<td>0.053 (-0.013, 0.118) 0.11</td>
<td>0.052 (-0.013, 0.118) 0.12</td>
</tr>
<tr>
<td>Legumes</td>
<td>-0.044 (-0.140, 0.052) 0.36</td>
<td>-0.037 (-0.142, 0.068) 0.49</td>
</tr>
<tr>
<td>Dairy products</td>
<td>-0.009 (-0.039, 0.022) 0.57</td>
<td>-0.009 (-0.040, 0.022) 0.56</td>
</tr>
<tr>
<td>Sweetened products</td>
<td>-0.004 (-0.031, 0.023) 0.76</td>
<td>-0.005 (-0.033, 0.022) 0.71</td>
</tr>
</tbody>
</table>

Model 1

Carbohydrate intake, g/d

Grains 0.029 (-0.055, -0.004) 0.02 β (95% CI) are the associations for each 1-g/d increase of carbohydrate intake from the food source, independent of other food sources of carbohydrate and total energy intake.

β (95% CI) is the association for each 1-g/d increase of other carbohydrate sources not specified in the model.
Table G.3 Associations between dietary fibre intake from six food sources and trunk fat mass (kg) in postmenopausal women by body mass index category

<table>
<thead>
<tr>
<th>Food Source</th>
<th>Body mass index ≤24.9 (n = 161)</th>
<th>Body mass index ≥25.0 (n = 187)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β (95% CI)</td>
<td>P-value</td>
</tr>
<tr>
<td>Model 1a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dietary fibre intake, g/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grains</td>
<td>−0.705 (−1.667, 0.257)</td>
<td>0.15</td>
</tr>
<tr>
<td>Breakfast cereals &amp; baked products</td>
<td>0.173 (−0.057, 0.403)</td>
<td>0.14</td>
</tr>
<tr>
<td>Fruit</td>
<td>0.010 (−0.163, 0.184)</td>
<td>0.91</td>
</tr>
<tr>
<td>Vegetables</td>
<td>0.036 (−0.042, 0.115)</td>
<td>0.36</td>
</tr>
<tr>
<td>Potatoes</td>
<td>0.844 (0.030, 1.658)</td>
<td>0.04</td>
</tr>
<tr>
<td>Legumes</td>
<td>−0.162 (−0.532, 0.207)</td>
<td>0.39</td>
</tr>
<tr>
<td>Model 2b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dietary fibre intake, g/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grains</td>
<td>−0.719 (−1.678, 0.240)</td>
<td>0.14</td>
</tr>
<tr>
<td>Breakfast cereals &amp; baked products</td>
<td>0.305 (0.008, 0.602)</td>
<td>0.04</td>
</tr>
<tr>
<td>Fruit</td>
<td>0.174 (−0.118, 0.467)</td>
<td>0.24</td>
</tr>
<tr>
<td>Vegetables</td>
<td>0.173 (−0.038, 0.385)</td>
<td>0.11</td>
</tr>
<tr>
<td>Potatoes</td>
<td>0.874 (0.061, 1.687)</td>
<td>0.04</td>
</tr>
<tr>
<td>Legumes</td>
<td>0.024 (−0.432, 0.480)</td>
<td>0.92</td>
</tr>
<tr>
<td>Totalc</td>
<td>−0.139 (−0.340, 0.061)</td>
<td>0.17</td>
</tr>
</tbody>
</table>

\(^{a}\) Adjusted for total carbohydrate intake, total energy intake, age, ethnicity, physical activity, and alcohol use. Dietary fibre intake from grains, breakfast cereals & baked products, fruit, vegetables, potatoes, and legumes are mutually adjusted. \(\beta (95\% \text{ CI})\) are the associations for each 1-g/d increase of dietary fibre intake from the food source, independent of other food sources of dietary fibre, total carbohydrate, and total energy intakes.

\(^{b}\) Adjusted for total carbohydrate intake, total energy intake, age, ethnicity, physical activity, and alcohol use. Dietary fibre intake from grains, breakfast cereal & baked products, fruit, vegetables, potatoes, legumes, dairy products, sweetened products, and total dietary fibre are mutually adjusted. \(\beta (95\% \text{ CI})\) are the associations for each 1-g/d increase of dietary fibre intake from the food source, independent of other food sources of dietary fibre, total dietary fibre, total carbohydrate, and total energy intakes.

\(^{c}\) \(\beta (95\% \text{ CI})\) is the association for each 1-g/d increase of other dietary fibre sources not specified in the model.
### Table G.4 Adjusted associations between dietary pattern scores (not mutually adjusted) and body composition measures among postmenopausal women by body mass index category

<table>
<thead>
<tr>
<th>Body composition</th>
<th>Western dietary pattern score quartiles&lt;sup&gt;a,b&lt;/sup&gt;</th>
<th>Prudent dietary pattern score quartiles&lt;sup&gt;a,b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q2</td>
<td>Q3</td>
</tr>
<tr>
<td>Body mass index ≤24.9 (n = 164)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>2.04 (-0.78, 4.85)</td>
<td>3.11 (0.09, 6.13)</td>
</tr>
<tr>
<td>Trunk fat mass (kg)</td>
<td>0.99 (-0.06, 2.03)</td>
<td>1.12 (0.003, 2.24)</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.005 (-0.02, 0.03)</td>
<td>0.02 (-0.01, 0.04)</td>
</tr>
<tr>
<td>Android-to-gynoid ratio</td>
<td>0.03 (-0.04, 0.09)</td>
<td>0.04 (-0.03, 0.11)</td>
</tr>
<tr>
<td>Body mass index ≥25.0 (n = 193)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>-0.99 (-5.17, 3.19)</td>
<td>3.52 (-0.92, 7.96)</td>
</tr>
<tr>
<td>Trunk fat mass (kg)</td>
<td>-0.30 (-2.18, 1.58)</td>
<td>1.04 (-0.96, 3.04)</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>-0.01 (-0.04, 0.01)</td>
<td>0.02 (-0.009, 0.04)</td>
</tr>
<tr>
<td>Android-to-gynoid ratio</td>
<td>-0.009 (-0.06, 0.04)</td>
<td>0.04 (-0.01, 0.09)</td>
</tr>
</tbody>
</table>

<sup>a</sup> All values are β (95% confidence interval), where Q1 was the reference category.

<sup>b</sup> All models are adjusted for age, ethnicity, total energy intake, and physical activity level (dietary patterns are mutually adjusted).

### Table G.5 Adjusted associations between dietary pattern scores (mutually adjusted) and body composition measures among postmenopausal women by body mass index category

<table>
<thead>
<tr>
<th>Body composition</th>
<th>Western dietary pattern score quartiles&lt;sup&gt;a,b&lt;/sup&gt;</th>
<th>Prudent dietary pattern score quartiles&lt;sup&gt;a,b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q2</td>
<td>Q3</td>
</tr>
<tr>
<td>Body mass index ≤24.9 (n = 164)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>1.99 (-0.86, 4.84)</td>
<td>2.90 (-0.28, 6.08)</td>
</tr>
<tr>
<td>Trunk fat mass (kg)</td>
<td>0.96 (-0.10, 2.01)</td>
<td>0.96 (-0.22, 2.13)</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.004 (-0.02, 0.03)</td>
<td>0.01 (-0.02, 0.04)</td>
</tr>
<tr>
<td>Android-to-gynoid ratio</td>
<td>0.02 (-0.04, 0.09)</td>
<td>0.03 (-0.04, 0.11)</td>
</tr>
<tr>
<td>Body mass index ≥25.0 (n = 194)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>-1.26 (-5.47, 2.96)</td>
<td>2.88 (-1.68, 7.43)</td>
</tr>
<tr>
<td>Trunk fat mass (kg)</td>
<td>-0.45 (-2.34, 1.44)</td>
<td>0.70 (-1.34, 2.75)</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>-0.01 (-0.04, 0.01)</td>
<td>0.02 (-0.01, 0.04)</td>
</tr>
<tr>
<td>Android-to-gynoid ratio</td>
<td>-0.03 (-0.06, 0.04)</td>
<td>0.04 (-0.02, 0.09)</td>
</tr>
</tbody>
</table>

<sup>a</sup> All values are β (95% confidence interval), where Q1 was the reference category.

<sup>b</sup> All models are adjusted for age, ethnicity, total energy intake, and physical activity level (dietary patterns are mutually adjusted).
**Table G.6** Associations between dietary glycemic index quartiles\(^a\) and measures of abdominal adiposity in postmenopausal women by body mass index category

<table>
<thead>
<tr>
<th>Abdominal adiposity</th>
<th>Body mass index ≤24.9 ((n = 164))(^{b,c})</th>
<th>Body mass index ≥25.0 ((n = 193))(^{b,c})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q2</td>
<td>Q3</td>
</tr>
<tr>
<td>Trunk fat mass (kg)</td>
<td>1.75 (0.67, 2.84)</td>
<td>0.49 (–0.62, 1.60)</td>
</tr>
<tr>
<td>Android-to-gynoid ratio</td>
<td>0.07 (–0.003, 0.13)</td>
<td>0.004 (–0.07, 0.07)</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>2.35 (–0.57, 5.28)</td>
<td>–0.98 (–3.97, 2.02)</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>–0.0004 (–0.03, 0.03)</td>
<td>–0.02 (–0.05, 0.005)</td>
</tr>
</tbody>
</table>

\(a\) Range of dietary GI (units/d): Q1 = 39.9–52.7; Q2 = 52.7–55.1; Q3 = 55.1–57.6; Q4 = 57.6–66.1.

\(b\) Values are β (95% confidence interval), where Q1 is the reference category.

\(c\) Adjusted for age, ethnicity, total energy intake, dietary fiber intake, alcohol, and physical activity level.

**Table G.7** Associations between dietary glycemic load quartiles\(^a\) and measures of abdominal adiposity in postmenopausal women by body mass index category

<table>
<thead>
<tr>
<th>Abdominal adiposity</th>
<th>Body mass index ≤24.9 ((n = 164))(^{b,c})</th>
<th>Body mass index ≥25.0 ((n = 193))(^{b,c})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q2</td>
<td>Q3</td>
</tr>
<tr>
<td>Trunk fat mass (kg)</td>
<td>0.79 (–0.41, 1.99)</td>
<td>0.58 (–0.82, 1.98)</td>
</tr>
<tr>
<td>Android-to-gynoid ratio</td>
<td>0.06 (–0.02, 0.13)</td>
<td>0.009 (–0.08, 0.10)</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>–0.11 (–3.24, 3.02)</td>
<td>0.16 (–3.49, 3.81)</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>–0.003 (–0.03, 0.03)</td>
<td>0.004 (–0.03, 0.04)</td>
</tr>
</tbody>
</table>

\(a\) Range of dietary GL (units/d): Q1 = 26.1–67.3; Q2 = 67.8–87.7; Q3 = 87.8–114.5; Q4 = 114.9–236.74.

\(b\) Values are β (95% confidence interval), where Q1 is the reference category.

\(c\) Adjusted for age, ethnicity, total energy intake, dietary fiber intake, alcohol, and physical activity level.