Methodological challenges and interpretation of dietary data from the 1997-1998 Food Habits of Canadians Survey

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Abstract

The Food Habits of Canadians Survey, conducted in 1997-1998 examined food and nutrient intakes of non-institutionalized adults aged 18-65 years (n=1543) randomly selected from across Canada using the multi-stage random sampling strategy. Dietary intake was assessed by 24-h recall and a repeat interview was conducted in a sub-sample (n=446). The overall response rate was 26%. Males, younger age adults (18-34 years), single persons and those with lower education levels were underrepresented in the study sample thus limiting the generalizability of the study results. Examination of the characteristics of the selected areas (n=63) by response rates, indicated that areas with a higher percentage below the low income cut-off level, higher percentage who moved residence in the past 5 years and higher percentage speaking non-official languages as the mother-tongue were associated with low response rates. Additionally, areas with lower percentage females were associated with low response rates indicating that depending on the community characteristics different approaches may be needed to enhance response rates. Within- to between- subject variance ratios for several nutrients were higher when adjusted for age, gender, education, season, smoking and size of family compared to the crude ratios (e.g. for energy 1.07 vs. 0.49 for males). As a result, more days would be needed to reliably estimate usual intake once the data are appropriately adjusted. Examination of the within- to between-subject variability ratios for nutrients by smoking status indicated that the diet of smokers was no more variable than that of non-smokers. However, smokers had higher intakes of total fat ($p<0.05$) and saturated fat ($p<0.05$) and lower intakes of folate ($p<0.05$) and vitamin C ($p<0.05$). Smokers also had lower intakes of fruit and vegetables compared to non-smokers ($p<0.05$). Given these differences, diet may be a confounder in studies examining smoking-disease relationships and therefore needs to be controlled for in such studies. In summary, important methodological issues in dietary surveys that ultimately influence the interpretation of dietary data including response rates, variability in intakes and the potential for confounding by diet while studying the determinants of chronic disease have been addressed.

Résumé

L'enquête canadienne des habitudes alimentaires faite en 1997-1998 a examiné l'apport alimentaire des adultes non institutionnalisés âgés de 18 à 65 ans (n=1543). Un échantillon canadien était sélectionné à partir de petites régions choisies au hasard selon un devis d'étapes multiples L'apport alimentaire était mesuré par un rappel de 24 heures et un sous-échantillon faisait un deuxième rappel (446). Le taux de réponse était de 26%. L'échantillon n'était pas totalement représentatif de la population car les homes, les jeunes adultes (18-34 ans), les gens seuls et ceux avec moins d'éducation étaient sous représentés. Une vérification des caractéristiques démographiques des 63 régions locales sélectionnées pour cette étude montrait que les régions ayant une forte proportion de gens qui avaient déménagés depuis moins de 5 ans, ou des gens ayant une langue maternelle autre que l'anglais ou le français, ou des gens sous le seuil de pauvreté avaient un plus faible taux de réponse. Les régions locales avec un pourcentage plus élevé de femmes avaient un meilleur taux de réponse. Ces résultants suggèrent que des approches particulières doivent être utilisées selon les caractéristiques de la population ā l'étude pour améliorer la participation. Une analyse de l'apport nutritionnel indique que le ratio de la variance 'intra' versus 'inter' était plus élevé en contrôlant les effets de sexe, âge, éducation, saison, tabagisme et taille de la famille (eg. 1.07 vs 0.49 pour l'apport des homes en

énergie). Il en résulte qu'une plus grande valeur de jours de rappel répétés serait nécessaire pour une estimation fiable après ajustement des derniers. Les fumeurs n'avaient pas une variabilité intra sujet plus élevé que les non-fumeurs mais l'apport alimentaire des fumeurs était plus élevé en lipides totaux ($p<0.05$), lipides saturés, ($p<0.05$) et plus bas en folate ($p<0.05$) et vitamine C ($p<0.05$). Les fumeurs avaient aussi un apport moins élevé en fruits et légumes. Ceci indique que l'apport alimentaire pourrait agir comme variable confondante dans les études sur les effets du tabagisme. En bref, plusieurs aspects méthodologiques des enquêtes nutritionnelles étaient examines: les taux de réponses, l'analyse de la variabilité intra et intra et inter sujet et les associations entre le tabagisme et l'apport alimentaire. Touts ces facteurs ont d'importantes implications pour les enquêtes nutritionnelles.

Statement of Originality

Contribution to knowledge

This thesis investigates the response rate of each selected enumeration area to determine characteristics of enumeration areas that are associated with better response rates. Generally, studies report overall response rate and have found that response rates are lower for males, younger age groups and those with lower education levels. The study data demonstrate that it is not adequate to only report the overall response rate as the response rates vary by certain characteristics, both at the individual level and at the level of the sampling area. Characteristics of the selected enumeration areas associated with response rates are reported here for the first time.

The need to adjust for variables that contribute to between- subject variability was demonstrated in the study by comparing within- to between- subject variance ratios using the mixed model procedure that adjusted for factors contributing to variability and the one that did not adjust for any of the factors. Adjusting for factors contributing to

variability yielded higher variance ratios for nutrients and foods compared to the unadjusted method. Using unadjusted ratios would result in fewer days of observation being needed, which may not yield precise estimates of nutrient intakes. The importance of adjusting for factors contributing to variability has not been reported in any previous literature.

Finally, the study demonstrated that smokers and non-smokers differ in nutrient intakes and food choices, confirming the poorer eating habits of smokers, this being the first such observation in Canada. Yet no study has investigated variability in nutrient intakes among smokers. This study was the first to do so.

Guidelines of Manuscript-Based Thesis

The Faculty of Graduate Studies and Research, McGill University provides guidelines for "an alternative to the traditional thesis format" such that "the dissertation can consist of a collection of papers that have a cohesive, unitary character making them a report of a single program of research" (http://www.mcgill.ca/gps/programs/thesis/guidelines/). The structure for the manuscript based thesis follows:

Candidates have the option of including, as part of the thesis, the text of one or more papers submitted, or to be submitted, for publication, or the clearly-duplicated text not the reprints) of one or more published papers. These texts must be bound together as an integral part of the thesis.

The thesis must be more than a collection of manuscripts. All components must be integrated into a cohesive unit with a logical progression from one chapter to the next. To ensure that the thesis has continuity, connecting texts that provide logical bridges between the different papers are mandatory.

The thesis must conform to the requirements of the "Guidelines for thesis preparation" including the following: a table of contents; and abstract in English and French; an introduction that clearly states the rationale and objectives of the research; a comprehensive review of literature; a final conclusion and summary; and a thorough reference list.

Where appropriate, additional material must be provided (e.g. in appendices) in sufficient detail to allow a clear and precise judgement to be made of the importance and originality of the research reported in the thesis.

When co-authored papers are included in a thesis the candidate is required to make an explicit statement in the thesis as to who contributed to such work and to what extent. This statement should appear in a single section entitled "Contributions of Authors" as a preface to the thesis. The supervisor must attest to the accuracy of this statement at the doctoral oral defence. Since that task of the examiners is made more difficult in these cases it is in the candidate's interest to clearly specify the responsibilities of all the authors of the co-authored papers.

Contributions of Authors

The Food Habits of Canadian Survey conducted between 1997-1998 was initiated to study the food and nutrient intake of Canadian men and women aged 13-65 years. The principal descriptive analyses of this survey including average daily intake of energy, macronutrients and micronutrients and food consumption patterns by age and gender were published by Gray-Donald et al (2000), Starkey et al. (2001), and Troppman et al. (2002).

The candidate was solely responsible for data management, coding original data, data verification, importing data from the dietary analyses program and building of the SAS data files as part of the preliminary work. The candidate conducted all the analyses, initial interpretation and preparation of the manuscripts. The candidate worked closely with Dr.K.Gray-Donald, the thesis supervisor and the Principal Investigator of the project, in developing research questions. Dr.Gray-Donald provided guidance with suggestions, additional analyses, interpretations and reviewing the manuscripts.

The first paper on *Low response rate in low income areas: Food Habits of Canadians Survey* was co-authored by the research supervisor, Dr.K.Gray-Donald. The candidate along with the supervisor decided on the choice of variables and the types of analyses to be conducted to determine the correlates of response rate.

The second paper on *Implications of day-to-day variability on measurement of* *usual food and nutrient intake,(J. Nutr., 133: 232-235, 2003, Palaniappan, U., Cue, R.I., Payette, H., Gray-Donald, K.)* was co-authored by the research supervisor, Dr.K. Gray-Donald, Dr.R. Cue, Department of Animal Science, McGill University and Dr.H. Payette, Centre de recherche sur le vieillissement, Institut universitaire de gériatrie de Sherbrooke. Dr. Cue provided statistical guidance with using the mixed model procedure to determine within- and between- subject variability and interpreting the results. Dr.H. Payette, a committee member for the candidate, critiqued and provided helpful suggestions on the issues relating to variability in food and nutrient intakes.

The third paper on *Fruit and vegetable consumption is lower and saturated fat intake is higher among Canadians reporting smoking (J. Nutr., 131:1952-1958, 2001, Palaniappan, U., Jacobs-Starkey, L., O'Loughlin, J. & Gray-Donald, K.)* was co-authored by the research supervisor, Dr.K.Gray-Donald, and by Dr.L. Jacobs-Starkey, School of Dietetics and Human Nutrition, McGill University and Dr.J. O'Loughlin, Department of Epidemiology and Biostatistics, McGill University and Department of Public Health, Montreal General Hospital. Dr.L.Jacobs-Starkey, a committee member for the candidate was also one of the Principal Investigators of the survey. Dr.J. O'Loughlin is an expert in the area of cardiovascular risk factors, particularly smoking. The co-authors thoroughly critiqued the manuscript drafts and provided valuable suggestions.

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Table of Contents

Chapter	Page No.
Abstract	i
Résumé	iii
Statement of Originality	v
Guidelines of Manuscript-Based thesis	vii
Contributions of Authors	viii
Acknowledgements	x
Table of Contents	xii
List of Tables	xiv
Appendices	xvi
Chapter 1	1
Introduction	1
1.1. Thesis Objectives	5
Chapter 2	8
Literature Review	8
2.1. Definition and Purpose of Dietary Surveys	8
2.1.1. Planning and Conducting a Survey	9
2.2. Response Rate	14
2.3. Dietary Methodology in surveys	24
2.3.1. Measurement Errors	28
2.4. Variability	36
2.4.1. Factors influencing variability	38
2.4.2. Effects of variability on dietary methodology	42
2.5. Dietary intakes of population sub-groups	44
Chapter 3	50
3.1. Survey Design	50
3.1.1. Target population	50
3.1.2. Sample Size	51
3.1.3. Sampling Procedure	51
3.1.4. Ethics	54
3.1.5. Data Collection	54
3.1.6. Nutrient Analyses	55
3.2. Quality Control	57
3.2.1. Interviewer Training	57
3.2.2. Data Entry	58
3.3. Thesis Research Methodology	60
3.3.1. Response Rate	60
3.3.2. Variability in food and nutrient intakes	64

3.3.3. Examination of nutrient intakes in sub-populations 66

Chapter 4 70
Low response rate in low income areas: Food Habits of Canadians Survey 70
Abstract 71
Methods 73
Results 77
Discussion 78
References 83

Chapter 5 90
Implications of day-to-day variability on measurement of usual food and nutrient intake 90
Transition 90
Abstract 93
Subjects and Methods 95
Results 99
Discussion 101
Literature Cited 105

Chapter 6 115
Fruit and vegetable consumption is lower and saturated fat intake is higher among Canadians reporting smoking 115
Transition 115
Abstract 118
Subjects and Methods 121
Results 127
Discussion 130
Literature Cited 135

Chapter 7 152
Discussion and Conclusions 152
Future Recommendations 156

References 159

List of Tables

Page No

Chapter 4

Table 1 Comparison of Census 1991 and Study population characteristics 86

Table 2 Correlation between response rate and independent variables for the selected enumeration areas 88

Table 3 Correlates of response rate using multiple regression (based on 1991 census data) 89

Chapter 5

Table 1 Intra- to inter- subject variances (s_w^2/s_b^2) by gender for selected nutrients using two different methods 110

Table 2 Number of days of observation needed for specific nutrients using two different methods........ 111

Table 3 Intra- to inter- subject variance ratio (s_w^2/s_b^2) by gender for different food groups by two different methods 113

Chapter 6

Table 1 Demographic characteristics of subjects by smoking status 143

Table 2 Nutrient intake stratified by men and women smoking status 144

Table 3 Food groups contributing to intake of carbohydrate, fat, folate and vitamin C by smokers and nonsmokers 146

Table 4 Average number of servings of food groups from Canada's Food Guide to Healthy Eating among men and women stratified by smoking status 149

Table 5 Ratio of intra- to inter- subject variability among men and women stratified by smoking status 150

Table 6 Percentage of men and women stratified by smoking status meeting recommendations for calcium, iron, zinc, folate and vitamin C 151

Appendices

		Page No.
Appendix 1	Introductory Letter	177
Appendix 2	Telephone log	178
Appendix 3	Ethics	179
Appendix 4	Sociodemographic questionnaire	180
Appendix 5	24-h recall form	181
Appendix 6	Food models	182
Appendix 7	Reprint permission	183
Appendix 8	Reprint: Fruit and vegetable consumption is lower and saturated fat intake is higher among Canadians reporting smoking	184
Appendix 9	Acceptance letter from The Journal of Nutrition- Implications of day-to-day variability on measurement of usual food and nutrient intake........	185
Appendix 10	Reprint: Implications of day-to-day variability on measurement of usual food and nutrient intake......	186

Chapter 1

Introduction

Diet has been linked to a number of chronic diseases including heart disease, cancer, osteoporosis and diabetes (Health and Welfare Canada, 1990, Fleet, 2001, Truswell, 2002). Evidence suggests that several nutrients and foods have either a causative or protective role in the development of chronic diseases. Research indicates that high consumption of saturated and trans- fatty acids increase the risk for coronary heart disease (Krauss et al., 2000). Although not conclusive, certain epidemiological studies indicate that increased consumption of vitamin C, vitamin E and carotenoids reduce the risk for cancer and coronary heart disease (Marchioli et al., 1999, Kushi et al., 1996) while several randomized clinical studies have found no significant reduction in the risks for diseases (Heart Protection Study Collaborative Group, 2002, Alpha-Tocopherol Beta Carotene Cancer Prevention Study Group,1994, Hennekens et al., 1996).

People generally do not consume nutrients; rather they derive the major portion of the nutrients from foods. Nutrients present in foods are highly correlated and attributing the cause to one nutrient may be misleading. For example, clinical trials initiated to prove the beneficial effects seen in observational studies with ß-carotene did not show a protective effect against cancer (Alpha-Tocopherol Beta Carotene Cancer Prevention Study Group,1994, Omenn et al., 1996). In fact, supplementation with ß-carotene increased the risk for cancer (Alpha-Tocopherol Beta Carotene Cancer Prevention Study Group, 1994). This could be due to the presence of several other nutrients and phytochemicals in natural foods which could likely have played a protective effect seen in observation studies (Tucker, 2001).

Epidemiological studies have shown that grains, fruits and vegetables lower the risk for several types of cancer and cardiovascular disease (Koo, 1997, Block et al., 1992, Ness and Powles, 1997, Truswell, 2002). Therefore, rather than a specific nutrient or a particular food, it is the composition of the whole diet that is important. This is because of the complex interaction of nutrients present in foods. Also, when a variety of foods are consumed there is a likelihood of obtaining a proper balance of nutrients which could possibly be important as well (Tucker, 2001).

Healthy eating is recognized as an important strategy for promoting health (Health and Welfare Canada, 1990). The Scientific Review Committee based on the scientific evidence defined a healthy diet as one that is based on consuming a variety of foods. The main objective of the recommendations were to help Canadians select a dietary pattern that would provide all the essential nutrients in recommended amounts while reducing the risk for chronic diseases (Health and Welfare Canada, 1990). Among the key recommendations were lowering fat and saturated fat intakes by choosing leaner cuts of meats and foods prepared with little or no fat and increasing complex carbohydrates and fiber with emphasis on increasing cereals, grain products and fruits and vegetables (Health and Welfare

Canada, 1990). The question then arises as to how do people currently compare in their food and nutrient intakes in relation to the recommendations.

With greater understanding of diet-disease relationships, there are indications that there is an increasing awareness among the general population regarding the importance of healthy lifestyle that emphasizes balanced diet. The recent National Population Health Survey indicates that more Canadians consider low fat food choices are important and that they have increased their fruit and vegetables consumption and lowered their fat intake (Health Canada, 1997). Several factors have contributed to the changes in food consumption patterns. More women in the workforce, increasing numbers travelling on work and vacation, increasing immigrant population, willingness to experiment new ethnic foods, and greater availability of convenience foods have all contributed to the changes (Health Canada, 1996).

Despite the indicated changes in eating habits there is very little information available about the current eating habits of Canadian adults in terms of absolute quantity and in terms of adequate or excessive intake of nutrients. The last national nutrition survey was conducted in the seventies (Health and Welfare Canada, 1975). Several decades later, provincial surveys including the Nova Scotia Nutrition Survey and Québec Nutrition Survey were conducted in 1990 (Kendall et al., 2001). The Saskatchewan Nutrition Survey was conducted in 1993-1994, the results of which were made available only recently (Stephen and Reeder, 2001). Lack of recent data on dietary patterns is a limitation particularly for health professionals who are interested in identifying population sub-groups with inadequate intakes and developing appropriate programs and policies.

One of the uses of food consumption data is to examine the prevalence of inadequacy of nutrient intakes in the population. The commonly used method of comparing mean intakes with the recommendations and determining the proportion of the population not meeting the dietary recommendations is inappropriate (Institute of Medicine, 2000). Newer recommendations involve adjusting for within-subject variability and studying the distribution. This is because a person's intake varies from one day to another and therefore intakes have to be adjusted for this component of variability. Very few dietary surveys have followed this method (Nova Scotia Department of Health, 1993, Santé Québec, 1995). Moreover, the new dietary recommendations based on new scientific evidence came into effect long after the dietary surveys were conducted in Canada and therefore there is no understanding of the current prevalence of inadequacies for the different nutrients.

Food Habits of Canadians Study conducted between 1997-1998 is the first national nutrition survey since the last national Nutrition Canada Survey to study dietary patterns of adults aged 18-65 years across Canada. The objectives of the Food Habits of Canadians study were to examine nutrient intakes for age-gender specific groups, evaluate the contribution of specific foods and food groups to nutrient intake, analyze the impact of fortification in specific food items for different age and gender groups, adjust nutrient intake distribution by accounting for within- subject variability so as to provide accurate data on the percentage of the population meeting requirements and quantifying the number of days required to estimate usual intake for nutrients.

1.1. Thesis objectives

The objectives of my research were to examine methodological aspects related to conducting a dietary survey. The first objective was to examine issues related to response rates. The characteristics of the people who responded to the survey need to be examined to determine the generalizability of the study results. Variability is another issue that needs to be examined both at the design and analytical stages of a study. The number of days of observation needed to obtain accurate estimates depends on variability of nutrient intakes. When determining the prevalence of inadequate intakes, within- subject variability needs to be quantified and adjustment for this variability needs to be undertaken (Institute of Medicine, 2000). Certain population sub-groups may have highly variable intakes with some having very high intakes and others with low intakes; and, it is possible that the sub-groups may have nutrient intakes that place them at risk for nutritional deficiencies or increased risk for chronic diseases. Smokers and non-smokers were considered for this aspect. Although a number of studies have examined differences in dietary patterns by smoking status, very few studies have examined prevalence of inadequate intakes of nutrients among smokers. Based on the discussion above, the specific objectives of this thesis were:

1. To examine response rates in the Food Habits of Canadians Survey and to examine community characteristics of the selected areas in relation to response rates:

a). to estimate the overall response rate for the study and for each of the selected area

b). to compare socio-demographic characteristics of the sample with those for the general population to determine generalizability of the study results.

c). to determine the correlates of response rates by examining what socio-demographic characteristics of the communities are related to better response rates in some areas compared to other areas.

2. To examine variability in nutrient and food intakes and to quantify the number of days of observation needed to measure usual intake at different levels of accuracy for nutrient and food groups:

a). to estimate and compare the ratios of within- to between- subject variability for nutrients and foods using a mixed model procedure that adjusts for factors that contribute to variability and the other that does not adjust for any of the factors

b). to estimate the number of days needed to correctly classify subjects into groups using both within- and between- subject components of variability and to accurately assess usual intakes for individuals using within- subject variability alone in the calculation.

3. To assess nutrient intakes in population sub-groups:

a). to examine differences in dietary patterns among smokers and non-smokers in terms of nutrient intakes and food choices that contribute to the differences in nutrient intakes

b). to compare the within- to between- subject variability ratios of smokers and non-smokers

c). to examine the prevalence of inadequacy in nutrient intakes by smoking status after adjusting for within- subject variability using the recently developed Dietary Reference Intakes recommendations for nutrients and

d). to investigate how the smokers and non-smokers compare in terms of meeting the guidelines for Canada's Food Guide to Healthy Eating.

Chapter 2

Literature Review

2.1. Definition and Purpose of Dietary Surveys

Surveys are commonly used to gather information about certain characteristics of the population. When the investigator simply observes what is going on in a study without disturbing any element in it, then the investigation is generally called a survey, which is derived from the Latin word 'supervidere' meaning to oversee (Kendall et al., 1997).

Dietary surveys can provide information on food and nutrient intakes of the population, estimate nutritional adequacy of different population sub-groups, identify nutritionally disadvantaged groups and evaluate the potential impact of certain dietary factors on diseases (Yetley et al., 1992, Ministry of Agriculture, Fisheries and Food, 1990), thereby, providing a basis for public health planners to develop nutrition programs (Yetley et al., 1992). Repeated dietary surveys are useful to monitor trends in nutrient intakes, observe changes in dietary habits (Yetley et al., 1992, Ministry of Agriculture, Fisheries and Food, 1990) and track achievement of national health goals (Willett, 1998). However, the use of different methods to collect and analyse data in the surveys can make it difficult to monitor trends over time.

Large-scale dietary surveys have been conducted in North America and Europe in order to assess dietary intake and nutritional status (McDowell, 1994, Delgado et al., 1990, Health and Welfare Canada, 1975, Euronut SENECA investigators, 1991). Smaller scale surveys at regional or provincial levels have also been employed to assess dietary status (Hedley et al., 1995, Santé Québec, 1995, Nova Scotia Department of Health, 1993).

2.1.1. Planning and Conducting a Survey

The objectives of surveys in general are to obtain dietary information from a sample which is representative of the whole population. Collecting information from everybody in the population is difficult. Therefore, a sample of the population that is representative of the general population is selected and relevant information is collected (Satin, 1993).

Proper planning of a survey is essential to obtain useful information from a representative sample of the population. The first step in planning a survey is to specify the objectives of the survey. Clear answers to the objectives will help determine who is to be observed, the regions to be covered and the variables to be observed or measured.

Defining the population: The population is a collection of units to which the survey results would eventually apply (Jolliffe, 1986). The population could be a collection of individuals identified by their place of residence (eg. provincial, national), occupation (eg. physicians, bus conductors) or certain characteristics (eg. smokers, nuns) (Satin, 1993).

The units or groups studied vary depending on the objectives of the dietary survey. The objectives of the first Canadian Nutrition Survey conducted between 1970-1972 were to measure food and nutrient intakes of all non-institutionalised

Canadians. Therefore, food consumption patterns of Canadian males and females of all ages including Aboriginal groups were examined (Health and Welfare Canada, 1975). Other surveys have not included Aboriginal groups (Stephen and Reeder, 2001) and have been region specific (Nova Scotia Nutrition Survey, 1993, Stephen and Reeder, 2001). Some surveys have examined dietary intakes of pregnant women (Health and Welfare, Canada, 1975) while others have excluded this category due to atypical dietary and physiological characteristics, different nutritional requirements and the need to use different sampling strategies owing to small numbers (Ministry of Agriculture, Fisheries and Food, 1990, Nova Scotia Nutrition Survey, 1993). In the United States, surveys have been conducted to study dietary patterns of specific ethnic groups. For example, in the Hispanic Health and Nutrition Examination Survey (HHANES), nutrition and health parameters of three groups of Hispanics, namely, Mexican Americans, Cubans and Puerto Ricans living in specific areas were examined (Rowland and Forthofer, 1993). In the United Kingdom, surveys concentrating on very specific groups such as civil servants (Stallone et al., 1997) have also been reported.

Sampling frame: A frame refers to a list of elements that covers the survey population (Fowler, 1988) from which a sample is selected. It can be a register like the health registration file or a list of people with telephones. The frame plays a vital role in the design of a survey (Fowler, 1988) because it determines how well a population is covered. In the case of a mail or telephone survey it is imperative to have a frame that has up-to-date and accurate addresses or telephone numbers (Frey, 1983). The frame chosen must also take into account the objectives of the study. If the objective of the survey is to assess dietary intake of non-institutionalised and non-native adults, then people living in institutions and people living on reserves are not included (Brule, 1996).

Provincial heart health and nutrition surveys done in several provinces used health insurance registers as the sampling frame (Stephen and Reeder, 2001, Nova Scotia Department of Health, 1993). Electoral registers were used in the Dietary Survey and Nutritional Status of British adults and in the WHO-Monica survey (Wolf et al., 1999). Whatever the type of frame selected, it is imperative that the lists include all members of the population defined. It is possible that some persons in the Health Insurance Registration File, telephone or housing list may have moved out of the area and the list may be outdated. Also, there is a likelihood of failure to include the homeless and those without a phone in surveys when a housing or telephone list is used as the sampling frame.

Sampling: There are several types of sampling techniques including simple random sampling, systematic sampling, stratified sampling, cluster sampling, multi-stage sampling and multi-phase sampling (Satin, 1993). Subjects could be selected using either one or a combination of more than one of these techniques.

Simple random sampling is a basic selection scheme where a sample of units are selected from the population so that each unit has an equal probability of being selected (Satin, 1993). In a large survey, it would be a long and tedious procedure to select subjects randomly; additionally, the persons so selected would be scattered all over the country making it impractical to conduct a survey.

In systematic sampling, the first person is randomly selected and then every nth person in the list is included (Hulley et al., 1988, Satin, 1993). This method is not practical to be used as the sole method of sampling in a survey because of the cyclic nature of selection and also because of the possibility of the investigator predicting and therefore manipulating who will be in the sample (Hulley et al., 1988), thus limiting the representativeness of the sample so selected.

Stratified sampling involves dividing the population into strata of homogenous groups and then selecting a random sample from each strata (Cole, 1997). Stratification may be done on age, gender, region or any other variable of interest. An advantage with this method is that work can be carried out in manageable units (Satin, 1993). Two stage stratified sampling was used for the Nutrition Canada and provincial surveys (Health and Welfare Canada, 1975, Nova Scotia Department of Health, 1993).

Sometimes instead of sampling individuals, it may be more convenient to sample groups or clusters of individuals. Cluster sampling involves sampling a whole unit, eg. sampling city blocks, villages or schools in order to obtain a sample of people (Satin, 1993). An advantage with this type of sampling is the reduced administrative costs. Another advantage is that one need not have a list of all subjects. One can select villages from a list of villages and then enumerate everyone in the village and then, depending on the objectives of the study, select individuals or households from the list. A disadvantage with this type of sampling is that neighbouring units tend to be more alike because people in the same neighbourhood are likely to have similar socio-economic characteristics (Satin, 1993).

As the name indicates, multi-stage sampling involves selecting a sample in several successive stages. From a list of all first stage units (eg. province, districts, city blocks), called primary units, a selected number of units are chosen. From these units, a sub-sample of units (eg. census division, households) called secondary units, are selected. If people in a city are to be sampled, city blocks and dwellings may form the first and second stage units respectively. Individuals can then be randomly selected from a list of persons within the household (Satin, 1993). In larger surveys like the third National Health And Nutrition Examination Survey (NHANES), for example, a stratified multi-stage random sampling technique was used where counties formed the primary sampling unit; city or suburban blocks in the counties comprised the second stage; households from a list of households in the city blocks were selected at the third stage and finally individuals within the households were selected from a list of all eligible members in the household based on age, sex and race (Vital Health Statistics, 1992). An advantage of multi-stage sampling is related to the cost and ease of administration.

Sample size: Sample size depends on the purpose of the study, the population and the various sub-groups being studied as well as the variability of the factors being examined (Browner et al., 1988, Campbell, 2002). Generally, surveys report an underrepresentation of older persons, young adults, Mexican-Americans, African Americans and people with lower incomes. Therefore, these groups are oversampled in order to obtain an adequate sample size which would help achieve reliable estimates and make valid inferences (Vital Health Statistics, 1992).

2.2. Response Rate

Once the survey has been conducted, it is essential to examine how many of the eligible subjects respond to the survey which can be determined by calculating the response rate. Response rate is estimated as the proportion of subjects from a list of eligible sample that provide a complete interview (Groves and Lyberg, 1988). Different investigators use different methods of calculating response rate, which appear to relate to the interpretation of the term 'eligible'. Groves and Lyberg (1988) suggested the following formula for calculating the response rate,

$$\text{Response Rate} = I/(I+NC+NI+UN+R) \qquad (1)$$

where, I = interviewed, NC= not contacted, but possible eligible units, NI = non-interviewed numbers, UN=unanswered numbers and R= refused eligible units.

Here the denominator includes everyone for whom the interview could be conducted (Groves and Lyberg, 1988). The non-interviewed category includes those not interviewed due to language problems or difficulty in hearing. However, these same factors could form part of the exclusion criteria already decided at the start of the study and therefore not form part of the response rate calculation. Therefore, the above formula could be modified to exclude those not interviewed and can be represented by,

RR = I/(I + NC + UN + R)

Some investigators exclude persons not contacted due to households being vacant or unanswered telephone numbers (Fowler, 1988) and the response rate calculation is represented by the formula,

RR = I/(I + R)

The distinction between non-contacted and unanswered numbers is not clear-cut. According to Groves and Lyberg (1988), non-contacted numbers are known eligible numbers, that is, if the purpose of the survey is to obtain information from households, then identification of household and business numbers will help to exclude business numbers and include only household numbers which are considered as eligible numbers. Once households are identified, it may still not be possible to contact any individual in the household due to a number of reasons including unanswered numbers. Non-contact depends on the method of contact. In surveys, where interviewers go from house to house, it is possible to identify vacant households by examining the surroundings or asking the neighbour. In mail surveys, it may be difficult to locate subjects because they have moved. In such cases, unless the mail is returned, it may not be possible to know if the mail was received, discarded, lost or forwarded (Frey, 1983). In telephone contacts, it may not always be possible to identify vacant households particularly when nonworking numbers are not clearly identified as such (Groves and Lyberg, 1988). The telephone number may belong to a household that uses the house only for seasonal stay (Sebold, 1988). An interviewer may call repeatedly, but the occupants may refuse to answer the phone resulting in non-contact with the selected household (Groves and Lyberg, 1988) due to an unknown number in the caller ID display. Some researchers make a rule that after a specific number of calls to the same number, unanswered numbers will be excluded assuming that these are non-working numbers. However, it is still possible that the telephone numbers belong to people who are infrequently at home due to work or frequent travel, thereby increasing the chance of losing busy people. Additionally, failure to make enough calls to establish contact with a household can also result in non-contact (Collins et al., 1988).

Refusals occur when the selected person refuses to answer questionnaires or take part in interviews or health examinations (Kalton and Kasprzyk, 1986) due to lack of time, employment or difficulty in finding access to transportation (Rowland and Forthofer, 1993). Other reasons cited for refusals are lack of interest in the topic of research (Jolliffe, 1986, Collins et al., 1988) and worry about their confidentiality (Jolliffe, 1986). In a face-to-face interview, subjects appear to be resistant to allow strangers into their homes (Frey, 1983). However, face-to-face interviews report higher response rates probably because of the personal approach and also because the subject is able to see the interviewer whose professional appearance and approach may elicit a favorable response (Campbell, 2002). Unlike face-to-face interviews, it is easier for the subjects to refuse participation very early during a telephone conversation (Collins et al., 1988). A problem with abrupt refusals is the difficulty in assessing the eligibility of the subject.

In health and dietary surveys, very rarely is the method for response rate calculation reported. Different methods of calculating response rates make it difficult to compare response rates across surveys. The Santé Québec Nutrition Survey (1995) reported a response rate of 69% based on the calculation that included only those contacted. If those not contacted were also included in the response rate calculation, the response rate would have been 56%.

Possible factors contributing to decision-making in responding to surveys: As surveys are increasingly facing low response rates, possible factors contributing to the subjects' decision to either participate or not participate in surveys have been examined. According to the social exchange theory (Dillman, 2000), one can postulate that some people willingly participate in dietary surveys because the topic is of interest to them. Inclusion of pre-paid envelopes possibly contributes to better response rates in mailed surveys. One possible reason for the low response rates seen in dietary surveys may be that many consider possible questions on dietary intake a source of embarrassment or feel they may be judged or consider questions on diet as a possible invasion of privacy. According to Groves et al. (1992), legitimacy of the social institution carrying out the survey may contribute favorably to the response rate. Long questionnaires reduce response rate. An interviewer's prior experience will affect the skill and confidence with which he/she approaches the respondent and persuade the respondent to participate in the study. Thus it can be seen that understanding the vast number of possible factors influencing participation would help increase response rates in surveys.

Effects of low response rates: Recently, most surveys have reported low response rates (Smith, 1995). This is true in health related and dietary surveys as well. In the five population based National Health Examination Surveys (NHES) conducted from 1960 through 1990, response rates have declined from 90% in the NHES I survey to approximately 70% in the third National Health And Nutrition Examination Survey (NHANES) (Rowland and Forthofer, 1993) which could be due to the heavier respondent burden in the NHANES.

Declining response rate is a matter of concern for a number of reasons. Low response rate results in a smaller final sample size, which could lead to loss of accuracy in the observed estimates. Low response rate also means that there is selective participation in the study where certain groups may be under- or over-represented in the sample, which may lead to possible bias in the estimation of population parameters (Osler and Schroll, 1992).

It is generally believed that the potential for bias increases as response rate decreases. While higher response rates may result in less biased data, there is no optimal response rate that can be suggested when the data would become biasfree. When there is a high non-response rate, it becomes essential to evaluate nonresponse bias in order to assess the quality of data and the potential effects on survey estimates (Khare et al., 1994).

It is a good practice to evaluate differences in the distribution of characteristics among respondents and non-respondents in order to determine generalizability of study results (Rowland and Forthofer, 1993). Generally, surveys have attempted to examine non-response bias by examining those who respond to surveys with those who do not respond on a number of socio-demographic variables. In health-related studies, socio-demographic and health related factors usually influence participation (Bisgard et al., 1994, Criqui et al., 1978). Compared to the responders, non-responders are more likely to be males, smokers, unmarried, less educated, belong to single person households, live in poor neighborhoods and belong to either the younger age group (18-29 years) or the older age group (more than 70 years) (Reijneveld and Stronks, 1999, Forthofer, 1983, Casey et al., 1999). By virtue of their lifestyle, the younger age group is more likely to be mobile and less likely to stay at home and therefore is difficult to recruit in surveys. A higher response rate for large families (5 or more people) compared to small families and single individuals (1 or 2 family households), could be due to availability of someone at home when the interviewer calls (Forthofer, 1983). Lower response rates by non-dominant ethnicity/race have also been reported (Jackson et al., 1996, Trowbridge et al., 1990). Difficulty in communication because of lack of adequate knowledge of the official languages could result in refusals leading to lower response rate. Lower response rates among people in urban metropolitan areas, particularly in inner city areas have been reported (Hedley et al., 1995), which could be attributed to the population being poor and mobile.

Researchers have used different techniques to examine differences between those who respond and do not respond to surveys:

1. *Asking others about the non-respondents* Researchers in the first National Health Examination Survey (NHES, Cycle I) contacted physicians to get information on health related characteristics for a sub-sample of the examined and non-examined subjects (Forthofer, 1983). The physicians provided data about overall health status, physiologic measurements and the presence of certain medical conditions. There were no differences in health status but the non-examined had fewer self-reported problems. This suggests that those who were examined probably were the 'worried well'(Forthofer, 1983).

2. *Studying persons who drop out after an initial interview* Characteristics of non-respondents who attended only the interview component and not the examination were compared with those who attended both the interview and examination components (Vital Health Statisics, 1993, Forthofer, 1983). Participation in the examination was inversely related to age. Increasing family size was a positive indicator for response. Also, persons living in the northeast, urban metropolitan centers had lower response rates compared to the other regions (Khare et al.,1994).

3. *Using public registers* In a health survey for asbestos workers, non-participants were compared with participants in terms of total number of sickness absences (Ohlson and Ydreborg, 1985) using registers from public register offices including Census Registers and Public Assistance office. Information on socioeconomic characteristics was obtained from census registers for all participants. Those who did not respond tended to have lower education and income levels and were more likely to be receiving assistance.

4. *Comparison of respondent characteristics to census data* Investigators of WHO MONICA risk factor survey suggested comparing characteristics such as education level of the respondents with the census data in order to investigate similarity with the general population (Wolf et al., 1999), but details on similarities or differences were not reported.

5. *Using information on the sampling frame about nonrespondents* In the Nurses Health Study that examined the effects of oral contraceptives, respondents were compared with non-respondents by examining several socio-demographic variables (age, gender, degree obtained, employment status, field of employment and region of residence) using the files of the American Nurses' Association (Barton et al., 1980). The respondents were more likely to be younger than the non-respondents. No other significant differences for the other variables were found. Other than the demographic factors reported, no information on any other health related factors were available.

6. *Fill out a short questionnaire* In the European SENECA project, subjects who were not willing to participate in the study were requested to complete a short questionnaire on education, housing, smoking, marital status and certain health and nutrition related questions and were compared with participants who were also asked similar questions (Euronut SENECA investigators, 1991). It was reported that females, smokers, persons with lower education level, individuals who did not eat a cooked meal daily and persons who self-rated their health as poor participated less. As dietary information per se was not collected for the non-respondents, differences in nutrient intakes by response status is not known.

7. *Using another study as reference* Forthofer (1983) reported comparison of characteristics of subjects in NHANES II with that in NHIS which had a good response rate (only 4% non-response) and hence considered credible. Comparison of distribution of selected variables between the two surveys indicated similarity in body mass index, and physician reported health conditions.

However, comparing respondents and non-respondents on socio-demographic variables alone for similarities and concluding that the results are representative of the general population can be misleading. It is still possible that the non-respondents and respondents differ on risk factors and disease. In a study that examined differences in cardiovascular health status between participants and non-participants, it was observed that after adjusting for age, a significantly greater percentage of non-respondents reported the presence of cardiovascular disease than the respondents. However, a greater percentage of respondents had risk factors such as family history of cardiovascular disease and hyperlipidemia. Therefore, estimates of relative risk or odds ratio obtained would be biased (Criqui et al., 1978).

Studies examining bias in dietary intake with respondents and non-respondents are lacking. The SENECA study from Denmark observed no significant differences between the respondents and non-respondents in terms of age, gender, marital status, smoking, education and frequency of hospitalization in the previous 12 years. However, the non-respondents were less likely to have cooked a meal and were more likely to rate their health status as poor (Osler and Schroll, 1992). It is possible that the non-respondents have a poor diet; research indicates that a higher percentage of people in the older age groups do not cook because of lack of skills or disease conditions which could result in the elderly eating poorly thereby increasing the risk for nutritional deficiencies (Ausman and Russell,1999). Thus, examining the sociodemographic details and concluding that the two groups are similar and that the results of the study are unbiased can be misleading.

Adjusting for nonresponse bias: Various methods of adjustment for nonresponse bias have been suggested (Rowland and Fortofer, 1993, Kalton and Kaspryzyk, 1986). One method of adjusting for nonresponse bias involves examining socio-demographic variables (generally age and gender) and reporting stratum specific findings (Rowland and Forthofer, 1993).

Another more standard method commonly used by researchers is to use weighted adjustment (Kalton and Kasprzyk, 1986, Rowland and Forthofer, 1993). The objective of weighting is to make the sample more nearly representative of the population (Fuller et al., 1993). When some information on the non-respondents is available, weighting is done on the assumption that the non-respondents would have given the same types of answers as the respondents with similar demographic characteristics (Bradburn, 1992).

Although weighting can adjust for nonresponse, it is still possible that weighting does not adequately adjust for factors not considered that may have influenced participation or non-participation in the study (Euronut SENECA Investigators, 1991). When response to a survey is very low, it is not known what factors contributed to influencing the respondents to participate, thereby raising doubts if the respondents would be really representative of the population that they are supposed to represent (Guenther and Tippett, 1993). Weighting in such cases may be of no real use; not only will large weights have to be applied resulting in unstable estimates, but also the representativeness of the respondents is still uncertain .

2.3. Dietary Methodology In Surveys

The commonly used dietary survey methods include the repeated 24-hr recall, food frequency questionnaire, diet history and food records (estimated and weighed food records) (Fehily, 1983, Willett, 1998, Thompson and Subar, 2001).

Although diet records provide quantitative data, certain aspects of the recording process result in bias. Weighed food records that involve weighing all the ingredients used in the preparation of dishes including wastage require a great deal of subject co-operation (Fehily, 1983). Those who keep weighed food records therefore may be more motivated and hence may not be representative of the general population (Freudenheim, 1993). As respondents to surveys using food records need to be literate, food records are of limited use in some population groups such as those with low levels of education and immigrants who are not fluent in the survey language/s (Thompson and Subar, 2001). Long periods of keeping food records can result in fatigue and reported intakes have been observed to decrease in the later days of record keeping (Gersovitz et al., 1978). When subjects record total food intake only once per day instead of at each meal, the record method then is almost similar to the 24-hr recall in terms of relying on memory rather than immediate recording (Thompson and Byers, 1994).

The food frequency method asks respondents to record the usual frequency of consumption of specific foods for a specific period of time, which may be days, weeks, months or years (Willett, 1998). To estimate relative nutrient intakes, semi-quantitative food frequency questionnaires incorporate questions suggesting specific portion sizes. The food frequency method is better suited for ranking subjects according to food or nutrient intake (Gibson, 1990) than for estimating population averages (Briefel et al., 1997). In order to calculate an individual's nutrient intake, it is necessary to know which food items were consumed as individual foods and which were consumed as components of mixed dishes and how much of each item was consumed. However, the food frequency method does not capture all the required information (Briefel et al., 1992). Although less costly than multiple 24-h recalls or food records, the food frequency method can contribute to errors due to an incomplete listing of possible foods; errors could occur in the estimation of frequency of consumption and in the estimation of specific portion sizes (Kushi, 1994, Willett, 1998). Although food frequency can be used to estimate usual intake during the past year, there are indications that the season in which the questionnaire is administered influences reporting of food intake (Subar et al., 1994).

The diet history method includes a detailed interview about usual patterns of eating, a food list with amounts and frequency usually eaten and a 3-day diet record (Thompson and Subar, 2001). An advantage with this method is that details of food preparation can be obtained. The diet history estimates usual intakes and permits ranking of individuals by nutrient intake (Freudenheim, 1993). This method however is time consuming and requires well trained personnel.

In the 24-hour recall method, the subject is asked to recall all foods and beverages consumed in the previous 24-hour period through an interview which can be either face-to-face or by telephone (Casey et al., 1999). The 24-hour recall method has several distinctive advantages over the food record and food frequency methods in dietary surveys. Due to its relatively low cost and low subject burden, the 24-hour recall method has frequently been used to assess the average intake of a large group of people (Beaton et al., 1979). Due to the relatively lower burden on the respondents by this method compared to the food record, those who agree to do the 24-hour recalls are more likely to be representative of the population than are those who agree to do food records (Thompson and Subar, 2001). Additionally, this method has an element of surprise and therefore subjects are less likely to alter their eating behaviour (Gibson, 1990). Although criticised for its shortcoming related to memory (Willett, 1998), interviews are structured with probes to help respondents remember food consumed. National dietary surveys employ a multiple-pass system in which food intake is recorded in a series of steps and reviewed in an effort to retrieve forgotten eating occasions and to include commonly forgotten foods (Moshfegh et al., 1999). While multiple 24-hour recalls can be used to assess an individual's intake, a single day's recall can be used to assess average dietary intakes of groups because means are not affected by within-subject variation (Institute Of Medicine, 2001). Many surveys including the National Health and Nutrition Examination Surveys (Briefel, 1997), the Continuing Survey of Food Intake in Individuals (Guenther, 1994) and the Nutrition Canada Survey (1970-72) (Health and Welfare Canada, 1975) have used the 24-hour recall method.

2.3.1. Measurement Errors

Once a decision on an appropriate dietary method has been made to answer the basic research question, steps must be taken to address a number of issues related to the measurement of variables of interest in order to avoid errors.

Respondent error: Respondent error may be either random or systematic. A subject may sometimes over- report and sometimes under- report food intakes, which is considered to be random error (National Research Council, 1986, Beaton, 1994, Willett, 1998). However, taking body weight into consideration during analysis leads to the observation that obese individuals under- report and lean individuals over- report intakes, then a bias is introduced because of the differential reporting (Beaton, 1994).

A number of studies have indicated the presence of under- reporting of energy intakes. Studies that have validated energy intakes with energy expenditure using doubly-labeled water indicate that obese subjects, women, elderly subjects, and subjects from lower occupation categories or higher social class underreport food intake (Goris et al., 2000, Samaras et al., 1999, Lafay et al., 2000, Briefel et al., 1997, Stallone et al., 1997). The doubly labeled water technique is based on the principle of energy balance, since balance between energy intake and energy expenditure is needed to maintain body weight (Trabulski an Schoeller, 2001). However, the doubly labeled water technique is expensive and cannot be used to validate energy intake in large surveys; additionally, this method does not measure the validity of reporting of other nutrients. Goldberg et al. (1991)

proposed a method for evaluating energy intake data which compared reported energy intake with energy requirements, based on estimated basal metabolic rate ($EI:BMR_{est}$) which takes weight and age into account. An $EI:BMR_{est}$ ratio of 1.35 was found to be representative of long term habitual intake below which sustaining life is considered impossible. This is easy to estimate and practical to use in large surveys. However, a potential problem associated with this method is that weight is a crude indicator of lean body mass.

As nutrients are derived from foods, examination of food intakes indicates the presence of bias in the reporting of certain foods. It has been suggested that certain foods such as fruits and vegetables that are considered healthy are overreported while foods rich in fat that are considered unhealthy are underreported (Goris et al., 2000, Hebert et al., 1997). Evaluation of specific foods associated with underreporting include fat (Goris et al., 2000) and carbohydrate rich snack foods (Poppit et al., 1998, Heitmann and Lissner, 1995). It is possible that other foods are also being underreported. However, there is lack of adequate knowledge of what these foods are. It has been suggested that misreporting the amounts of foods consumed may be due to social desirability bias. One way to reduce social desirability bias is to not indicate the purpose of the study to the subjects. The presence of other persons during the interview may affect reporting of foods due to social desirability. Therefore another way to reduce social desirability bias would be to ensure other family members are not present during the interview (Thompson and Subar, 2001).

The dietary method chosen may also contribute to underreporting. It has been suggested that the process of keeping food records itself possibly leads to undereating (Goris et al., 2000). It is also possible that subjects change their eating habits to make recording easier or deliberately omit recording of certain foods because of embarassment (Macdiarmid and Blundell, 1997). Mertz et al. (1991) reported that food records under-reported energy intake by as much as 700 kilocalories below the energy requirement. In one small study, the food frequency method overestimated energy intake by approximately 700 kilocalories; the 24-h recall method yielded energy intakes that were closest to total energy expenditure for young women (Sawaya et al., 1996). Although the doubly labeled water and other biochemical parameters can be used to examine the presence of underreporting, reducing underreporting and obtaining a true picture of the usual intakes are challenging issues and beg further research.

Examiner errors: The interviewer can be a potential source of error. Interviewers should be trained to avoid making any positive or negative comments about 'good' or 'bad' dietary habits. In the 24-h recall method, the interviewers should have a set of rules to correctly identify, describe, quantify and check all the foods or recipes that may be reported by different subjects in order to avoid any type of error (Slimani et al., 2000).

Estimating portion sizes: Information about foods consumed by subjects have to be converted into information on energy and nutrient intakes. To achieve this, an estimate of the amounts of each food item consumed is required. Measuring aids are generally used to help individuals quantify the amounts of foods eaten. Measuring aids can be either three-dimensional aids (households measures, real food samples and food models) or two-dimensional aids (food photographs, computer graphics, drawings) (Cypel et al., 1997).

Error can be introduced when the respondent fails to estimate portion sizes accurately. Error in portion size estimation could be either random or systematic. In addition to the random error in estimating portion sizes by the respondent, error in the calibration of food models could result in systematic error (Thompson and Byers, 1994).

Considerable research has focussed on estimating portion sizes. Identifying portion size of foods consumed is a complex process. The subject has to relate the amount of food consumed to an amount of food in a 2- or 3- dimensional model and also depend on memory to recollect the amount of food consumed (Cypel et al., 1997). In a study using photographs to determine errors associated with estimating food portion sizes, it was observed that portion sizes for foods like butter and margarine tended to be significantly overestimated (Nelson et al., 1996). In a study where three-dimensional models served as the reference, it was observed that the two- and three- dimensional measurement aids produced similar intake results (Posner et al., 1992) indicating that there appears to be no single best method for estimating portion sizes (Cypel et al., 1997).

Research indicates that providing the respondents with aids can help them recall the amount of foods consumed as the aids help to visualise size, shape and volume. When asked to speak out loud as they recollect the food consumed on the previous day, respondents use visualisation strategy to estimate volume and amounts and use actions such as pouring or moving hands to the mouth. Respondents prefer aids that were similar in size and shape to actual portions of liquid or amorphous foods consumed and prefer the ruler for solid foods (Chambers et al., 2000).

For the upcoming dietary survey to be conducted by the USDA, newly developed food portion aids that include life-size pictures, grids, wedges, circles and several amorphous mounds printed on transparent pages placed over an image of a full-size dinner plate are planned to be used along with cups, spoons and plates to help respondents recall the foods consumed. The models will be used in the multiple-pass technique to provide cues to the respondents to help jog the memory (Moshfegh et al., 2001). It can be seen that estimating portion sizes can be challenging and a number of studies are being conducted to improve on the already available methods to obtain better estimates of intakes.

<u>Nutrient composition tables</u> Assessing food and nutrient intakes in dietary surveys ultimately depends on the food composition tables. Food composition data need to be comprehensive, up-to-date and free of error to reflect dietary intakes of populations (West and van Staveren, 1997, National Research Council, 1986).

Error due to the nutrient database can be either random or systematic. Variability due to soil, fertiliser application and genetic variation, storage and processing can contribute to variability of the nutrient contents of individual foods (National Research Council, 1986, Willett, 1998). The nutrient values obtained are generally averages of several samples of the foods and the error is generally considered to be small (National Research Council, 1986) with the amount of error dependent upon the nutrient. It is generally assumed that the small variations between samples for protein, for example, do not cause serious errors (West and van Staveren, 1997). There is higher variability for minerals found in processed foods, for example, sodium has 21% variability while iodine has been reported to have a variability of 158% and hence not reliable and data of such minerals found in foods should be used with caution (Pennington, 1996).

Systematic error could occur due to incorrect identification of the food item and use of inappropriate analytical methodology (National Research Council, 1986). Incorrect identification of foods leads to biased data even if correct analytical techniques are used. Therefore care should be given to use a correct food nomenclature system to identify foods (National Research Council, 1986). Additionally, for some nutrients, not all chemical forms of the nutrient are measured due to lack of an appropriate analytical method, leading to underreporting (National Research Council, 1986). For example, there are approximately 50 different carotenoids that possess Vitamin A activity. Generally, older databases have values that were obtained by assay techniques that were not adequate to determine all the carotenoids in the foods and therefore there may be an underestimation of vitamin A (Granado et al., 1997, Mangels et al., 1993). Thus, investigators examining the protective effects of carotenoids must be aware of this limitation. If possible, it has been suggested that updated values be incorporated into the database (Granado et al., 1997).

Most databases do not reflect the fortified values for folate in foods. Databases do not account for the synthetic form of folate that is present in fortified flour, grains and breads. Since re-analyzing all foods for folate will be a long and laborious process, studies have assigned values to foods based on levels of fortification recommended by the regulations. For example, United States and Canada stipulate the amount of synthetic folic acid to be added to flour, bread and grain products. Studies have used these values to update the folate values for foods (Lewis et al., 1999). Such methods can at best provide only approximate values.

Sometimes, when nutritional information is not available, a value of zero is assigned to the missing values in some databases and investigators should be aware of this as this could lead to an underestimation of nutrient intakes (Cowin and Emmett, 1999). If missing values have been imputed, it is possible that the imputed value may not be as representative as a properly obtained analytical value; however, it is likely to be much closer to the real value than zero (Smith, 1994).

Nutrient values for cooked dishes in databases are usually adjusted for cooking losses. However, when recipes are incorporated into the database based on raw ingredients, error could occur because of changes in nutrient content due to preparation and heat treatment (West & van Staveren, 1997).

Coding and computation errors: Coding error could arise when food items are incorrectly coded (e.g. if skim milk is coded as whole milk). Sometimes descriptions of the foods in the nutrient data bases may be inadequate making it difficult to match the food consumed with an appropriate food item or brand in the database resulting in an error when an inappropriate food is substituted (Slimani et al., 2000). In this case, if nutrient composition does not match exactly, for example, different levels of low fat yogurts are available and if the nutrient composition for the appropriate level of fat is not used, then there is a possibility of introducing error. Coding errors can be reduced if coding rules are established which could be beneficial when handling inadequate descriptions of foods. When the respondent fails to recollect information of products then default rules can be established but they are less accurate. In a study assessing the use of vitamin and mineral supplements, default values were assigned to nutrients when respondents did not know the amount of nutrients in pills. The default values used were based on the most common responses for the nutrient supplements (eg.vitamin A, vitamin C) from earlier surveys (Subar and Block, 1990a). Duplicate coding of recalls by independent coders or peer review of codes have been commonly used as a measure of quality control for coding (West and van Staveren, 1997).

2.4. Variability

In order to assess the nutritional status of individuals or a group, precise estimates of usual dietary intake are essential (Basiotis et al., 1987). Usual intake refers to long term average daily nutrient intake of an individual (Nusser et al., 1996). In order to measure usual intake an understanding of variability in food intake is needed.

Variability in food intake can be classified into two types, namely, within- or intra- subject variability and between- or inter- subject variability. An individual's food intake is not constant in the types and amounts of food consumed from one day to the next contributing to within- or intra- subject variability (National Research Council,1986). Physical activities, feasting, health conditions, intermittent periods of weight reduction are some reasons that contribute to variability in eating patterns (Beal, 1981). Also, individuals differ from each other in their pattern and amount of food intakes contributing to between- or inter- subject variability (Liu et al., 1978, Marr and Heady, 1986).

A number of studies have addressed the issue of variability in nutrient (Marr and Heady, 1986, Beaton et al, 1979, Beaton et al 1983, Sempos et al, 1985, Nelson et al., 1989, McGee et al., 1982, Neuhaus et al., 1991, Guenther and Kott,1996) and food intakes (Sempos, 1986, Borrelli et al., 1992). When two or more days of dietary intake are available, within- and between- subject variability can be estimated using analysis of variance (Beaton et al., 1979, 1983). These can then be used to calculate the variance ratio, s_w^2/s_b^2, where s_w^2 = within- person variance and s_b^2 = between- person variance (Nelson et al., 1989). Within- subject variability includes day-to-day variability and random error in methodology (Beaton et al., 1979). The ratio is generally above 1.0 (greater within- subject variability than between- subject variability) for most nutrients in studies conducted in North America. The variance ratio depends on the nutrient. For nutrients found in high concentrations in a few foods, for example, vitamin A and cholesterol, the ratio is large (reported range, 1.6 to >100) (Willett, 1998). This is because of the presence of high within- subject variability. For example, on the first day of observation, when the individual had carrots, intakes of vitamin A will be high and when the same subject did not consume any vitamin A containing foods on the second day of observation, his intake of vitamin A will be 0 (Institiute of Medicine, 2001). Conversely, for nutrients from foods consumed everyday in reasonably similar quantities, for example, carbohydrate and fat, the ratios range from 1.2 to 2.0 (National Research Council, 1986, Willett, 1998). When nutrient intakes are expressed as nutrient densities (per 1000 kcals), between- subject variability is reduced; however, within- subject variability is not affected greatly, resulting in higher variability ratios (Beaton et al., 1979). Similar within- to between- subject variability ratios for different nutrients have been reported using 24-hr recalls and food records (Beaton et al., 1979, Beaton et al., 1983, Sempos et al., 1985).

Studies on variability in food intakes are scant (Borelli et al., 1992, Sempos et al., 1986, Hartman et al., 1990). In women who maintained food records for 29 days spread over two years, higher variance ratios were reported for meat (3.2) and bread and cereals food groups (2.5) while milk and fruit and vegetables food groups had lower ratios (1.4 and 1.6 respectively) (Sempos et al., 1986). A ratio of 12.2 was reported for dark green vegetables due to infrequent consumption. Higher variability seen for foods has implications in studies that investigate possible association between food and disease, because more repeated observations are needed.

2.4.1. Factors influencing variability

A number of factors contribute to variability in dietary intakes:

Age: Nelson et al. (1989) reported differences in within- to between- subject variability ratios for different age groups; ratios were lower for most nutrients among toddlers, higher for children (aged 5-17 years) and intermediate for adults. Varying reports of within-/between- subject variability ratios for children have been reported. For example, for energy and macronutrients, lower ratios (range 0.85 to 1.33) were reported among school children, aged 9-12 years (Bellu and Cucco, 1997), whereas in another study among children aged 13-15 years, higher ratios were reported (range 2.2 to 2.7) (Nelson et al., 1989). In the former study, once the between- subject variability was taken into account by examining the ratios based on nutrient densities (per 1000 kcals), an increase in within-/between subject variability ratios were observed (Bellu and Cucco, 1997). Increases in the variability ratios after controlling for differences in intakes between individuals was also observed among adults (Beaton et al., 1979, Beaton et al., 1983).

Sex: Differences in the within- to between- subject ratios have been reported by gender with women reporting higher variability ratios than men which appear to be associated with smaller between- subject variability among females (Beaton et al., 1979, Nelson et al., 1989). Differences in the ratios across gender disappear once the nutrients are expressed in terms of nutrient densities (Beaton et al., 1979).

Day of the week: People tend to alter their eating patterns on weekends compared to weekdays which include changes in the types and amounts of food consumed (Beal, 1981). Many American families traditionally tend to have large meals on Sundays (Willett, 1998). Mean intakes of nutrients are higher on weekends than on weekdays (Tarasuk and Beaton, 1991a, Basiotis et al., 1989), resulting in higher variability in energy and nutrient intakes when comparing weekends and weekdays (Tarasuk and Beaton, 1991a). However, for nutrients like vitamin A where both within- and between- subject variability in daily intakes are large, a weekend effect is not likely to be found.

Season: In developed countries, the effect of season on variability in nutrient intakes is not generally present (van Staveren et al., 1986). In less developed countries without extensive food preservation and transportation facilities, the influence of season on nutrient intake is high (Willett, 1998). Seasonal variations in energy intake due to high within- subject variability have been reported in a study in Bangladesh (Torres et al., 1990). The higher within- subject variability seen could be due to the dependence of the population on seasonal availability of locally produced foods (Nyambose et al., 2002).

Socio-economic status: In developing countries, the link between food intake and income contributes to between- person variability (Willett, 1998). At the same time, rare consumption of expensive foods contributes to within- person variability. For example, consumption of meat once or twice per week by an individual might contribute to higher iron intakes on some days compared to other days thus contributing to within- person variability for this nutrient (Willett, 1998). However, it is also possible that iron contribution in developing countries may come from greens and other plant sources on other days and on the day of meat consumption, meat may replace these sources, thus contributing to variability in the quality (Groff and Gropper, 2000) in addition to quantity within subjects.

Variability ratios are not similar in all developing countries. It was reported that pregnant women had higher variance ratios for energy and carbohydrate (Nyambose et al., 2002), while in another study the ratios were lower (Launer et al., 1991). The reasons attributed to the differences were that in the former study, the population were poor subsistence farmers who depended upon locally produced seasonal foods that contributed to large within- subject variability; in the latter study, the population consumed a limited number of foods which were closely linked to income therefore contributing to greater between- subject person variability (Launer et al., 1991). Similarly, in a study on adults in an Andean community, it was observed that the large variability ratios were mainly due to low between- subject variability, which was attributed to a homogenous diet among the adults (Berti and Leonard, 1998). In two rural areas of India, high between- subject variability was observed for most nutrients (Hebert et al., 2000). However, this could be due to the heterogenity in the sample selected in relation to education and occupation.

Consecutive days of report: When dietary information is collected on consecutive days there is a likelihood of the subjects showing a training effect (Gibson, 1990). Also, less within- person variation on consecutive days has been reported (Freedman et al., 1991) which may be due to the fact that individuals are likely to consume the same food over consecutive days when left-overs are consumed or the same food avoided consecutively (Institute of Medicine, 2001) due to religious fast. However, it has been suggested that in order to maintain homeostatic balance, compensation could likely occur, when overeating on one day is compensated by reduced food intake on the next day or food intake is increased to compensate for lower intake on the previous day (de Castro, 2000). Other studies do not support this effect (Tarasuk and Beaton, 1991a). There may be lack of independence with consecutive days of intake and for practical and analytical purposes, it is generally assumed that consecutive days of intake are not independent and therefore random days are sampled (Institute of Medicine, 2001).

Menstrual Cycle: Patterns associated with menstrual cycle activity have also been reported (Tarasuk and Beaton, 1991b, Gong et al., 1989) with more food consumption and therefore higher energy intake 3-10 days prior to the onset of the menstrual period than after. However, there appear to be differences in the source of macronutrients contributing to the increased energy intake with Dalvit (1981) suggesting carbohydrate and Tarasuk and Beaton (1991b) reporting fat-rich foods being the main contributors.

In summary, dietary data should be collected on randomly selected, non-consecutive days; weekdays and weekends should be adequately represented. Seasonal effect can be taken into account by administering the survey to cover all seasons of the year. Because of differences in the amount of foods consumed by gender and age, nutrient intake should be reported separately by gender and specific age groups.

2.4.2. Effects of variability on dietary methodology

Variability in dietary intake has implications for study design in terms of choosing the appropriate dietary method and number of days needed to measure dietary intake (Beaton et al., 1979).

Number of days of dietary measurement An important question that needs to be addressed at the stage of study design is the number of days of observation needed to obtain dietary estimates that are accurate (Marr and Heady, 1986, Beaton et al., 1979, Nelson et al., 1989). Accuracy has been described in terms of reliably classifying individuals into appropriate categories (Nelson et al., 1989) and in absolute terms so that the intakes of individuals are within specified limits of usual intake (Beaton et al., 1979, Willett, 1998). The number of days required increase with higher degree of precision required (Nelson et al., 1989, Willett, 1998).

Implications of the effects of variability in interpretation of dietary data The presence of within- subject variability may mask correlation or bias regression toward zero thus resulting in concluding that there is no evidence of a relationship (Liu et al., 1978, Beaton et al., 1979). With knowledge of variability in dietary intake the estimates can be improved by applying a de-attenuating factor (Willett, 1998). For example, if the correlation between two variables measured for 4 days was found to be 0.29, then a correction factor can be applied by obtaining estimates of within and between subject variability. A higher correlation value can be obtained whereby the correction factor results in a de-attenuating effect.

Additionally, information on variability is essential in the interpretation stage for assessing the prevalence of inadequate intakes. Assessing the proportion of population that is at risk of inadequate intakes is an important public health concern (Institute of Medicine, 2001).

Statistical methods such as the National Research Council (NRC) method and the Iowa State University method (ISU) have been proposed to adjust intake distributions that will remove day-to-day variability in intakes and reflect only the between subject variability in intakes (National Research Council, 1986, Institute Of Medicine, 2001, Nusser et al., 1996). Not removing the day-to-day variability in intakes will produce biased estimates of prevalence of inadequacy (Institute Of Medicine, 2001). Once data have been adjusted, the intakes can be compared with the Estimated Average requirement using the EAR cut-point method to estimate prevalence of inadequate intakes (Institute Of Medicine, 2001).

2.5. Dietary intakes of population sub-groups

Evidence suggests that in addition to age, gender and heredity, some of the determinants of health are income, education, lifestyle factors (e.g. smoking) and culture (Health Canada, 1999a). Those with lower income and educational levels, for example, are more likely to suffer more illnesses and mortality compared to those with higher income and educational levels (Health Canada, 1999a). Unhealthy lifestyle practices, lack of dietary knowledge and poor dietary choices are likely to increase the risk of developing chronic disease.

One of the purposes of dietary surveys is to identify population sub-groups that may be at risk of nutritional deficiencies. Some of these sub-groups include smokers, those belonging to the lower socio-economic groups and certain ethnic and racial groups.

<u>Smokers</u>

Smoking is a major cause of preventable diseases and mortality. Studies have consistently indicated that dietary patterns are different between smokers and non-smokers (Dallongville et al., 1998, Subar et al., 1990b, Bolton-Smith et al., 1991) which may contribute to different risks for chronic diseases by smoking status. Also, in houses where one of the partners smokes, evidence indicates that the dietary pattern of the non-smoking spouse is similar to that of the smoker, thereby increasing the risk for chronic disease in the non-smoking spouse (Osler, 1998).

Smokers have a higher risk for developing cardiovascular disease, respiratory disease and cancer compared to the non-smokers (Diana, 1993) due to the effects of components of cigarette smoke, lipoprotein metabolism and lipid peroxidation (Dallongville et al., 1998). Smokers have also been reported to consume higher amounts of saturated fats and lower amounts of vitamin C, folate, fiber, vitamin A and iron compared to the non-smokers (Subar et al., 1990b, Subar and Harlan, 1993, Thompson et al., 1993). Smokers are less likely to choose whole grain breads, cereals and fruits and vegetables than the non-smokers (Margetts et al., 1993, Larkins et al., 1990). Thus the poor dietary choices made by the smokers in addition to exposure to the oxidative components of cigarette smoke increase the risk for chronic disease, indicating the need to control for diet while examining smoking-disease relationships.

Socioeconomic status

Socioeconomic status can be described in several ways. Generally, educational, occupational and income levels have been used to characterize socioeconomic groups. In Canada, there are indications that those belonging to the low socio-economic group have an increased likelihood for developing diabetes, anaemia and cardiovascular disease (Health Canada, 1999a).

Differences in food and nutrient intake by socio-economic status have been reported. In the first Nutrition Canada Survey (1970-1972), differences in nutrient intake by income level were reported for women and not for men. Women from higher income groups reported higher mean intakes of energy, protein and calcium (Myers and Kroetsch, 1978). Other studies have shown that subjects from lower socioeconomic levels reported less healthy eating patterns, consuming smaller amounts of fish and vegetables but more potatoes, fried foods and sugar compared to those from higher income and education levels (Galobardes et al., 2001, Roos et al., 1996). This pattern contributed to higher intakes of fat and saturated fat and lower intakes of fiber, vitamin A, vitamin C, calcium, iron and folate.

Persons from low income households and those with less education are more likely to underreport energy intakes than other groups (Hill and Davies, 2001). Price et al. (1997) reported that socio-economic characteristics including low education and occupation levels were associated with underreporting among women and not men. In the Whitehall II survey, subjects from lower employment grades reported lower energy intakes compared to those in the higher employment grades as estimated by comparing energy intake with energy expenditure based on basal metabolic rate (Stallone et al., 1997). Under-reporting could be associated with higher body weight which appears to be a problem among those from lower socio-economic class (Basiotis et al., 2002, Health Canada, 1999a), necessitating the need to control for socio-economic status in studies investigating the role of diet and obesity.

Ethnicity

Dietary patterns are usually influenced by one's cultural and religious practices (Shatenstein and Ghadirian, 1998). Furthermore, certain demographic factors including age, gender, income, profession, education, duration of residence in the new country influence lifestyle factors including diet that ultimately determine health (Shatenstein and Ghadirian, 1998, Kumaniyaka and Krebs-Smith, 2001).

Ethnicity appears to play a role in a number of diseases. High levels of obesity, diabetes and cardiovascular diseases have been reported among ethnic minority groups and immigrant populations (Landman and Cruickshank, 2001). A major unresolved issue in the study of ethnicity and disease is whether the association between ethnicity and disease is due to genetic or environmental factors. At best it can be said that the association could be due to the combination of both factors. Among environmental factors, diet may play a role in these diseases.

In the United States, African Americans report low intakes of fiber, folate, grains, fruit and vegetables and high intakes of meat and cholesterol which is consistent with the fact that this group tends to have less favorable cardiovascular and cancer mortality rates (Kumaniyaka and Krebs-Smith, 2001). Intakes below the recommendations for calcium, folate, zinc, and iron have been reported among Mexican American women of low socio-economic status (Ballew and Sugerman, 1995). In a study comparing dietary intakes of immigrants and non-immigrants in Ontario, immigrants reported lower intakes of fat while calcium and iron intakes were low particularly for those from Asian countries (Pomerleau et al., 1998 a, b).

Most studies examining diet in various ethnic groups, use broad classifications to describe the groups; whereas the groups within themselves maybe highly diverse and with different dietary practices (Kumaniyaka and Krebs-Smith, 2001). Because of the heterogeneous nature of the ethnic groups the sample size for each group in the survey is small and the estimates are therefore less precise (Kumaniyaka and Krebs-Smith, 2001), indicating that adequate information from a general survey cannot be obtained for specific sub-group populations. More targeted studies are needed for identifying nutritional imbalances by ethnicity sub-groups.

Although, a general population survey can provide some direction related to nutritional issues, better interpretable data can be obtained by studies targeting specific groups. For example, while the National Health and Nutrition examination surveys (NHANES) provided extensive information about the health and nutrition information of the general U.S. population, comparable data were not available for any of the ethnic groups within the United States (National Centre for Health Statistics, 2002). This led to the development of the Hispanic Health and Nutrition Examination survey specifically targeting Mexican Americans, Cubans and Puerto Ricans.

In summary, successful health and nutrition intervention strategies need an understanding of behaviors that vary by socioeconomic conditions, ethnicity/race and lifestyle characteristics. To develop programs and interventions adequate knowledge of what the people are consuming in terms of nutrients and food groups are needed for which well conducted studies are essential.

Chapter 3

Methods

3.1. Survey Design

The Food Habits of Canadians Survey conducted between September 1997 to August 1998 was a cross-sectional survey conducted to identify nutrient intake and food consumption patterns of a random sample of adults. A multi-stage random sample design was used to select the sample. The survey was conducted across all seasons and interviews conducted on all days of the week. Approximately one-third of the respondents were re-interviewed to estimate within- subject variability.

3.1.1. Target Population

The target population for the survey was non-institutionalized adult men and women, aged between 18 and 65 years living across Canada. Although not part of the current thesis research, adolescents aged 13 to 17 years were also enrolled in the survey. In households, where the adult respondent indicated the presence of one or more adolescents, request was made to ascertain if their children would be willing to participate in the survey.

Approximately 15% of the Canadian population was not sampled because of inaccessibility and increased cost associated with travel to more remote locations. Subjects living in institutions were also not sampled.

Pregnant and lactating women were not included in the study because of distinct physiological conditions and special nutritional requirements that are different from the general population and also because of the likelihood of a small sample responding to the survey unless special sampling techniques were used to oversample this group. Children and those over 65 years were also excluded from the study. Those who did not speak English or French were not included unless an interpreter was available in the household.

3.1.2. Sample Size

Sample size was estimated using the formula, $N = (4z_\alpha^2 S^2) \div (W^2)$, where z_α^2 = the standard normal deviate, 1.96, S = standard deviation of the variable, W = desired total width (Browner et al., 1988).

The sample size required was calculated using standard errors published by the Santé Quebec nutrition survey (per 1000 kilocalories of protein, iron and zinc). For example, the mean intake of protein (per 1000 kilocalories) for men was 40.1g with a standard deviation of 35. Using the above formula, with a 95% confidence interval and a total width of 10%, a sample size of 130 was derived. The sample size required was approximately 120 to 200 for each age and sex group for the selected nutrients. It was therefore decided that approximately 200 subjects per age and sex group would be needed, yielding a total of 1600 subjects.

3.1.3. Sampling Procedure

A multi-stage random sampling technique was used. Canada was divided into five regions, namely, the Atlantic Provinces (New Brunswick, Nova Scotia, Prince Edward Islands, Newfoundland), Quebec, Ontario, Prairies (Manitoba, Saskatchewan, Alberta) and British Columbia. From each region, four census divisions were randomly chosen with a probability of selection being proportional to the population of each division. This provided twenty census divisions[1] across the country. From each of the census divisions, two census sub-divisions[2] were selected, the probability of selection being proportional to the population. This yielded forty sub-divisions across the country. For each of the sub-divisions, two enumeration areas (EA)[3] were randomly selected with probability of selection being proportional to the population, creating eighty enumeration areas across the country. The 1991 census data were used for the sampling, as it was the most recent census containing the data at the start of the study.

Households were then randomly selected from each of the enumeration areas. This was done using the most recent telephone directory that was available on CD-ROM (Pro- CD, 1996). The computerised telephone list provided the names and full street addresses for those with listed telephone numbers. The Pro-CD list could not indicate whether the households fell within the selected EAs. Therefore, street index lists and maps were used in the urban and rural areas respectively to

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[1] Census Division (CD) refers to the general term applied to geographical areas established by provinical law, which are intermediate between Census Subdivisions and the province (eg. Divisions, counties, regional districts, regular municipalities)

[2] Census Sub-Division refers to the general term applied to municipalities (as determined by provincial legislation) or their equivalent. In Newfoundland, Nova Scotia and British Columbia, the term refers to geographic areas that have been created by Statistics Canada in cooperation with the provinces as equivalents to municipalities.

[3] Enumeration Area (EA) is a geographical area canvassed by the census representative. EAs are to be as compact as possible to minimize travel and optimize census representative work. EAs are delineated so that census representatives may locate them with as little difficulty as possible. Therefore, whenever possible, EAs follow easily recognizable physical features such as the road network and rivers. The number of dwellings in an EA generally varies between 375 dwellings in large urban areas to a minimum of 125 in rural areas. It is the smallest geographical unit for which census data are usually available.

ensure that the households fell into the selected EA. In some places where there were no house numbers as in some rural areas, interviewers called the house to secure the mailing address. All addresses that fell within the boundaries of the selected EAs were first chosen. Then the list was checked for household and business addresses. Business numbers were eliminated. If there was more than one number for the same address, then only the first number was chosen. If there were more than three numbers then it was assumed that the numbers belonged to an apartment building. From the list, two hundred households were randomly selected in order to assure an adequate number of households. A letter describing the purpose of the study with a request for participation of the household was sent (**Appendix 1**).

The dietitian-interviewer then contacted the households by telephone to recruit subjects. The interviewer attempted to enrol one adult per household to reach a total of twenty adult respondents from each enumeration area. Subjects were randomly selected within a household by requesting the person with the next closest birthday to participate in the study. A total of six telephone calls was made at different times on weekdays and weekends in order to contact the subjects. Each interviewer completed a log documenting the different times of the day and days of the week telephone calls were made to each respondent (**Appendix 2**). Records of those who agreed to participate, refused, not reached, ineligible or unavailable were maintained. At least six attempts were to be made before the household was classified as not reached. Reasons for ineligibility due to age, pregnancy, lactation or language were also recorded. Records of returned letters and telephone numbers with messages that indicated that the number was not in service were maintained. These were coded as having moved and not considered part of the survey.

A repeat interview was conducted on 29% of the adult sample in order to estimate within- subject variability. A systematic random sampling technique was used for this purpose whereby the second person initially interviewed and every third person thereafter was selected.

3.1.4. Ethics

Ethics Approval was obtained from the Ethics Committee of McGill University (**Appendix 3**)

3.1.5. Data Collection

Socio-demographic and dietary data were obtained by the dietitian during a face-to-face interview with the respondent. The interview averaged thirty minutes. Appointments for interviews were made on different days of the week, including weekends, to ensure that all days of the week were represented. Interviews were held in the respondents' home or at another convenient location.

Socio-demographic data were collected by means of a questionnaire (**Appendix 4**). Information on age, gender, place of birth, marital status, education, smoking status, height, weight and number of household members was obtained.

Dietary information was collected using the 24-hour recall method (**Appendix 5**). Detailed descriptions of all foods, beverages and supplements consumed during the 24-hour period before the interview including the quantity, cooking method and brand names were recorded (Thompson and Byers, 1994). Food models including a plate, graduated cup, two bowls, spoons and a ruler were used to assist in the description of foods (**Appendix 6**). A multiple-pass 24-hour technique was used which had a number of cues to help the respondents recall their food intakes (Johnson et al., 1996). The subjects were first asked to recall their food intake over the previous 24-hour period, followed by probing for detailed descriptions of foods, beverages and supplements including foods portion sizes and brand names and methods of cooking and then by a review of intake and clarifications (Johnson et al., 1996).

Supplement composition was determined using the Health Canada Drug Product Database (Health Canada, 2000), product labels or by contacting the company. When adequate information was not available to identify brand or amount of nutrient present in the supplement, default values were assigned based on the mode reported for the supplement.

3.1.6. Nutrient analyses

Candat nutrient analysis program was used for the analyses of the 24-hour recalls. Candat used the 1997 Canadian Nutrient File (Health Canada, 1997) that was the most recent at the start of the survey. Candat consists of a Master and an Institute File. The Master File has data for 4668 foods from the Canadian Nutrient File. Foods that were not on the Master file were added to the Institute file which allows entry of food data from other sources. Approximately 270 food items were added to the institute file. Nutritional information for these foods were obtained from the USDA database, recipes (where separate ingredients were summed) or from the food manufacturer when possible.

For foods consumed as mixtures of individual foods, the database had pre-defined options. For example, when the respondent reported having consumed pizza with pepperoni, the option available on Candat was chosen. When adequate descriptions of each food ingredient in a food mixture were available on the recall form, each of the food items was entered separately. If little or no specific information was provided then a default food was used. For example for spaghetti and tomato sauce, if information on amounts of each were provided, these were entered. However, if no information on relative amounts was provided then the default choice in the program was used. Sometimes, an appropriate choice was not available. For example, for prepared pudding, options that were available included pudding prepared with whole milk and 2 per cent milk. Therefore, when the subject reported consuming a low calorie pudding prepared with skim milk, then a perfect match was not possible. In this case, a new food code and appropriate nutritional information were entered in the Institute File. For foods that were new and did not exist in the database, information was obtained from the nutrition label, and, when possible from the manufacturer. Low fat frozen dinners, for example, fell into this category.

When the survey was initiated, fortification with folate was not mandatory; therefore the nutrient database does not reflect the fortified values for folate. The

Canadian Nutrient File does not provide complete data for vitamins D and E and consequently these were not analyzed. Similarly, information on all forms of carotenoids is not available.

To examine food choices, foods that were similar were grouped together. Fruits were classified as citrus and non-citrus based on differences in vitamin C content; dairy products were grouped as milk, cheese, yogurt, ice-cream/pudding (Ritter, 2000). To investigate food choices according to the recommendations based on Canadian Food Guide to Healthy Eating (Health and Welfare Canada, 1992), foods were categorized into the four food groups, including grains, dairy, meat and fruit and vegetables. Foods that were not included in any of the above food groups were categorized as the 'other' food group (e.g. chips, soft drinks). Food portions were determined using food density (g/ml) and all foods with similar densities within a category were divided by the same weight of a standard portion size (eg. cooked rice or pasta=70g in the grain products food group). The Good Health Eating Guide Resource (Canadian Diabetes Association, 1996) was also used to determine standard weights for some foods, particularly for mixed foods to determine how many portions of each food group went into each of the mixed foods.

3.2. Quality Control

3.2.1. Interviewer training

Registered dietitians residing in the five regions were selected to obtain dietary information from the subjects. The dietitian-interviewer was responsible for recruiting the subjects by establishing contact through telephone and obtaining dietary and socio-demographic data. Selecting dietitians from local regions had several advantages in terms of cost and time. The interviewers could travel easily to the selected areas and conduct the interviews with the subjects. Also, they were familiar with locally available foods.

The interviewers were given an intensive two-day training session in Montreal. The purpose of the training was to ensure uniformity in data collection, including consistency in interviewing techniques and obtaining accurate recording of food intakes. The objectives of the survey were explained to the interviewers. Procedures for making telephone calls, including maintaining logs of the phone calls made and responses obtained, were taught. Training sessions for conducting dietary interviews and use of food models were also held. Emphasis was placed on getting a complete description of the foods consumed including type of cooking and brand names of foods. Mock interviews were conducted and feedback was given to the interviewers on how to modify their techniques. Neutral probing techniques were encouraged. A session on data entry was also held to enable the dietitians to understand the level of detail they needed to collect for each food and how the foods from the 24-hour recalls would be analyzed.

3.2.2. Data Entry

Foods from the 24-hour recalls were entered into the Candat nutrient analysis program. Prior to the start of the data entry, guidelines for methods of data entry and portion size calculations were established to ensure uniformity of data entry for all recalls. Bimonthly sessions were held among the data entry personnel and the project coordinator to decide on the standard procedures to be used. These sessions helped to clarify certain questions regarding appropriate food choices to be made particularly for those foods that were not on the database and for new foods that had entered the market since the creation of the nutrient program. Records were kept of food coding questions and answers. A decision was made on whether a similar food in the database was to be used, or whether the USDA database was to be checked for dietary information, or whether the manufacturer or fast food chain or restaurant was to be contacted or whether a recipe was to be found. For manufactured food items, information on the label such as ingredients, nutritional information and weight were used. For foods from fast food chains, information for most foods were available on the internet or by contacting the head office. Before making the decision, such questions as how does the reported food compare with the description of foods that are already available, would the use of a food already on the database reflect the nutritive value of the new food, how much of the food was consumed and was it a major part of the diet were taken into consideration (Ingerwersen et al., 1996). The answer arrived at was entered in the records and the data entry personnel used these to code the foods to ensure consistency.

Quality control of data entry was accomplished by double verification of all 24-hour recalls entered; the first verification was done by the individual entering the recall and the second verification was done by a peer who was also trained in data entry. Initially, all data were stored in individual files in the Candat program. This allowed records to be reviewed, edited and corrected. After all foods were entered, a primary validation was conducted using the Candat program, which indicated an invalid unit if present. Corrections were then made. The contents of every individual file were printed and crosschecked with the original 24-hour recall form by the person who entered the recall. This was done to ensure that correct foods and quantities were entered. If errors were detected, these were corrected. The next step involved a second verification by another data entry person. Any errors detected were modified. After final correction, information in individual files was combined into a single file and imported into a database. Data cleaning was then done where extreme intakes of nutrients and foods were checked. Thus at each step from data entry to data use, checks were made to ensure the quality of the data.

3.3. Thesis Research Methodology

3.3.1. Response Rate

The response rate for each enumeration area was calculated using the following formula:

$$\text{Response rate} = \frac{I}{I+NC+UN+R}$$

(Groves and Lyberg, 1988)

where *I = completed interviews*

NC= not contacted but possible eligible units

UN=unanswered numbers

R= refused eligible units

Socio-demographic characteristics of the sample data were compared with the 1991 census data to examine if those who responded were representative of the general population. Similarly, the census data were examined to determine the correlates of response rates for the selected enumeration areas.

Description of the census data

The 1991 census data are available on CD-ROM and provide extensive information on geographic and socio-demographic variables (Census 1991, CD-ROM, Statistics Canada). Data for each enumeration area, census sub-division, census division and province are available in two files. The first file has census data on total population and includes such information as number of males, females, age, mother -tongue, number of persons in the households, composition of family (husband-wife families, lone parent families), and house ownership. The second file has information collected on a sample of 20% of the total population and includes information on place of birth, stability in terms of living at the same address for $<$ or $\geq$ 5 years, education level, unemployment rate, mean household income and percentage below low income cut-off[4]. For some variables (for example, percentage below the low income cut-off) some enumeration areas had zero values, indicating that information was not available for the enumeration

[4] Low Income Cut-off (LICO) represents income levels at which families spend disproportionate amounts of their income for food, selter and clothing (Canadian Institute for Health Information, 1999). LICOs are set at 20% above the average income levels spent on the basic necessities and takes family size and degree of urbanization into account (Statistics Canada, 2001).

area due to confidentiality purpose and hence was not included in the analyses for the study.

From the above data, percentage of males and females aged 18 to 64 years (18-34, 35-49, 50-64 years); percentage in different categories of marital status; percentage speaking official and non-official languages as mother-tongue; percentage with own house and rented house; percentage households with one, two, and more than 3 persons per household; percentage husband-wife families and single parent families; percentage in the same residence for the past 5 years; percentage with different levels of education; percentage reporting Canada as place of birth were calculated.

<u>Comparison of survey respondents with the census data</u>

In order to determine whether those who responded to the survey were representative of the general population of the country, the survey data and the 1991 census data were compared on several demographic variables including gender (% males and females), age (% males and females belonging to 18-34y, 35-49y and 50-65y), civil status (% single, married, divorced/separated, widowed), education level (% ≤ high school education, CEGEP/Trade, University), number of household members (% 1 to more than 6 person households) and country of birth (% reporting Canada as place of birth). For example, the percentage of males and females in the age groups, 18-34, 35-49 and 50-65 years in the survey sample were compared with the percentage of persons in the appropriate age and sex categories in the census data. Similarly, smoking status and body mass index of the study sample were compared with figures obtained in the national surveys (National Population Health Survey, 1995, Health Canada, 1999b).

<u>Examination of characteristics of the selected enumeration areas</u>

The census data were examined to study the characteristics of the selected enumeration areas in order to answer the question why certain enumeration areas had better response rates than other areas. Variables that were considered included % males, age (% 18-34y), marital status (% married), education (% less than or equal to high school education), percentage below the low income cut-off level, mother-tongue (% speaking non-official languages), number of household members (% > 3 persons), country of birth (% Canada as place of birth), house ownership (% ownership), place of residence (% moved in the past 5 years) and urban-rural category.

Pearson's correlation was performed to examine the correlation between variables (Bland, 1996) including response rate, % males, % 18-34y, % married, % less than or equal to high school education, % below the low income cut-off, % non-official languages as mother-tongue, % households with more than 3 members, % Canada as place of birth, % house ownership and % moved within the last 5 years. Simple linear regression analyses were performed to examine the relationship between the response rate and each of the independent variables (Bland, 1996). Multiple regression analyses were performed to determine the correlates of response rate (Kleinbaum et al., 1988). An appropriate model was selected using the automated stepwise selection procedure (Kleinbaum et al., 1988). An all subset regression based on adjusted R^2 and Akaike Information Criterion (AIC) was run on the variables selected by the stepwise regression and the best model with a high adjusted R^2 and a low AIC value was chosen. Multiple regression analysis was conducted for the final model selected.

3.3.2. Variability in food and nutrient intakes

Estimation of within- to between- subject variability ratios

Data were analyzed separately for males and females to quantify the components of variance, namely, within- and between- subject variability. As a first step, the distribution of each nutrient was examined for normality. A mixed model procedure that computes residuals was performed and normality of the residuals was examined (Littell, 1996). If the distribution was found not to be normal, then appropriate transformations were performed (log or square root) and the process repeated. The best fitting distribution was then selected.

Within- and between- subject variability were estimated by the mixed model procedure for males and females in two ways; one that was unadjusted and the other adjusted for gender, age, education, smoking, season and size of family. The above analyses were performed using both untransformed and transformed data but since similar ratios were obtained for all nutrients, the results for untransformed data are reported. Mixed model procedure allows the use of data for subjects with either one or two days of intake; data from both days of intake were used for estimating within- subject variability while one day's intake were used for estimating between subject variability. Similar procedures were used for determining within- to between- subject variability ratios for foods and food groups.

Estimation of number of days to measure usual intake

The number of days required to estimate usual intakes of foods and nutrients at various levels of reliability was estimated separately for males and females. Within- and between- subject variances obtained by the mixed model procedure that adjusted for several factors were used to determine the number of days. Two different methods were used for this purpose.

Method 1: Both within- and between- subject variances were used to obtain an estimation of the number of days required to obtain good correlation between observed and true intakes and was obtained by the formula:

$$d = \frac{r^2}{1-r^2} \times \frac{s_w^2}{s_b^2}$$

where, d is the number of days, r represents the unobservable correlation between observed and true mean nutrient intakes of subjects, and, s_w^2/s_b^2 is the within-/between- subject variance ratio (Nelson et al., 1989).

Method 2: Only the within- subject variability was used in this method. The number of days of observation needed to assess actual intakes of individuals with a given level of confidence was calculated as follows:

$d = (Z_\alpha\ CV_0/\ D_0)^2$ where, d = number of days needed per person, Z_α = normal deviate e.g. 1.96, CV_0 = within- subject variation, calculated as square root of within-subject variance (or standard deviation)/ mean intake, D_0 = specified limit as percentage of long term intake (Beaton et al., 1979). Using this calculation, the number of days needed for the observed estimate of a person's intake to lie within a specified percentage of the true mean, 95% of the time can be obtained (Willett, 1998).

Nutrients examined in the analyses included the macronutrients, fat, protein, and carbohydrate, and the micronutrients, calcium, iron, folate, and vitamin C. Foods including meat, vegetables, fruits (including juice), green leafy vegetables (lettuce/spinach/cabbage), milk and bread were examined as were the four food groups based on Canada's Food Guide to Healthy Eating (Health and Welfare Canada, 1992).

3.3.3. Examination of nutrient intakes in sub-populations

In order to investigate whether certain subgroups had low quality diets, smokers and non-smokers were compared in terms of nutrient intakes; major foods contributing to the nutrient intakes were also examined to assess if food choices differed by smoking status.

Nothing is known about variability in nutrient intakes of smokers. The day-to-day variability of those who smoked and did not smoke was examined by computing within- to between- subject variability ratios for energy, calcium (mg), folate (μg), vitamin C (mg), zinc (mg) and iron (mg).

Several steps were involved in determining the components of variability. The distribution of nutrients was examined for normality and appropriate transformations performed for nutrients that were skewed (National Research Council, 1986). Within- and between- subject variability components were obtained using the nested model of analysis of variance[5]. For this purpose, the subset with two days of dietary intake was used (Institute of Medicine, 2001, Nusser et al., 1996).

A typical analysis of variance yields variances attributable to the model and the error (Bland, 1996). These values were used to estimate between- subject and observed standard deviations.

$$\text{V(subject)} = \frac{\text{MSE (model)-MSE(error)}}{\text{Number of days (eg.2)}} \qquad \text{(i) (NRC, 1986)}$$

Standard deviation of between- subject variance can be obtained as square root of the above and is represented by,

SD (between-) = square root [V(Subject)] (ii) (NRC, 1986)

$$\text{SD(observed)} = \sqrt{\frac{[\text{V(subject)} + \text{V(error)}]}{\text{Number of days (eg. 2)}}} \qquad \text{(iii) (NRC, 1986)}$$

Difference between each person's intake and the mean intake of the group was then calculated. This difference was then multiplied by the ratio of between-

[5] The nested model procedure was used and published prior to the mixed model procedure that was used subsequently for the paper on variability. The mixed model procedure is a new tool and is now being widely used in statistical analyses.

subject variation to the total variation and then added back to the mean intake of the group (NRC, 1986, IOM, 2001) and is given by the formula:

Adjusted intake =

$$\text{(observed intake} - \text{mean intake)} \times \frac{\text{SD (interindividual)}}{\text{SD (observed)}} + \text{mean intake}$$

(NRC, 1986)

These adjusted intakes were then transformed to the original scale and used for further analyses. This process provides a distribution with reduced variability. An advantage with this method is that the values obtained for the sub-group with two days intake can be applied for the whole group.

The adjusted data were then used to estimate the prevalence of inadequate intakes by using the Estimated Average Requirement (EAR) cut-off method (Institute Of Medicine, 2001). The proportion not meeting the requirements for folate, vitamin C, iron and zinc were examined by comparing the adjusted intakes with the Estimated Average Requirements (Institute Of Medicine, 2000 a, Institute Of Medicine, 2000b, Institute Of Medicine, 2002a, Institute of Medicine, 2002b) for each of the nutrients by smoking status for males and females. All the above analyses controlled for education, an indicator of socio-economic status.

As underreporting has been a problem in most surveys, underreporting was assessed by calculating the ratio of energy intake to estimated basal metabolic rate (EI/BMR_{est}), for males and females by smoking status. BMR was calculated using the FAO/WHO/UNU formula (1985). An EI/BMRest ratio of 1.35 was considered to be the cut-off level as values below this was considered not possible to sustain life (Goldberg et al., 1991).

All the above analyses were performed using SAS (version 6.12, Cary, NC).

Chapter 4

Low response rates in low income areas: Food Habits of Canadians Survey

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In preparation

Running head: Correlates of response rate

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Abstract

Background: Declining response rates are a matter of concern in dietary surveys. Although studies have examined socio-demographic characteristics of the study sample and have compared respondents and non-respondents on a number of variables, no study has examined community characteristics to determine what characteristics of the selected regions are associated with response rates. The objectives of the present study were to estimate the response rate by sampling area and to examine the characteristics of the selected areas to determine the correlates of better response rates.

Methods: Enumeration areas (n=80) were randomly selected from across Canada using a multi-stage random sampling strategy. Non-institutionalised adults aged 18-65 years (n=1543) from these areas were contacted by telephone. Data from the 1991 census database were examined to determine the correlates of response rates by the characteristics of the selected enumeration areas.

Results: The overall response rate was 26% with a range from 4% to 57% for the selected areas. Examination of the survey data indicated that males, younger adults (18-34y), single persons and those with lower education were underrepresented in the study. Evaluation of the characteristics of the selected enumeration areas indicated that stability of place of residence, official languages as the mother-tongue, lower percentage of those below the low income cut-off levels and higher percentage of females in enumeration areas, were factors that characterised better response rates.

Conclusion: These differences indicate that approaches optimizing response rates may vary by community characteristics.

Key words: response rate, enumeration, characteristics

Dietary surveys provide information on food and nutrient intakes of the population and can be used to determine nutritional adequacy of the different population sub-groups, identify nutritionally disadvantaged groups and evaluate diet-disease risks.[1,2] For these purposes it is important to obtain information from a representative sample of the population through a representative sampling frame and good response rates. Studies indicate that response rates to dietary surveys are declining.[3,4] Low response rates raise the concern that the information obtained from those who respond may not be representative of the general population. Those who respond may be considered 'health conscious' or labeled as the 'worried well'[5] thus resulting in bias[6]. It is thus important to evaluate factors associated with non-response in order to assess possible consequences on survey estimates[6] and develop more suitable strategies where needed. Few studies have examined factors associated with response to surveys. [2,3,7,8]

The objectives of this study are to estimate the response rates by sampling area in the Food Habits of Canadians Survey and to document their association with the community characteristics of these areas.

Methods

Study Description

Data for this analysis are from the Food Habits of Canadians Study (1997-98), a national survey of non-institutionalized adults (n=1543) aged 18-65 years.[9,10,11] The sample was randomly selected from within five regions in Canada, including the Atlantic Provinces, Quebec, Ontario, the Prairie Provinces and British Columbia using a multi-stage random sampling strategy.[9] Fifteen per cent of the

Canadian population who lived in more remote regions were not sampled owing to cost considerations. In each region, four census divisions were randomly selected with the probability of selection being proportional to the size of the population yielding 20 census divisions across the country. Two subdivisions were randomly selected within each census division, and two enumeration areas were selected within each subdivision, yielding 80 enumeration areas. Within each enumeration area, a random sample of households was drawn from the 1996 computerized telephone listings of each area (Pro-CD Inc., Mass.). Letters were mailed to inform household occupants of the survey, and one adult member (the person with the next birthday) was invited to participate. A dietitian-interviewer then telephoned each household to arrange a face-to-face interview. Six attempts were made by telephone to reach the household. Pregnant and lactating women and those who did not speak English or French were excluded.

Response Rate Calculation

The response rate for each enumeration area was calculated as,

Response Rate = I/(I+NC+UN+NI+R) [12]

where, I = interviewed, NC= not contacted, but possible eligible units, UN=unanswered numbers, NI = non-interviewed numbers and R= refused eligible units.

Since we had excluded those who did not speak English or French and those who were not in town during the survey period, the above formula was modified as,

Response rate = I/(I+NC+UN+R)

Here the denominator included all subjects for whom an interview could have been completed. Those not contacted include households where less than 6 attempts were made to establish contact with a household member. The unanswered numbers include those numbers for whom the required 6 attempts were made.

Characteristics of study sample compared to Census data

In order to examine the representativeness of the study sample to the general Canadian population, the survey data were compared with the 1991 census data (Census 1991, CD-ROM, Statistics Canada) on a number of demographic variables including percentage of males and females belonging to different age categories (18-34y, 35-49y, 50-65y), country of birth (proportion of subjects reporting Canada as place of birth), marital status (percentage reporting being single, married, divorced/separated, widowed), education level (percentage with less than or equal to high school education, CEGEP/Trade, university degree) and number of household members (one to more than 6 person households).

Response rates by the characteristics of the selected Enumeration Areas

In order to determine the correlates of response rates by the characteristics of the selected enumeration areas, data from the 1991 Census database (Census 1991, CD-ROM, Statistics Canada) were examined for a number of variables, including gender (% males), age (18-34y, 35-49y and 50-64y), marital status (single, married, divorced/separated, widowed), education level (less than or equal to high school education, trade/CEGEP, university degree), percentage below the low income cut-off, mother-tongue (official vs non-official languages), number of household members (1 to > 6), composition of family (single vs two parent family), country of birth (Canada vs elsewhere), house ownership (yes/no), moved within last 5 years (yes/no) and urban-rural category. A total of 63 enumeration areas were considered for the analyses as Statistics Canada assigned a zero value for percentage below the low income cut-off for some enumeration areas that had less than 250 persons for confidentiality reasons.

Statistical Analyses

The response rate for each enumeration area was the dependent variable. Independent variables included the enumeration area characteristics as listed above.

Pearson's correlation was performed to examine the correlation between variables[13] including response rate, males, % 18-34y, % married, % less than or equal to high school education, % below the low income cut-off, % non-official languages as mother-tongue, % households with more than 3 members, % Canada as place of birth, % house ownership and % moved residence within the last 5 years.

Multiple regression analyses were performed to determine the correlates of response rate. An appropriate model was selected using the automated stepwise selection procedure[14]. An all subset regression model based on adjusted R^2 Akaike information Criterion (AIC) was run on the variables selected by the stepwise regression and the best model with a high adjusted R^2 and a low AIC value was chosen. Multi-collinearity test was also conducted with the independent variables to ensure that highly correlated variables were not selected. Variance Inflation Factor of >3 and Var Prop ≥ 0.7 were used as indicators of collinearity problems. Multiple regression analysis was conducted for the final model selected. All analyses were performed using SAS (version 6.12, 1996, Cary, NC).

Results

Response rate

The mean response rate as defined previously for the eighty enumeration areas (EAs) was 26% with a range by EA from 4% to 57%. The refusal rate was 57 per cent. Many refusals were due to abrupt termination of the telephone contact, giving no chance for the interviewer to explain the study. The non-contact rate was 17%, indicating difficulty in locating the respondents.

Comparison of the study sample with the census data

Comparison of survey data with the Census 1991 data **(Table 1)** indicated that males, younger adults (18-34 y), single persons and those with lower education were under-represented in the study.

Correlates of response rate

Examination of the data from the 1991 Census database for investigating the characteristics of the selected areas, indicate that the correlation between the response rate and % younger age (18-34y), % house ownership, % non-official languages and % below the low income cut-off range between 0.37 and - 0.43 (p-value <0.01) (**Table 2**).

In the multiple regression model, percentage below the low income cut-off, % males, % mobile and % speaking non-official languages as mother-tongue were independent correlates of lower response rates (**Table 3**). The model explained 42% of the variability. Holding the percentage of males at the population mean and varying the other predictors to be +1SD of the means, the response rate obtained with higher levels of positive indicators (nonmovers, above low-income cut-off levels and speaking official languages as the mother-tongue) in the enumeration areas was approximately three times higher than that obtained with lower levels of positive indicators.

Discussion

This report examines the correlates of response rate in a large dietary survey. In the study sample, males, those in the younger age group, those with lower education levels and single persons were underrepresented, indicating that the survey was not representative of the total population. Examination of the census data for each small area sampled indicated that areas with lower response rates had a more mobile population, higher percentage below the low income cut-off and higher percentage speaking non-official languages, indicating that large surveys may underrepresent these groups who are suspected as being at elevated risk for poor nutrition.[15,16,17] Optimal approaches to obtaining good response rates may vary by community characteristics.

Low response rate is a problem in many recent surveys. In the Saskatchewan Nutrition Survey, the response rate was 46%.[18] The Quebec Nutrition Survey reported a response rate of 69% while the Nova Scotia Nutrition survey reported a response rate of 80%[4]. In the above studies, of the sample initially selected, only those with whom contact was established were included in the calculation of response rate. If those not contacted were also included in the response rate calculation, the response rate would be 55.8% in the Santé Québec Nutrition survey for example. The first national Nutrition Canada survey conducted in 1970-1972 reported a response rate of 46%.[19] Dietary surveys in the United States have better response rates possibly owing to door-to-door recruitment, but are concerned with decreasing response rates as well.

Studies comparing survey respondents and non-respondents find non-responders are more likely to be male, smoker, unmarried, have lower education levels, belong to single person households, live in poor neighborhoods and belong to either the younger age group (18-29 years) or the older age group (more than 70 years) or report poor health status [5,20,21,22]. By virtue of their lifestyle, the younger age group is more likely to be mobile and less likely to stay at home and therefore are difficult to recruit in surveys. Higher response rate for large families (5 or more people) compared to small families and single individuals (1 or 2 family households), could be due to availability of someone at home when the interviewer calls.[21]

Although we did not have the data to compare respondents and non-respondents on some of these demographic factors, we could examine the response rates by enumeration areas to determine which characteristics of the areas predicted response rates. In the present study, factors that characterized better response rates in certain enumeration areas compared to other areas included low mobility, official languages as mother tongue, lower percentage below the low income cut-off levels and higher percentage of females in the enumeration areas. The reason for gender being a predictor of response rate is difficult to explain particularly as the percentage of females in different enumeration areas varies very little. Low response rates observed in the present study in highly mobile areas could be attributed to the interviewer having out of date names from the previous year's phone list. In the present study, very low response rates were observed in certain large cities. In the Ontario Health Survey, metropolitan Toronto reported the lowest response rates for males and young persons.[23] Additionally, in the present study, it was observed that the response rates were lower in enumeration areas where a higher percentage of the population reported speaking non-official languages as their mother tongue. Lower response rates by ethnic minorities have also been reported.[24,25] Difficulty in communication because of lack of adequate knowledge of the official languages could result in refusals.

One of the exclusion criteria for the study included those who were unable to speak either English or French. It is possible that some of the non-responders in the selected enumeration areas could have belonged to the exclusion criteria, but it was difficult to confirm because of the abrupt termination of the telephone call.

The lower response rate observed in enumeration areas with a higher percentage below the low income cut-off and a higher percentage speaking non-official languages has certain dietary implications. Subjects from lower socio-economic status groups tend to report less healthy eating patterns[26] while immigrants report lower fat, calcium and iron intakes[27,28] compared to rest of the population, thereby indicating that a general dietary survey may not provide a representative description of food intake.

A commonly used method for addressing the issue of lower response rates among particular groups is to weight the data to be proportional to the national or regional levels. However, it is possible that there may be some unknown variables that may have influenced participation in dietary surveys[8,29] particularly in areas with very low response rates. Because of the small numbers of participants who responded in certain groups, weighting might lead to unstable estimates.[29] There is also a concern that the nutritional and health information of those interviewed would be representative of the rest of the hard to reach group.

In conclusion, the study indicates that the response rates vary not only by easily measured personal characteristics but also by characteristics of the small geographical units from which people are recruited. Low response rates in disadvantaged communities raise concern whether those who respond are representative of those who do not respond. A general dietary survey may not provide reliable information on the total population as is indicated by lower response rates observed in enumeration areas with higher percentage below the low income cut-off, higher percentage speaking non-official languages and higher mobility rates. Reaching the hard to reach group is a challenge that needs to be addressed in dietary surveys.

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Table 1

Comparison of Census 1991 and Study population characteristics

Characteristics	Canadian population (%)	Study sample (%)
Males	49.9	37.1
Females	50.2	62.9
Marital Status		
Single	30.7	18.0
Married	54.1	68.0
Divorced/Separated	8.8	3.2
Widowed	6.5	10.8
Age distribution		
Males:18-34	43.9	21.9
35-49	34.8	46.5
50-65	21.4	31.6
Females: 18-34	43.6	21.2
35-49	34.7	47.3
50-65	21.7	31.5
Size of households		
1 person	22.9	14.1
2 persons	31.4	31.0
3 persons	17.4	20.1
4-5 persons	25.0	31.8
≥ 6 persons	3.33	2.90

Education Level		
≤ High school	48.4	43.3
CEGEP/Trade	36.7	25.0
University	15.0	31.7
Canada (place of birth)	83.1	85.5

Table 2

Correlation between response rate and independent variables for the selected enumeration areas

Characteristics	r (correlation coefficient)	p-value
Male (% of total population)	-0.09	0.46
.Age, 18-34y (%)	-0.37	0.003
Married (%)	0.20	0.11
Non-official mother-tongue (%)	-0.40	0.001
House ownership (%)	0.37	0.003
Canada place of birth (%)	0.35	0.01
Size of family, >=3 persons (%)	0.16	0.21
Education, < high school (%)	-0.24	0.06
Below the low income cut-off (%)	-0.43	0.001
Mobile, place of residence, > 5y (%)	-0.29	0.02

Table 3

Correlates of response rate using Multiple Regression (based on 1991 Census Data)

Variable	Range	Parameter estimate	p-value
Males (%)	41.0 – 56.5	-1.35	0.01
Non-official mother-tongue (%)	0 – 69.5	-0.23	0.01
Mobile (%)	8.2 – 100	-0.15	0.01
Below low income cut-off (%)	0.5 – 46.3	-0.48	0.001

Chapter 5

Implications of day-to-day variability on measurement of usual food and nutrient intake

Transition

One of the methodolgical issues involved in conducting a dietary survey was discussed in Chapter 4. Response rate was discussed in terms of the characteristics of the sample data and characteristics of the selected areas. Another methodological issue that often limits interpretation of data is the number of days of observation needed to estimate dietary intakes. The number of days needed depends on whether the objective is to assess individual or group intake. Examination of the components of variability is needed to calculate the number of days needed to estimate intakes accurately. In the following chapter, two different statistical methods have been used for estimating the components of variability for selected nutrients and foods. The estimates so obtained have been used to calculate the number of days needed to estimate food and nutrient intakes for different levels of accuracy for individuals and groups.

Implications of day-to-day variability on measurement of usual food and nutrient intake[1]

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Implications of day-to-day variability on measurement of usual food and nutrient intake[1]

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Footnotes

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Abstract

Day-to-day variability in dietary intake makes it difficult to measure accurately the 'usual' intake of foods and nutrients. The objectives of the present study were to estimate within- and between- subject variability for foods and nutrients by adjusted and unadjusted models and to assess the number of days required to assess nutrient and food group intakes accurately by two different methods. Adult men and women aged 18-65 years (n=1543) in the Food Habits of Canadians Study provided a 24-h recall. A repeat interview was conducted in a sub-sample in order to estimate components of variability. Within- and between- subject variability were determined by mixed model procedure (crude and adjusted for age, gender, education, smoking, family size and season). The number of days required to obtain various degrees of accuracy were ascertained by two methods, one that uses the variance ratio for groups and one that considers within- subject variability alone for individuals. Variance ratios were higher using the adjusted compared to the unadjusted method (e.g. for men energy 1.07 vs 0.49). More days were required to accurately reflect usual intake using the adjusted model (energy 5 vs 2 days), indicating the need to control for confounders to obtain reliable estimates of intakes.

Key words: • within- person variability • between- person variability • 24-h recall, • dietary methodology

An increasing number of studies point to dietary intake as a risk factor for numerous chronic diseases (1). Accurate measurement of usual intake, which refers to long term average daily nutrient intake of an individual (2), is required to make links between diet and disease. Because dietary intake of an individual is not constant from day to day (3), an understanding of variability in food intake is required to estimate usual intake. Variability in food intake arises both because each individual differs in the types and amounts of food consumed from one day to the next (within- or intra- subject variability) (4) and because individuals differ from each other in their food intakes (between- or inter- subject variability) (5, 6). Variability in dietary intake influences the number of days required to estimate food and nutrient intakes accurately. The number of days required to obtain reliable estimates of food and nutrient intakes for individuals (4, 7) varies from that required to correctly classify individuals into groups for analytical purposes (8, 9).

A number of studies have examined within- and between- subject variability for different nutrients (7, 8, 10, 11); however less work has been done on variability in food intakes (12, 13). With increasing interest in the association between foods and disease risk (14, 15), a clearer understanding of variability in food intakes is important.

When ≥ 2 days of intake data are available, both between- and within- subject variability can be determined by analysis of variance (7-8, 16-19). Mixed models that take into account both fixed and random effects are now available (20).

These models can be used to control for other factors that may influence variability.

The objectives of the present study are to compare ratios of within- to between- subject variability for foods and nutrients by the mixed model procedure adjusting for several factors with the mixed model procedure unadjusted for other factors, and, to estimate the number of days needed in order to correctly classify subjects correctly into groups using within- and between- subject variances, and, the number of days required to accurately assess usual intakes for individuals using within- subject variability alone in the calculation.

Subjects and Methods

Dietary data used in the study are from the Food Habits of Canadians Survey, the most recent national survey in Canada, conducted between September 1997 and August 1998. A description of the sample design and selection is provided elsewhere (21). Briefly, a sample of 1543 non-institutionalized adults aged 18-65 years were randomly selected from five regions of Canada, including the Atlantic provinces, Quebec, Ontario, the Prairie provinces and British Columbia, using a multi-stage random sampling strategy (21). They were interviewed between September 1997 and August 1998. Pregnant and lactating women and those who did not speak English or French were excluded. The final sample included 572 men and 971 women. For the present study, two subjects who did not report their level of education were excluded resulting in 571 men and 970 women. A repeat interview was conducted on 29% of subjects in order to estimate within-subject variability in nutrient intake. Systematic sampling was used for this purpose; the second person initially interviewed and every third person thereafter were selected providing a sub-sample of 466 subjects.

Information on height, weight, smoking status and educational level was collected by questionnaire. Dietary intake was recorded by dietitians using the 24-h recall method in a face-to-face interview. Detailed descriptions of all foods and beverages consumed during the 24-h period prior to the interview, including the quantity, cooking method and brand names were recorded. Quantities were estimated using standard graduated glasses, bowls, spoons and a ruler. Supplement intakes were not considered for the present analyses. Nutrient intakes were analyzed using the Candat nutrient analysis program (Godin London Inc., London, Ontario) and the 1997 Canadian Nutrient File.

Nutrients examined in this analysis included the macronutrients, fat, protein, and carbohydrate, and the micronutrients, calcium, iron, folate, vitamin A and vitamin C. Carotene and vitamin E were not assessed, as data are not available for these nutrients for many foods in the Canadian nutrient file.

Foods including meat, vegetables, fruits (including juice), green leafy vegetables (lettuce/spinach/cabbage), milk and bread were examined as were the four food groups based on Canada's Food Guide to Healthy Eating (22). These latter groups did not include mixed dishes from different food groups where foods were entered as a mixed dish. For mixed foods, when specific amounts for each ingredient were described it was possible to categorise into specific food groups.

Total grams of the food grouping consumed was used as a measure of intake. The frequency of consumption of foods was examined in the sub-sample with two days of intake to provide information on variability in food intake.

The distribution of each nutrient was examined for normality and appropriate transformations (log and square root) were performed for nutrients with skewed distributions (23). An appropriate transformation could not be found for Vitamin A.

Within- and between- subject variability were estimated by the mixed model procedure for males and females in two ways; one that was unadjusted for the fixed effects and the other adjusted for the fixed effects of gender, age, education, smoking, season and size of family. It should be noted that in the analyses, means and variances are being considered separately. Mixed model procedures also enable examining variances by gender in addition to adjusting for the fixed effect means of gender, age, smoking, education, family size and season. An analysis of heterogenity of variances yielded variances attributed to males and females separately in both models. Thus, the results presented (which it should be noted, are variances and variance ratios) are stratified by gender. The above analyses were performed using both untransformed and transformed data but because similar ratios were obtained for all nutrients, the results for untransformed data are reported. The mixed model procedure permits the use of data for subjects with either one or two days of intake; data from both days of intake being used for estimating within- subject variability while one day's intake are used for estimating between subject variability.

Within- and between- subject variances obtained by the mixed model procedure that adjusted for factors were used to determine the number of days required to obtain reliable estimates of food and nutrient intake by two different methods, one using both within- and between- subject variances and the other using only the within- subject variability. The first method allows estimation of the number of days required to obtain a specified level of correlation between observed and true intakes and is obtained by the formula,

$$d = \frac{r^2}{1-r^2} \times \frac{s_w^2}{s_b^2}$$

where, d= number of days, r represents the unobservable correlation between observed and true mean nutrient intakes of subjects, and, s_w^2/s_b^2 is the within-/between- subject variance ratio (8). A higher value of r indicates a higher proportion of subjects correctly classified and a lower proportion misclassified (8). If the ratio of variances is low, then fewer days of observation are required to classify subjects correctly (8, 9) which may be because of low within- subject variability or high between- subject variability.

For some purposes, it may be necessary to assess actual intake of individuals with a given level of confidence (7). The number of days of observation needed for a given level of confidence (7) can be calculated as follows:

$d = (Z_{\alpha}\, CV_0 / D_0)^2$ where, d = number of days needed per person, Z_{α} = normal deviate e.g. 1.96, CV_0 = within- subject variation, calculated as square root of within-subject variance (standard deviation)/ mean intake, D_0 = specified limit as percentage of long term intake (24). Using this calculation, the number of days needed for the observed estimate of a person's intake to lie within a specified percentage of the true mean, 95% of the time can be obtained (24). All analyses were performed using the mixed model procedure (Proc Mixed) of SAS (version 6.12, 1996, Cary, NC, USA).

Results

The sub-sample obtained for the repeat interview was very similar to the total sample with regard to age, education level, smoking status, family size and body mass index for both males and females (data not shown).

Within- to between- subject variability ratios (s_w^2/s_b^2) obtained for the selected nutrients using the mixed model procedure that adjusted for other factors tend to be higher than the unadjusted model (1.07 vs 0.49 and 2.04 vs 1.76 for energy in males and females respectively) (**Table 1**). The higher ratios obtained using the adjusted mixed model procedure occurred because adjusting tends to reduce between- subject variability.

Using both within- and between- subject variances in the computation for estimating the number of days, approximately 2 – 6 days were required to estimate nutrient intakes with good accuracy (r = 0.8) (**Table 2**). Using within-subject variability alone in order to estimate the accuracy of individual measurements, many more days were required to estimate nutrient intakes within 20% or 30% of usual intake. Comparison of both methods indicates that more repeat observations are required in order to obtain estimates of usual nutrient intakes for individuals than that required to place subjects in groups relative to each other.

Variability in food and nutrient intake is a measure of how frequently a food is consumed and how much of the food is consumed. Examination of frequency of consumption of foods in the sub-sample, indicated that except for green leafy vegetables, fruits and milk, only 5 % or less reported not consuming any of the major food groups or foods on both days of interview (data not shown).

Variability ratios (s_w^2/s_b^2) for food groupings were computed by the mixed model procedures described previously for nutrients (**Table 3**). The within-/between- subject ratios for most food/food groups tend to be slightly higher by the mixed model procedure that adjusted for other variables (1.15 vs 0.96 and 2.07 vs 1.87 for grain products among males and females respectively), indicating that, as for nutrients, adjustment tends to reduce the between-subject variability and thereby increasing the ratio. The variance ratios were generally higher for food groupings than for nutrients, with the exception of fruits (including juices) and milk food groups. These higher variance ratios mean that more days of food intake would be required than those estimated for nutrients.

The mixed model procedure that permits controlling for variables that may influence variability indicated that gender, age and education were significant fixed factors explaining variability in the mean intake of most foods and nutrients; smoking was a significant fixed factor explaining variability in the mean carbohydrate, iron and folate intakes; the fixed effect factor household size explained variability in the mean intakes of iron and folate; indicating that these factors need to be recorded and controlled for in dietary analyses.

Discussion

The need for adjusting within-/between- subject variability for differences between subjects in terms of basic demographic factors such as age is clear. The ratios tended to be higher with the adjusted model compared with the unadjusted model for most nutrients and foods/food groups. The higher ratios among men for energy and macronutrients with the adjusted mixed model procedure indicate that fewer days would be obtained if unadjusted values are used which could then result in unreliable estimates of intakes. Within-/between- subject variance ratios were generally lower for nutrients compared to foods; food groups based on Canada's Food Guide to Healthy Eating had lower ratios than specific foods. The higher variability for foods makes obtaining reliable estimates of food intake from few repeated observations difficult.

Adjusting for several factors when estimating variance ratios, results in a reduction in between- subject variance. This may be due to differences in total intake because of age, sex, smoking status or physical activity. The resulting higher variance ratio indicates that more days are needed to obtain reliable estimates of nutrient intakes. Not adjusting for these factors and thus estimating a lower number of days required could result in the study having insufficient power to detect differences in intakes when these variables are controlled in multivariate analyses.

In the present study, gender, age, smoking, education, season and size of family contributed to variability in the intakes of most foods and nutrients. Similar to other studies, gender, age and smoking contributed to variability in nutrient intakes (7, 25, 26). It has been reported that there are differences in consumption of certain foods by level of education and family size (25, 27-29). As reported in other studies, in the present study, season did not contribute to variability (11, 30).

The within- to between- subject variability ratios were generally >1 as reported in other studies (7, 8, 10-12). The ratios for energy, protein, carbohydrate, calcium, vitamin C, iron, (7,8) grains, vegetable and fruit food groups (12) were similar to those reported for similar populations. The variance ratio for fat was similar to that reported in literature among males (7); the ratio was however higher for women. For women, the within- subject variability was higher than for men and the between- subject variability lower, possibly reflecting inconsistent use of low fat products or less regular consumption of fat containing foods. The number of days required to estimate usual intakes for carbohydrate and calcium were similar to that reported in other studies for similar populations using within/between variance method (8).

Nutrients had lower within- to between- subject variability ratios compared to foods possibly owing to the fact that nutrients come from many food sources. Among foods, there was greater variability in the intake of specific foods compared to whole food groups. It is possible that 2d of measured intake for each individual is not sufficient to get a true picture of variability in some less routinely eaten foods.

A question often asked at the design stage pertains to the number of days of observation needed to assess usual intakes of individuals and groups (7,9). In our analyses, considerably more days were required to obtain reliable estimate of intakes for individuals compared to relative ranking of subjects into groups. If the objective is to obtain accurate estimates of individuals for counseling purpose (7), then the method involving the use of within-subject variability needs to be considered due to large day-to-day variation in dietary intakes of each individual. Studies have indicated that most nutrients have high within- subject variability resulting in a greater number of days to estimate intakes reliably for individuals (7, 24, 9). The food frequency method may be an option for specific foods (7); however, food frequency questionnaires have been estimated to measure nutrient intakes only as accurately as 2-3 repeat 24-hr recalls (31).

A possible limitation of the present study was that the day of the week effect (3, 24) was not taken into account. Attention was given to avoid conducting a repeat interview on the same day of the week for each subject; however, the choice of days was not necessarily a weekday and a weekend day. Interviews for the same subject were not done on consecutive days to avoid misleading correlations associated with consecutive days of dietary assessment (3).

In conclusion, within-/between- subject ratios for foods and nutrients tended to be higher with adjustment compared to the unadjusted model indicating the need to adjust for confounding variables when calculating the number of days in order to obtain reliable estimates of nutrient intakes.

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Table 1

Intra- to inter- subject variances (s_w^2/s_b^2) by gender for selected nutrients

by two different methods

Nutrient	Men n=571		Women n=970	
	Proc Mixed [1]	Proc Mixed [2]	Proc Mixed[1]	Proc Mixed [2]
Energy, kJ	1.07	0.49	2.04	1.76
Protein, g	1.53	0.79	3.24	2.98
Fat, g	0.99	0.62	2.95	2.56
Carbohydrate, g	1.39	0.76	1.58	1.42
Iron, mg	2.04	1.04	2.29	2.03
Calcium, mg	1.16	0.92	1.23	1.18
Folate, µg	1.51	1.21	1.95	1.77
Vitamin C, mg	1.03	0.93	1.43	1.34

[1] Adjusted for fixed effects of gender, age, education, smoking, size of family, season

[2] Unadjusted for fixed effects

Table 2

Number of days of observation required for specific nutrients using two different methods[1]

Nutrient	Gender	CV (%)		Attenuation Factor[2]			Specified limit (% of long term intake)[3]		
		intra	inter	0.9	0.8	0.7	10	20	30
Energy, kJ	M	28.3	27.4	5	2	1	30	8	3
	F	33.1	23.2	9	4	2	42	11	5
Protein, g	M	39.7	32.1	7	3	2	61	15	7
	F	34.6	25.6	14	6	3	46	12	5
Fat, g	M	42.2	42.4	4	2	1	68	17	8
	F	50.8	29.6	13	5	3	99	28	11
Carbohy-drate, g	M	32.0	27.1	6	3	1	39	10	4
	F	34.4	27.3	7	3	2	46	11	5
Iron, mg	M	38.4	26.9	9	4	2	57	14	6
	F	39.0	25.8	10	4	2	58	15	7

Calcium,	M	46.2	42.9	5	2	1	82	21	9
mg	F	44.3	44.5	5	2	1	75	19	8
Folate, µg	M	44.2	36.8	6	3	2	75	19	8
	F	50.2	36.8	8	4	2	97	24	11
Vit.C, mg	M	67.4	66.3	4	2	1	175	44	19
	F	64.8	54.3	6	3	1	161	40	18

[1] n=571 men, 970 women

[2] Attenuation Factor is the correlation between observed and true mean nutrient intakes and number of days, $n=[r^2/(1-r^2) \times (s_w^2/s_b^2)$ where r=unobservable correlation coefficient between observed and true mean nutrient intakes of individuals and s_w^2/s_b^2 is within subject/between subject variance (8)

[3] number of days, $n=[(1.96 \times CVw)/D_0]^2$ where D_0=specified % of the true mean and CVw is within person coefficient of variation (7, 24)

Table 3

Intra- to inter- subject variance ratio (s_w^2/s_b^2) by gender for different food groups by two different methods

Food Group	Men (n=571)		women (n=970)	
	Proc Mixed[1]	Proc Mixed[2]	Proc Mixed[1]	Proc Mixed[2]
Canada's Food Guide To Healthy Eating Food Groups				
Grain products	1.15	0.96	2.07	1.87
Meat and alternatives	2.84	1.71	4.89	4.52
Milk products	1.32	1.23	0.96	0.96
Vegetables & fruit	1.63	1.33	1.71	1.58
Foods				
Meat	1.83	1.30	3.44	3.19
Vegetables (all types)	7.99	7.19	3.78	3.60

Green leafy vegetables	2.19	2.26	3.82	3.61
Fruits (incl. juice)	1.17	0.98	1.35	1.25
Milk	1.33	1.23	0.69	0.69
Bread	4.74	2.96	5.66	4.55

[1]Adjusted for the fixed effects of gender, age, education, smoking, size of family, season

[2]Unadjusted for fixed effects

Chapter 6

Fruit and vegetable consumption is lower and saturated fat intake is higher among Canadians reporting smoking

Transition

In Chapter 5, it was shown that there is a need to control for factors that may influence variability in dietary intake in order to obtain reliable estimates of nutrient intakes.

One factor influencing variability that should be controlled for is the smoking status of individuals. Smokers tend to have a poor quality diet in terms of nutrient intakes and food choices. However nothing is known about how variable the diets of the smokers are compared to the non-smokers and how well the smokers are able to meet the new dietary recommendations.

The next objective of this research study was to assess if the smokers were more variable than the non-smokers in nutrient intakes. The within-/between-subject variability ratios for selected nutrients were compared between the smokers and non-smokers. Also, it was of interest to determine if the smokers were different from the non-smokers in terms of nutrient intakes and if so, what food choices contributed to the differences in nutrient intake. Additionally, nutrient and food intakes were compared with the new dietary reference intakes and the Canada's Food Guide to Healthy Eating to determine how the smokers and non-smokers compared in terms of meeting the recommendations.

Fruit and vegetable consumption is lower and saturated fat intake is higher among Canadians reporting smoking

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Fruit and vegetable consumption is lower and saturated fat intake is higher among Canadians reporting smoking

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Running title: Dietary patterns of smokers and non-smokers

ABSTRACT

Understanding differences in dietary patterns by smoking status is important for nutritionists and health educators involved in helping individuals to make healthy dietary and lifestyle choices. Although smokers are known to have a poor quality diet compared to non-smokers, no study has examined nutritional adequacy and variability in nutrient intake of smokers. The aim of the study was to compare dietary habits of smokers to non-smokers in terms of nutrient intake, food groups contributing to nutrient intake, nutritional adequacy and day-to-day variation in nutrient intake. Non-institutionalized adults aged 18-65 years (n=1543) who participated in the Food Habits of Canadians Survey (1997-1998) were studied. Subjects, selected from across Canada using a multi-stage random sampling strategy, completed an in-home 24-hour dietary recall. Repeat interviews were conducted in a sub-sample to estimate variability in nutrient intake. Smokers had higher intakes of total and saturated fat, and lower intakes of folate, vitamin C and fiber than non-smokers. There were no significant differences in calcium, zinc and vitamin A intakes or day-to-day variation in nutrient intake by smoking status. Smokers consumed significantly fewer fruits and vegetables than non-smokers leading to lower intakes of folate and vitamin C. In conclusion, smokers have a less healthy diet than non-smokers, placing them at higher risk for chronic disease as a result of both dietary and smoking habits. Diet may act as a confounder in smoking-disease relationships.

KEY WORDS: • smokers and non-smokers • nutrient intake • food groups

• supplement use • humans

Smoking is a major risk factor for cardiovascular disease, respiratory disease and cancer (1). It has been postulated that the increased risk for these diseases among those who smoke compared with those who do not smoke may be due in part to differences in other lifestyle behaviors including dietary habits (2). In the second National Health and Nutrition Examination Survey (NHANES II), people who smoke reported lower intakes of vitamin C, folate, fiber and vitamin A than those who do not smoke (3). People who report smoking also tend to have higher intakes of saturated fats and lower intakes of polyunsaturated fat, iron, β-carotene and vitamin E compared with people who do not smoke (4-8); in addition they tend to differ in the way they select their food. They are more likely to choose white bread, sugar, meat, butter, whole milk and eggs and less likely to consume whole-wheat bread, high fiber breakfast cereals, fruits and vegetables than non-smokers (9, 10). In addition to a poorer diet, people who smoke are also exposed to free radicals, produced by cigarette smoke, that could provoke lipid peroxidation in cell membranes (1, 11, 12). Several studies have shown that micronutrients such as vitamin A, particularly β-carotene, vitamin C, vitamin E, folic acid and phenolic compounds derived from fruits and vegetables have protective effects against cigarette smoke induced toxicity by preventing lipid peroxidation (1, 13). Because those who smoke have low intakes of fruits and vegetables that are rich in antioxidants, they are more likely to be susceptible to oxidative damage caused by free radicals.

Indeed people who smoke have a poor quality diet in terms of nutrient intakes and food choices. There is, however, a lack of data on nutritional adequacy and variability in nutrient intake among people who smoke. Examination of the main food group contributors to nutrient intake (for example, folate, vitamin C) by smoking status will provide insight on food choices responsible for differences in nutrient intake. Also, few studies that have examined smoking and diet have controlled for socio-economic status.

Data used in the study are from the Food Habits of Canadians Survey conducted in 1997-98, which is the most recent national nutrition survey in Canada (14). The aim of this study was to assess how dietary habits of those who smoke differ from those who do not smoke in terms of nutrient intake, contribution of food groups to nutrient intake, nutritional adequacy and within-subject variability in nutrient intake.

Subjects and Methods

A sample of 1543 non-institutionalized adults aged 18-65 years were randomly selected from 5 regions of Canada, including the Atlantic Provinces, Quebec, Ontario, the Prairie provinces and British Columbia, using a multi-stage random sampling strategy (14). The Canadian population living in more remote regions (15%) was not sampled owing to cost considerations. In each region studied, four census divisions were randomly selected with the probability of selection being proportional to the size of the population. This yielded 20 census divisions across the country. Two subdivisions were randomly selected within each census division, and two enumeration areas were selected within each subdivision, yielding 80 enumeration areas. Within each enumeration area a random sample of households was drawn from the 1996 computerized telephone listings of residential homes in each area (Pro-CD Inc., Mass, Canada). Letters were sent to inform household occupants of the survey, and to invite the adult member in the household with the next upcoming birthday, to participate. The letter was followed by a telephone call from a dietitian-interviewer to arrange a face-to-face interview. The criteria for exclusion were pregnant and lactating women and persons who did not speak English or French. The final sample included 572 men and 971 women. Approximately 17% of potential subjects could not be contacted; 57% refused to participate, resulting in an average response rate of 26%. Survey data were compared to the 1991 Census data (Statistics Canada, Census 1991, CD-ROM, Ottawa, Canada). The socidemographic profile of the study sample was found to be comparable to that of the general Canadian population (number of people born in Canada: 86% Vs 84%, number of subjects with less than high school education: 22% Vs 26% and single marital status: 26% Vs 32% respectively) (14). In addition, the percentage of adults reporting a BMI of >27 was 32% in our study and 31% in the National Population Health Survey (15). The percentage of adults (over 18 years of age) reporting smoking in our study was 20% and in the Canadian Tobacco Use Monitoring Survey was 28% (16). A repeat interview was conducted in a systematic sample of 22% of subjects in order to estimate within-subject variability in nutrient intake.

Self-reported height, weight, smoking status and educational level were collected. Subjects who answered yes to the question "Do you smoke more than 5 cigarettes per day?" were categorized as smokers; all others were categorized as non-smokers. This level was chosen as the cut-off in order to determine smoking status because it is difficult to categorize the small number of people who smoke very little. The average number of cigarettes used by smokers is 19 cigarettes per day in Canada (16). Three levels of education included those with (1) a high school (Grade 11) or less, (2) pre-university (2 year program) or Trade school and (3) a University degree. Education is used as an indicator of socio-economic status.

Dietary intake was recorded by the dietitians using the 24-hour recall method (17). Detailed descriptions of all foods, beverages and supplements consumed during the 24-hour period prior to the interview, including the quantity, cooking method and brand names were recorded. Quantities were estimated using standard graduated glasses, bowls, spoons and a ruler. Quality control was ensured during dietary data collection and entry in order to minimize error and increase reliability (18). Dietitians were trained to use research forms, tools and food and nutrient database that were used for coding. Furthermore, they resided in the regions surveyed, ensuring familiarity with the local food supply and food preparation methods. An adapted multiple pass technique was employed (19); the subjects were first asked to recall their food intake over the previous 24 hour period, followed by probing for detailed descriptions of food, beverages and supplements including food portion sizes, and then by a review of intake and clarifications.

Nutrient intakes were entered, double verified by another person and analyzed using the Candat nutrient analysis program (Godin London Inc., London, Ontario, 1997) and the 1997 Canadian Nutrient File. Approximately 270 food items were added to the database, as these were not available on the Canadian Nutrient File. Nutrient information was obtained from food manufacturers' data when possible or from the American database (20). The nutrient database includes over 5000 food items and 40 nutrients. Folic acid supplementation of flour in Canada occurred after the data collection.

Foods were classified into 51 food groups for the purposes of describing types of foods in the following manner: Fruits were classified as citrus and non-citrus fruits (due to differences in vitamin C content). Vegetables were categorized according to specific nutrient contribution by each subgroup (lettuce/cabbage/greens, other dark green vegetables, dark yellow/orange vegetables, tomatoes, potatoes, and non-dark green vegetables). Dairy products were grouped as milk, cheese, yogurt, cream and ice cream/pudding. The meat group was classified according to the type of meat (beef, pork, poultry, bacon/sausages/lunchmeats, fish/seafood, organ meats, lamb and other meats). Grain products were categorized as breads, pasta/rice/grains, cereals and mixed dishes. The alcohol group included beer, alcoholic coolers, liquor and wine. Other foods were broken into clear categories such as sugar/syrup/gelatin, carbonated beverages, candies/chocolates. These food groups were used to determine the main contributors to nutrient intake (carbohydrate, fat, folate and vitamin C) by smoking status. The percentage of subjects consuming the food on the day of the intake and the average amount of that food eaten by consumers were analyzed and compared using χ^2 and t-tests.

To determine whether subjects in the two smoking categories met the recommendations for food groups based on Canada's Food Guide to Healthy Eating (21), foods were categorized into the following food groups: grains, dairy, meat and fruits and vegetables. Food portions were determined using food density (g/ml) and all foods with very similar densities within a category were divided by the same weight of a standard portion size to get units of portion size (e.g. cooked rice or pasta=70g in the grain products food group; corn/ other vegetables=85g in the vegetables and fruit group). In addition, the Good Health Eating Guide Resource (22) was consulted to determine weights for some foods and also to establish how many portions of each food group went into each of the mixed foods. Mixed food groups were broken down into constituents for contribution to the four food groups (e.g. 1 cheese pizza=1 grain product and 0.2 milk product).

Data were collected on supplement use on the day of the recall. Supplement composition was determined using the Health Canada Drug Product Database (23), product labels or by contacting the company. When adequate information was not available to identify brand or amount of nutrient present in the supplement, default values were assigned based on the modal value for the supplement. For vitamin B complex preparations, the lowest values found in any identified supplements were used.

Nutrients examined in this analysis include calcium (mg), iron (mg), zinc (mg), folate (μg), vitamin A (RE), vitamin C (mg) and fiber (g) as well as total fat, saturated fat, monounsaturated fat and alcohol, which are expressed as percentage of energy. Carotenoid data are not available in the Canadian Nutrient file. These nutrients were chosen because the mean percent of energy from fat and saturated fat are generally above the Nutrition Recommendations of 30% and 10% respectively (24); vitamin C is a nutrient of concern for those who smoke (25) while calcium, iron and folate are often below recommended levels in Canadians (14, 24, 26). Zinc was also assessed because of its role in limiting free-radical induced oxidative damage (27).

The distribution of each nutrient was examined for normality and appropriate transformations (log and square root) were performed for nutrients with skewed distributions (28). However, an appropriate transformation was not found for alcohol. Using the sub-sample with two days of intake, inter (between) and intra (within) subject variability were estimated separately for males and females by ANAOVA (29). Using this measure of variation, the entire study population distribution was adjusted for within-subject variability using the NRC method (30). Differences in nutrient intake by smoking status were assessed separately for men and women using the general linear method of ANOVA, adjusting for education. Multiple comparisons were corrected for using Scheffe's method (29). Possible effect modification by level of education and age was examined by including interaction terms for smoking and education and smoking and age.

A comparison of the day-to-day variability between people who smoked and people who do not smoke was examined by computing intra (within) to inter (between) subject variability ratio for energy, calcium (mg), folate (mcg), vitamin A (R.E.), vitamin C (mg), zinc (mg) and iron (mg).

The percentage meeting the National Academy of Science Recommendations for calcium (AI), iron, zinc, folate and vitamin C (EAR) were examined (25, 31, 32, 33) by smoking status.

To assess underreporting of food intake, the ratio of reported energy intake (EI) to estimated energy requirements (BMR_{est}) was calculated separately for males and females by smoking status. BMR was calculated from the reported height and weight using the FAO/WHO/UNU formula (1985) (34) and is reported as $BMR_{est.}$ All analyses were performed using SAS (version 6.12, 1996, Cary, NC, USA)

Results

There were no significant differences by smoking status in age or BMI among males and females. However, those who smoke had a lower level of education than those who do not smoke ($p<0.001$) (**Table 1**).

Total energy intake did not differ by smoking status (**Table 2**). However, people reporting smoking consumed more total fat and saturated fat and significantly lower intakes of folate, vitamin C and fiber than those who did not report smoking. There were no significant differences in calcium, zinc or vitamin A intakes by smoking status. Although most patterns of intake were very similar in men and women, men who smoked consumed more monounsaturated fat and women who smoked consumed less iron than people who did not smoke. The percentage of subjects consuming alcohol did not differ between the two smoking groups. Alcohol consumption among women who reported drinking alcohol was higher in those who reported smoking (Wilcoxon test, $z<0.01$). There was no interaction of smoking by education level on nutrient intake. There were no interactions by age and smoking status for most nutrients with the exception of folate intake, which was higher among non-smoking women in the 35-49 and 50-65 years age groups; among young women there was no association of smoking status with folate intake.

The mean EI/BMR_{est} for men who smoke and do not smoke was 1.44 ± 0.61 and 1.44 ± 0.58, respectively, indicating little if any underreporting. The mean EI/BMR_{est} for females who smoke Vs those who do not smoke was 1.23 ± 0.62 Vs 1.28 ± 0.53 respectively indicating underreporting in both groups. EI/BMR_{est} ratio was similar across BMI categories (<20, ≥20-25, ≥25-<27 and ≥27 kg/m^2).

Food Groups

Food choices differed by smoking status **(Table 3).** Because men and women reported similar food group choices contributing to carbohydrate, fat, vitamin C and folate intakes, results are reported by smoking status alone. The order in which foods appear in the table is the order in which each food contributed to the overall nutrient intake of the study sample. The frequency of consumption on the day of recall and mean intake of each food by the consumers of that food are reported. The differences in food group intake for primary sources of carbohydrate indicated that those who did not smoke were more likely to consume pasta, cakes/cookies, non-citrus fruits, cereals and milk. The portion sizes of cereals were larger for smokers. Other differences were apparent in food sources of folate and vitamin C, indicating better food choices among people who do not smoke. Although, overall, the most important contributors to folate and vitamin C were fruits and vegetables in both groups, significantly fewer smokers report ed consuming different categories of fruits and vegetables on the day of the recall and they were more likely to consume carbonated beverages, coffee and tea.

The average number of servings of vegetables and fruit fell below the minimum suggested number of 5 servings/d for people of both sexes who smoke (**Table 4**). Only 30% of people who smoke compared to 48% of people who do not smoke (χ^2<0.001) met the minimum suggested number of portions for fruits and vegetables.

Variability in eating pattern

Day-to-day variability in nutrient intake was compared to evaluate whether people who smoke had more variable intakes of nutrients. Intra/inter subject ratios were generally above 1 for all nutrients examined (**Table 5**). There were no distinct patterns in variability by smoking status.

Comparison of nutrient intake with Dietary Reference Intake

To examine whether people who smoke met the recommended levels of intake despite lower intakes of some nutrients, we analyzed the percentage of men and women meeting the Dietary Reference Intake for calcium (Adequate Intake, AI), folate, vitamin C, iron and zinc (Estimated Average Requirement, EAR) by smoking status (**Table 6**) (25, 31-33). A higher percentage of people who smoke failed to meet the EAR for smokers for vitamin C (χ^2<0.001). Most men met the EAR for iron (98% vs. 99.5%) irrespective of smoking status, whereas for women, a smaller percentage of those who smoke met the EAR for iron (87% of those who smoke vs. 93% of those who do not smoke, χ^2<0.01). Most people in both smoking categories met the EAR for zinc. Most women, irrespective of smoking status, had mean intakes below the EAR for folate. Stratification by education level did not modify these relationships.

Supplement use

Overall, 38.5% of subjects reported using dietary supplements. People who smoked were less likely to take dietary supplements (21.3% Vs 29.7% among men, χ^2<0.001 and 37% Vs 43.5% among women, χ^2<0.001). Women who reported not smoking were more likely to take calcium supplements than females who reported smoking (18% vs. 10%, χ^2<0.05).

Discussion

Our results suggest important dietary differences between those who smoke and those who do not. Those who smoke had relatively higher intakes of fat and saturated fat, and lower intakes of folate, vitamin C and fiber. Food choices by smoking group support the observed nutrient differences.

Several studies have reported that antioxidants such as ascorbic acid may attenuate adverse health effects associated with cigarette smoking by scavenging the free radicals produced by tobacco smoke (2, 13). However, the intake of antioxidants by smokers is low, placing them at higher risk of oxidative stress (9, 35, 36). High intake of saturated fat raises total cholesterol and LDL-cholesterol levels and is a risk factor for coronary heart disease (37). People who smoke tend to have high intakes of saturated fat and also to have increased levels of VLDL-cholesterol and low HDL-cholesterol levels (38). In addition, low folate intake is a risk factor for coronary heart disease and certain forms of cancer (39). On the basis of our results, we find that people who smoke have slightly higher intakes of total fat and saturated fat (9%) and lower intakes of folate (14%), vitamin C (24%) and fiber (23%). This is consistent with those reported in other populations (3, 6). Although the differences may appear small, such dietary differences are predicted to be associated with higher levels of cardiovascular disease risk and decreased life expectancy (40). Consequently, in addition to the toxic effects of smoke, those who smoke are at increased risk of developing chronic diseases related to diet.

Although fruits and vegetables were among the most important contributors to folate and vitamin C, a smaller proportion of smokers consumed these foods leading to lower mean intakes of these two vitamins. This effect was consistent among several food groupings of fruits and vegetables, which is consistent with other studies (3, 41, 42). The average number of servings of fruits and vegetables was below the minimum recommended 5 servings/day for people of both sexes who smoked. Possible reasons for lower consumption of fruits and vegetables include changes in taste acuity induced by smoking that could influence food choices (2). Finally, several studies suggest that those who smoke and those who do not have different health priorities and habits (43-45).

People who do not smoke were more likely to use supplements, particularly non-smoking women who were more likely to take calcium supplements than women who smoke supporting other studies indicating healthier lifestyle among those who do not smoke (46, 47) .

Diet may be a confounder when studying the relationship between smoking and chronic disease. Those who smoke have been reported to have higher intakes of saturated fat and in addition, to have unfavorable lipid and lipoprotein levels (38) so that the effects of smoking and diet are acting in the same direction. Therefore, failure to control for the confounding effect of diet when examining the relationship between smoking and chronic diseases may result in overestimation of relative risk.

Two methodological issues not addressed in earlier studies on diet and smoking status include $EI:BMR_{est}$ and intra- and inter- subject variability that have been examined in this study. In our study, the mean EI/BMR_{est} values for males and females were similar to those reported in NHANES III and other studies (48, 49). Although men appear to report adequate intakes, the mean EI/BMR_{est} among females was approximately 1.25, below the cut-off of 1.35, indicating underreporting (50). The lower EI/BMR_{est} values for women appear to be a problem in surveys (51). The similar EI/BMR_{est} values among those who smoke and do not smoke provides evidence that underreporting was similar in the two smoking groups.

People who smoke did not report higher variability in nutrient intakes. The lack of difference in day-to-day variation indicates that those who smoke have no more variable diet than those who do not smoke.

Previous studies reporting on differences in BMI by smoking group have found differing results, with some reporting lower BMI among smokers and others, including our results not showing any differences in BMI (9, 52-56). There is similar disagreement in the literature as to whether energy intakes are higher among smokers or not (6, 10, 53).

The extent to which we can generalize these results to the Canadian population is limited by the low response rate achieved. Response rates to health surveys appear to be dropping (57, 58). The sample, however, appeared to be representative of the socio-demographic profile of Canadians.

In conclusion, those who smoke consumed a less healthy diet than those who do not smoke. The finding that nutrient and food group intake varied by smoking status has public health implications since the less healthy dietary patterns of those who smoke places them at an even greater risk for developing chronic disease than those who do not smoke. Studies examining smoking disease relationships should control for the confounding effect of diet given these consistent findings for nutrient intakes from both food and supplement sources.

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Table 1

Demographic Characteristics of Subjects by Smoking Status

	Men (n=571)		Women (n=970)	
	Smokers (n=127)	Non-smokers (n=444)	Smokers (n=181)	Non-smokers (n=789)
Age[1] (years)	42±11	44±11	44±10	44±11
Education Level[2]				
n (%)	67 (53%)	154 (35%)	106 (59%)	340 (43%)
≤ High School	29 (23%)	106 (24%)	45 (25%)	206 (26%)
PreUniversity/Trade	31 (24%)	184 (41%)	30 (16%)	243 (31%)
University				
BMI (kg/m^2)	26.4±4.3	26.8±4.0	24.9±4.6	25.5±5.1

[1] Values are means ± SD
[2] p=0.001 (χ^2 analysis)

Table 2

Nutrient intake stratified by sex and smoking status [1,2]

Nutrient	Men (n=571)		women (n=970)	
	Smokers (n=127)	Non-Smokers (n=444)	Smokers (n=181)	Non-smokers (n=789)
Energy (kilocalories)	2544±810	2562±826	1650±541	1726±463
(KiloJoules)	10634±3386	10709±3453	6897±2261	7215±1935
Total Fat (% of total energy)	31.2±7.09	29.5±6.68*	29.5±6.70	28.5±5.90*
Saturated Fat (% of total energy)	10.3±3.10	9.39±2.87 *	9.85±2.95	9.09±2.69*
Monounsaturated Fat (% of total energy)	12.1±3.06	11.3±3.32 *	11.0±2.99	10.6±2.57
Calcium (mg/d)	943±491	976±517	693±346	733±334
Iron (mg/d)	16.9±6.73	18.0±6.16	11.6±4.59	12.6±3.85*
Zinc (mg/d)	13.6±6.52	13.4±4.95	9.23±5.18	9.30±3.74

Folate (μg/d)	254±108	299±130*	197±112	225±91*
Vitamin A [3](RE/d)	1622±968	1745±1115	1601±1923	1971±1953
Vitamin C (mg/d)	120±107	152±117 *	95±79	130±87*
Fibre (g/d)	13.7±6.43	17.5±8.76*	11.5±6.92	14.0±6.87*

[1] Values are means±SD (adjusted for within-subject variability by sex)
[2] $p \leq 0.05$ (Comparison of smokers vs. non-smokers stratified by sex, ANOVA with Scheffe's test)
[3] RE, retinol equivalents

Table 3

Food groups contributing to intake of carbohydrate, fat, folate and vitamin C by smokers and non-smokers[1]

Nutrient	Smokers (n=308)			Non-smokers (n=1233)		
	Food Group	Freq[2] (%)	Amount[3] (g/d)	Food Group	Freq[2] (%)	Amount[3] (g/d)
Carbohydrate	Breads	87.3	98.1±72.8	Breads	86.6	110.0±78.0*
	Carbonated beverages	42.9	720.1± 540.6	Pasta/rice/grains	40.6**	231.4±215.4
	Sugar/syrups/ jams/gelatin/ cocoa mixes	61.7	45.8±119.9	Cakes/cookies/ pies/granola bars	48.1**	81.6±86.8
	Pasta/rice/ grains	27.0	227.2±173.2	Non-citrus fruits	60.0**	191.8±162.3
	Cakes/ cookies/pies/ granola bars	38.6	77.1±81.6	Cereals	36.9**	85.0±94.4*
	Potatoes boiled/ mashed	29.2	198.1±149.6	Carbonated beverages	36.7*	525.2±350.6***
	Milk/ chocolate milk	70.5	326.6±322.4	Milk/ chocolate milk	78.8**	299.0±333.2
	Cereals	22.7	114.8±134.5	Potatoes boiled/ Mashed	28.2	200.7±165.1

Fat	Beef/Veal	32.5	153.0±127.3	Cakes/cookies/ pies/granola bars	48.1**	81.6±86.8
	Margarine/ butter/lard	63.6	12.6±16.5	Breads	86.6	98.2±73.0*
	Cheese	38.6	77.1±73.7	Margarine/ butter/lard	57.6	11.5±31.3
	Sausages/bacon/ lunch meats	32.5	153.0±127.3	Beef/veal	27.5	133.9±118.4
	Breads	87.3	110.0±78.0	Cheese	48.1**	81.6±86.8
	Cakes/cookies/ pies/granola bars	38.6	77.1±73.7	Sausages/ lunchmeat/bacon	27.5	133.9±118.4
	Milk/chocolate milk	70.5	326.6±322.4	Mixed meat/ poultry/fish dishes	15.9	223.3±220.2
	Mixed meat/ poultry/fish dishes	15.6	183.0±134.5	Milk/chocolate milk	78.8*	299.0±333.2
Folate	Breads	87.3	98.2±72.8*	Citrus fruit juice	35.4**	300.0±231.1
	Lettuce/ greens/ cabbage	30.5	87.1±101.6	Lettuce/ greens/ cabbage	38.9*	81.0±82.8
	Citrus fruit juice	22.1	315.2±300.0	Breads	86.6	109.7±78.0
	Other non-dark green vegetables	52.9	90.0±120.5	Other non-dark green vegetables	63.3**	83.0±88.8
	Hamburger/ pizzas	9.74	224.8±219.2*	Legumes/nuts/ seeds	28.1*	45.6±66.7
	Milk/ chocolate milk	70.5	326.6±322.4	Other dark green vegetables	32.5*	69.6±70.8

	Coffee/Tea	87.3**	1106.7± 905.5*	Milk/chocolate milk	78.8**	299.0±333.2
	Tomatoes/ juice/ sauce	38.6	147.0±166.8	Non-citrus fruits	28.1*	45.6±66.8
Vitamin C	Citrus fruit juice	22.1	315.2±256.8	Citrus fruit juice	35.4**	299.8±230.1
	Citrus fruits	10.7	214.0±142.1	Citrus fruits	20.2**	203.7±151.1
	Non-citrus fruits	35.4	169.3±144.8	Non-citrus fruits	60.0**	191.8±162.3
	Other dark green vegetables	26.0	64.4±65.1	Other dark green vegetables	32.5*	69.6±70.8
	Tomatoes/ juice/sauce	7.47	397.4±364.4	Fruit drinks/juice drinks	35.4**	299.8±230.1
	Fruit drinks/juice drinks	22.1	315.2±256.8	Non-citrus fruit juice	32.5*	69.6±70.8
	Non-citrus fruit juice	26.0	64.4±65.1	Tomatoes/ juice/sauce	9.08	348.8±311.9
	Potatoes boiled/mashed	29.2	198.1±149.6	Dark yellow/orange vegetables	39.5	89.0±90.7

[1] Values are mean±SD Significantly different from smokers *** $p < 0.001$ ** $p < 0.01$ * $p = 0.05$ (χ^2 analysis or Student's tests) Please note: For some foods, * appear in the smokers' category. This is because the food did not appear in the first 8 foods in the non-smokers group but statistical testing was done
[2] Freq (%) refers to the number of subjects consuming the particular food on the day of recall
[3] Amount (g/d) refers to the mean intake among consumers of that food

Table 4

Average number of servings of Food Groups from Canada's Food Guide to Healthy Eating among men and women stratified by smoking status[1,2]

Food Groups	Men (n=571)		Women (n=970)	
	Smokers (n=127)	Non-smokers (n=444)	Smokers (n=181)	Non-smokers (n=789)
Grain products	6.2±4.0	7.2±4.6*	4.1±2.7	5.1±2.9*
Vegetables and fruit	4.0±3.7	5.6±4.1*	3.7±3.6	4.8±3.5*
Milk products	1.8±1.8	1.8±1.9	1.3±1.3	1.5±2.1
Meat and alternatives	3.4±2.9	3.4±2.7	2.1±2.1	2.0±1.8

[1]Values are means±SD

[2] $p \leq 0.05$ (Comparison of smokers vs. non-smokers stratified by sex, ANOVA with Scheffe's test)

Table 5

Ratio of intra-inter subject variability among men and women stratified by smoking status

Nutrient	Men (n=571)		Women (n=970)	
	Smokers (n=127)	Non-smokers (n=444)	Smokers (n=181)	Non-smokers (n=789)
Energy	1.19	1.05	1.06	1.69
Calcium	0.98	0.96	0.98	1.19
Iron	2.93	1.27	1.35	1.59
Zinc	1.62	1.99	0.84	1.84
Folate	0.82	1.47	1.13	1.41
Vitamin C	0.69	1.43	0.86	1.34

Table 6

Percentage of men and women meeting recommendations for calcium, iron, zinc, folate and vitamin C by stratified by smoking status[1]

Nutrient	Men (n=571)		Women (n=970)	
	Smokers (n=127)	Non-smokers (n=444)	Smokers (n=181)	Non-smokers (n=789)
Calcium (mg)	33.1	33.0	17.1	15.8
Iron (mg)	98.4	99.6	87.3	93.4**
Zinc (mg)	75.6	77.3	70.7	77.5
Folate (μg)	25.2	35.6*	8.3	12.8
Vitamin C (mg)	36.2	72.7***	39.2	77.2***

[1]Adjusted for within subject variability prior to calculating the prevalence of adequate intakes
Significantly different from smokers: *** $p<0.001$ ** $p<0.01$ *$p<0.05$ (χ^2 analysis)

Chapter 7

Discussion and Conclusion

The World Health Organization's Guide to Nutrition states that the ultimate purpose of dietary assessment is to improve human health (Beghin et al., 1988). Dietary assessment is also essential for investigating diet-disease relationships (Hu, 2002, Kromhout, 2002). Accurate measurement of diet is essential to establish the link between diet and disease. A number of methodological factors impact the accuracy of dietary measurements thereby influencing the interpretation of the data.

The present study examined methodological issues related to dietary surveys and how these issues may impact the interpretation of data. The objectives of the study were broken down into three questions: (1) what characteristics of the sampling areas were associated with response (2) how variable were the nutrient and food intakes using two different statistical methods and how many days of observations are needed to estimate nutrient and food intakes by two different methods of calculation, and, (3) how did one important health variable, smoking compare in terms of nutrient intake, variability of intake, food choices and adequacy of intake.

A discussion on dietary survey methodology should consider the sampling and response rate obtained. When those who are sampled refuse to participate then this is a matter of concern because those who do respond are likely to be different from those who do not respond. The overall response rate for the present study was 26% with a range by sampling area from 4% to 57%. Comparison of socio-demographic variables of the study sample with the census data indicated that those who were young, male, single and with less than high school level of education were underrepresented, thus limiting the generalizability of the study results to the general population. Examination of response rate by enumeration area indicated that the response rate varied by the characteristics of the communities. The main correlates of low response rate in enumeration areas were higher percentage of males, higher percentage below the low income cut-off levels, higher percentage speaking non-official languages as mother-tongue and higher percentage moved in the last 5 years, thereby indicating that large surveys may not be able to reach the hard-to-get groups who may have different dietary profiles. The reason why gender was an indicator of response rate is not known given the near equal ratio of males and females in each enumeration area. In a regression model with the percentage of males constant and changing the percentage of other predictors indicated that the response rate was nearly three times higher with positive indicators (higher percentage of non-movers and lower percentage below the low income cut-off levels and lower percentage speaking non-official languages as mother-tongue) compared to that obtained with lower levels of positive indicators. These indicate that different approaches for recruiting people may be needed depending on the characteristics of the enumeration areas chosen.

Measurement of usual food and nutrient intake should take variability into account because individuals vary in the type and amount of food consumed from one day to the next and also individuals differ from each other in food intakes. Several factors including age, gender, season, education and smoking status contribute to between subject variability. The need to adjust for factors contributing to variability was underscored in the study examining within- and between- subject variability. Higher variance ratios obtained from the mixed model procedure that adjusts for different factors (age, gender, smoking, education level, family size, season) indicated that not adjusting for the confounders results in estimations of fewer days of intake being needed to measure usual intake, which could then result in lack of power to detect differences. The variance ratios were higher for foods and food groups based on Canada's Food Guide to Healthy Eating compared to nutrients; individual foods had higher variance ratios compared to food groups as well. Using the variance components in the calculation for estimating the number of days required to measure usual intake indicated that more days are needed to assess nutrient intakes accurately for individuals compared to placing subjects relatively into groups. Greater variability in the intake of specific foods compared to whole food groups suggests that it is possible that two days of measured intake for each individual is not sufficient to get a true picture of day to day variability in some less routinely consumed foods; food frequency may therefore be a method of choice for foods. (Beaton et al., 1979)

Understanding nutrient inadequacies or excesses in sub-groups of the population is important to identify poor dietary habits and develop appropriate intervention programs to help individuals make healthy dietary and lifestyle choices. Comparison of smokers and non-smokers indicated that smokers had a poor diet compared to non-smokers in terms of higher saturated fat intake and lower folate and vitamin C intakes. These differences were reflected in their food choices with fewer smokers reporting consuming fruits and vegetables on the day of the recall and being more likely to consume carbonated beverages, coffee and tea. A lower percentage of smokers met the minimum suggested number of portions for fruits and vegetables compared to non-smokers. It was also hypothsized that the diets of smokers would be more variable than those of the non-smokers. However, no distinct patterns of variability in nutrient intake by smoking status were observed indicating that the diet of smokers is no more variable than that of non-smokers. Comparison of the adjusted nutrient intakes with the recommendations indicated that a greater percentage of smokers failed to meet the Estimated Average Requirement for vitamin C, indicating that the smokers are at higher risk for chronic disease both due to their smoking and poor dietary habits. Diet maybe a confounder when studying the relationship between smoking and chronic diseases suggesting the need to control for the confounding effect of diet. Failure to do so may result in an overestimation of the relative risk.

A common source of error reported in dietary studies is the systematic underreporting of intake by obese persons, women, elderly subjects, and, subjects from lower occupation categories or higher social class (Goris et al., 2000, Samaras et al., 1999, Lafay et al., 1997, Briefel et al., 1997, Stallone et al., 1997, Albanes et al., 1987). The doubly labeled water technique has been used to validate energy intake with energy expenditure. However, this method is expensive to be used in large surveys. An alternative method suggested by Goldberg et al. (1991) involves estimating basal metabolic rate by using information on weight, age and gender. The estimated basal metabolic rate when compared with the cut-off value of 1.35 feasible for survival (Goldberg et al., 1991) indicated that in the present study, women irrespective of their BMI and smoking status underreported energy intake. Underreporting may result from omission of foods and underreporting of portion sizes and frequency of intakes (Institute of Medicine, 2002). Evidence suggests that foods such as cakes, pastries, snacks, cheese, fried potatoes, meat mixtures, fish, poultry, milk, soft drinks and high fat foods are underreported (Krebs-Smith et al., 2000, Lafay et al., 2000, Bingham et al., 1995). Therefore it is not known if the intakes of some nutrients like calcium that are reported as low for women in studies, including the present study, truly reflect low intake of these nutrients.

Future recommendations

Considerable work needs to be done to improve response rates, measuring food intake as opposed to nutrients and handling underreporting, all of which are methodological issues that need to be considered in dietary surveys. The present research indicates how a general survey may not be successful in recruiting subjects who are the most vulnerable, particularly the poor and those from different ethnic and cultural groups. If nutrient intakes of low income or ethnic groups are to be examined then these sub-groups need to be studied exclusively by employing house-to-house interviews in specific areas with a large concentration of the interested segments of the population (Vital Health Statistics, 1993) in order to obtain relatively good response rates and also be representative of the group studied.

Because foods have been identified to have high variability requiring more days of observation to estimate food intakes accurately, the food frequency method may need to be the alternative method to study food-disease relationships. However, food frequency methods have generally been developed with nutrients in mind. By summarizing foods based on known nutrients, one may be missing out on other unknown factors in foods.

The problem associated with underreporting is challenging and needs to be evaluated further. One possible suggestion is to recruit obese subjects in a metabolic study and provide them with a wide range of food choices in known quantities at each meal. The subjects can be watched unobtrusively while they select the foods and consume their meals. The subjects can then be asked to recall the foods consumed, including description and amounts consumed, on the previous day. In addition, energy expenditure by doubly labeled water technique can be assessed and used to validate the reported energy intake.

A future goal of studies examining underreporting would be to develop adjustment techniques for energy and nutrient intakes that are likely to be underreported. Adjustment would be useful for large dietary surveys where it may be impractical to use extensive laboratory techniques to validate reported food and nutrient intakes.

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Appendix 1

Introductory Letter

FOOD HABITS OF CANADIANS

March 5, 1998

Dear Sir or Madam,

We are conducting an important study of the food habits of Canadians. This information is crucial for future public health initiatives and the agri-food sector. Your household was randomly selected from the telephone directory for inclusion in this survey. We hope you will agree to participate.

Your in-person interview will take approximately 30 minutes and focus on food habits. A professional dietitian will call you in the next two weeks to request an interview with the adult (age 18-65) in your household who has the next birthday. The interview may take place at your home or any other agreed upon location, at a convenient time. Some study participants will be asked to do a second, shorter interview at a later date. Our dietitian will be happy to answer questions you may have about your present diet.

If there are any adolescents (13-17 years) in your household, we would like to invite the adolescent with the next birthday to complete the same interview, with your consent. Our dietitian will discuss this with families with adolescents.

Thank you very much for considering this important request. All information collected will be kept strictly confidential and will be used only for research purposes. Your dietitian-interviewer is your contact person. If you have any concerns about this survey, please contact me.

Sincerely,

Louise Johnson-Down, RD, M.Sc.
Survey Coordinator

Louise Johnson-Down, RD, M.Sc.
McGill University, Macdonald Campus, 21,111 Lakeshore
Ste. Anne de Bellevue, Québec H9X 3V9
Tel: 514-398-7808; Fax: 514-398-7739; Email: czld@musica.mcgill.ca

Appendix 2

Telephone Log

FOOD CONSUMPTION STUDY (BIC)

Long Distance Telephone Call Record Sheet

Dietitian-Interviewer's Name: ______________________________

Date	Area Called	Area Code/Number	Respondent Name and Number

* Personal telephone bill with proof of payment must accompany this form. Keep a copy for your own records.

Appendix 3

Ethics

MCGILL UNIVERSITY
FACULTY OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

CERTIFICATE OF ETHICAL ACCEPTABILITY FOR RESEARCH INVOLVING HUMANS

The Faculty of Agricultural and Environmental Sciences Ethics Review Committee consists of 4 members nominated by t and Environmental Sciences Nominating Committee and elected by Faculty, an appointed member from the community ethical issues.

The undersigned considered the application for certification of the ethical acceptability of the project entitled:

Advances in the measurement of dietary intake

as proposed by:

Applicant's Name Katherine Gray-Donald

Supervisor's Name N/A

Applicant's Signature

Supervisor's Signature

Degree / Program / Course N/A

Granting Agency FRSQ

The application is considered to be:

A Full Review ______

An Expedited Review ✓

A Renewal for an Approved Project ______

A Departmental Level Review ______
Signature of Chair / Designate

The review committee considers the research procedures and practices as explained by the applicant in this application, t ethical grounds.

1. Prof. Robin Beech
Department of Parasitology

Signature / date

2. Prof. Peter Jones
School of Dietetics and Human Nutrition

Signature / date

3. Prof. Paula Ribeiro
Department of Parasitology

Signature / date

Signature / date

5. Member of the Community – L. Prichard

Signature / date

Edmund S. Idziak
Chair of the Faculty of Agricultural and Environmental Sciences Ethics Review Committee
MS3-036

Signature / date Jun 12/00

Revised May, 1999

Appendix 4

Sociodemographic Questionnaire

DETERMINATION OF THE FOOD AND NUTRIENT INTAKE OF CANADIANS

SOCIODEMOGRAPHIC QUESTIONNAIRE

Enumeration Area		___ ___
Respondent Number:	______________________ Name	___ ___
Age Group:	Adult 0 Child 1	___
Language of Interview:	English 1 French 2 Other 3: ______________	___
Respondent Gender:	Male 1 Female 2 (non-pregnant)	___
Date of Interview: ______________________		___ ___ d ___ ___ m
Day of the Week:	0 Sunday 1 Monday 2 Tuesday 3 Wednesday 4 Thursday 5 Friday 7 Saturday	___
Time Interview Started: ______________________		___ ___ h ___ ___ m

To begin, I would like to ask you some general questions about you

1. In what country were you born? ______________________ ___ ___ ___
   ** Country of Origin code sheet*

2. Please tell me your civil status: ___
   1 Single 3 Widowed
   2 Married/Common law 4 Divorced/Separated

3. And your birth date? ______________________ __ __ / __ __ / __ __ (d m y)
   calculate age to closest year ______________________

4. What is the last grade of schooling you completed? ___
   1 Elementary incomplete
   2 Elementary complete
   3 Secondary incomplete
   4 Secondary complete
   5 Technical/Trade school
   6 Junior college/CEGEP
   7 University
   8 Post-graduate education

5. Do you smoke more than five (5) cigarettes a day? ___
   1 Yes 2 No

6. In general, compared to people of your age, would you say your health is ___
   1 Excellent 2 Very Good 3 Good 4 Fair 5 Poor

   What is your height ______________ ; ______________ *cm* ___ ___ ___

   What is your weight ______________ ; ______________ *kg* ___ ___ ___ . ___

7. How many people live here on a regular basis? ______________ ___ ___
   Be sure to include yourself.

   How many are:
   < 13 y.o. ________ 13-17 ________ 18-65 ________ >65 ________ ___ ___ ___ ___

Appendix 5

24-hour recall form

FOOD HABITS OF CANADIANS

Respondent # ______________________________
Name

Day of the Week: 1 M 2 T 3 W 4 T 5 F 6 S 0 S

Date: ______________________________
Day Month

24-HOUR RECALL

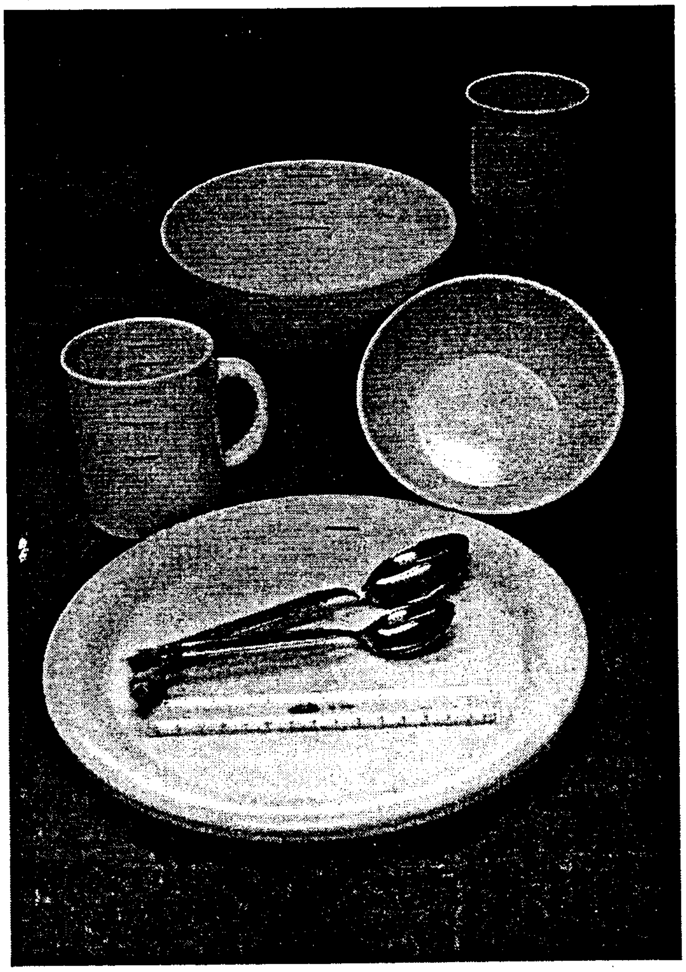
Time	Food Source*	Code	Description of Food Eaten and How Prepared	Amount Eaten
			water	
			supplement(s):	

* Where food came from, such as home, restaurant, takeout, delivery etc.

Appendix 6

Food models

Food Portion Models



Food Portion model	Measures indicated			Maximum capacity
Spoons				
Small		3.5 ml		6 ml
Large		7 ml		11 ml
Plates		250 ml		600 ml
Bowls				
Small	125 ml	250 ml	410 ml	525 ml
Large	250 ml	500 ml	875 ml	1100 ml
Mugs	225 ml	300 ml	350 ml	420 ml
Glasses	125 ml	250 ml	325 ml	375 ml

Appendix 7

Reprint Permission

Reprint Permission from The Journal of Nutrition for:

1. Fruit and vegetable Consumption is lower and saturated fat intake is higher among Canadians reporting smoking. Palaniappan, U., Jacobs-Starkey, L., O'Loughlin, J. & Gray-Donald, K. J. Nutr. 131:1952-1958, 2001.

2. Implications of day-to-day variability on measurement of usual food and nutrient intake. Palaniappan, U., Cue, R.I., Payette, H., & Gray-Donald, K. J.Nutr. (in press).

October 28, 2002

To
Karen King
Director of Communications
American Society for Nutritional Sciences

RECEIVED
OCT 2 8 2002
ASNS

Dear Ms.King,

Sub: Request for reprints

I am writing to request permission to reprint entire articles published in The Journal of Nutrition to be included as part of my doctoral thesis.

The articles include:

1.Fruit and Vegetable Consumption is Lower and Saturated Fat Intake is Higher among Canadians Reporting Smoking. J Nutr 131:1952-1958, 2001. Palaniappan, U., Jacobs-Starkey, L., O'Loughlin, J., Gray-Donald, K.

2. Implications of day-to-day variability on measurement of usual food and nutrient intake.
(Accepted October, 2002, Manuscript No. 2002/006015
Authors: Uma Palaniappan, Roger Cue, Helene Payette, Katherine Gray-Donald.)

I would require 10 reprints of each to be included in my thesis, which will be submitted to my examiners. The articles will be reproduced in its entirety without any change. I am the first author for both articles

I will be happy if you could fax your response to 514-398-7739 (Attention: Uma Palaniappan) or by e-mail:upalan@po-box.mcgill.ca. I look forward to hearing from you soon.

Sincerely,

Uma Palaniappan

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Per:
Executive Officer, ASNS

10/28/02

** TOTAL PAGE.001 **

Appendix 8

Reprint

Fruit and vegetable Consumption is lower and saturated fat intake is higher among Canadians reporting smoking. Palaniappan, U., Jacobs-Starkey, L., O'Loughlin, J. & Gray-Donald, K. J. Nutr. 131:1952-1958, 2001.

Fruit and Vegetable Consumption Is Lower and Saturated Fat Intake Is Higher among Canadians Reporting Smoking[1]

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ABSTRACT Understanding differences in dietary patterns by smoking status is important for nutritionists and health educators involved in helping individuals to make healthy dietary and lifestyle choices. Although smokers have a poor quality diet compared with nonsmokers, no study has examined nutritional adequacy and variability in the nutrient intake of smokers. The aim of this study was to compare dietary habits of smokers with nonsmokers in terms of nutrient intake, food groups contributing to nutrient intake, nutritional adequacy and day-to-day variation in nutrient intake. Noninstitutionalized adults aged 18–65 y (n = 1543) who participated in the Food Habits of Canadians Survey (1997–1998) were studied. Subjects, selected from across Canada using a multistage, random-sampling strategy, completed an in-home 24-h dietary recall. Repeat interviews were conducted in a subsample to estimate variability in nutrient intake. Smokers had higher intakes of total and saturated fat, and lower intakes of folate, vitamin C and fiber than nonsmokers. There were no significant differences in calcium, zinc and vitamin A intakes or day-to-day variation in nutrient intake by smoking status. Smokers consumed significantly fewer fruits and vegetables than nonsmokers, leading to lower intakes of folate and vitamin C. In conclusion, smokers have a less healthy diet than nonsmokers, placing them at higher risk for chronic disease as a result of both dietary and smoking habits. Diet may act as a confounder in smoking-disease relationships. J. Nutr. 131: 1952–1958, 2001.

KEY WORDS: • *smokers and nonsmokers* • *nutrient intake* • *food groups* • *supplement use* • *humans*

Smoking is a major risk factor for cardiovascular disease, respiratory disease and cancer (1). It has been postulated that the increased risk for these diseases among those who smoke compared with those who do not smoke may be due in part to differences in other lifestyle behaviors, including dietary habits (2). In the second National Health and Nutrition Examination Survey (NHANES II),[3] people who smoke reported lower intakes of vitamin C, folate, fiber and vitamin A than those who do not smoke (3). People who report smoking also tend to have higher intakes of saturated fatty acids and lower intakes of polyunsaturated fat, iron, β-carotene and vitamin E compared with people who do not smoke (4–8); in addition, they tend to differ in the way they select their food. They are more likely to choose white bread, sugar, meat, butter, whole milk and eggs and less likely to consume whole-wheat bread, high fiber breakfast cereals, fruits and vegetables than nonsmokers (9,10). In addition to a poorer diet, people who smoke are also exposed to free radicals, produced by cigarette smoke, which could provoke lipid peroxidation in cell membranes (1,11,12). Several studies have shown that micronutrients such as vitamin A, particularly β-carotene, vitamin C, vitamin E, folic acid and phenolic compounds derived from fruits and vegetables have protective effects against cigarette smoke–induced toxicity by preventing lipid peroxidation (1,13). Because those who smoke have low intakes of fruits and vegetables that are rich in antioxidants, they are more likely to be susceptible to oxidative damage caused by free radicals.

Indeed, people who smoke have a poor quality diet in terms of nutrient intakes and food choices. There is, however, a lack of data on nutritional adequacy and variability in nutrient intake among people who smoke. Examination of the main food group contributors to nutrient intake (for example, folate, vitamin C) by smoking status will provide insight on food choices responsible for differences in nutrient intake. Also, few studies that have examined smoking and diet have controlled for socioeconomic status.

Data used in the study are from the Food Habits of Canadians Survey conducted in 1997–1998, which is the most recent national nutrition survey in Canada (14). The aim of this study was to assess how dietary habits of those who smoke differ from those who do not smoke in terms of nutrient

[1] Supported by Fonds de la recherche en santé du Québec and the Beef Information Center with funds obtained from the Beef Industry Development Fund.

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[3] Abbreviations used: AI, adequate intake; BMI, body mass index; BMR, basal metabolic rate; EAR, estimated average requirements; EI, energy intake; NHANES, National Health and Nutrition Examination Survey; RE, retinol equivalents.

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intake, contribution of food groups to nutrient intake, nutritional adequacy and within-subject variability in nutrient intake.

SUBJECTS AND METHODS

A sample of 1543 noninstitutionalized adults aged 18–65 y was randomly selected from five regions of Canada, including the Atlantic Provinces, Quebec, Ontario, the Prairie provinces and British Columbia, using a multistage, random-sampling strategy (14). The Canadian population living in more remote regions (15%) was not sampled due to cost considerations. In each region studied, four census divisions were randomly selected with the probability of selection being proportional to the size of the population. This yielded 20 census divisions across the country. Two subdivisions were randomly selected within each census division, and two enumeration areas were selected within each subdivision, yielding 80 enumeration areas. Within each enumeration area a random sample of households was drawn from the 1996 computerized telephone listings of residential homes in each area (Pro-CD, Mass, Canada). Letters were sent to inform household occupants of the survey and to invite the participation of the adult member in the household with the next upcoming birthday. The letter was followed by a telephone call from a dietitian-interviewer to arrange a face-to-face interview. The criteria for exclusion included pregnancy and lactation, and inability to speak English or French. The final sample included 572 men and 971 women. Approximately 17% of potential subjects could not be contacted; 57% refused to participate, resulting in an average response rate of 26%. Survey data were compared with the 1991 Census data (15). The sociodemographic profile of the study sample was found to be comparable to that of the general Canadian population (number of people born in Canada: 86 vs. 84%; number of subjects with less than high school education: 22 vs. 26%; and single marital status: 26 vs. 32%, respectively) (14). In addition, the percentage of adults reporting a body mass index (BMI) of >27 kg/m^2 was 32% in our study and 31% in the National Population Health Survey (15). The percentage of adults (≥18 y of age) reporting smoking in our study was 20% and in the Canadian Tobacco Use Monitoring Survey was 28% (16). A repeat interview was conducted in a systematic sample of 22% of subjects to estimate within-subject variability in nutrient intake.

Self-reported height, weight, smoking status and educational level were collected. Subjects who answered yes to the question "Do you smoke >5 cigarettes per day?" were categorized as smokers; all others were categorized as nonsmokers. This level was chosen as the cut-off point to determine smoking status because it is difficult to categorize the small number of people who smoke very little. The average number of cigarettes used by smokers is 19 cigarettes/d in Canada (16). Three levels of education included the following: *1*) high school (Grade 11) or less; *2*) preuniversity (2-y program) or trade school; and *3*) a university degree. Education was used as an indicator of socioeconomic status.

Dietary intake was recorded by the dietitians using the 24-h recall method (17). Detailed descriptions of all foods, beverages and supplements consumed during the 24-h period before the interview, including the quantity, cooking method and brand names were recorded. Quantities were estimated using standard graduated glasses, bowls, spoons and a ruler. Quality control was ensured during dietary data collection and entry to minimize error and increase reliability (18). Dietitians were trained to use research forms, tools, and a food and nutrient database that were used for coding. Furthermore, they resided in the regions surveyed, ensuring familiarity with the local food supply and food preparation methods. An adapted multiple-pass technique was employed (19); the subjects were first asked to recall their food intake over the previous 24-h period, followed by probing for detailed descriptions of food, beverages and supplements including food portion sizes, and then by a review of intake and clarifications.

Nutrient intakes were entered, double verified by another person and analyzed using the Candat nutrient analysis program (Godin London, London, Canada) and the 1997 Canadian Nutrient File. Approximately 270 food items were added to the database, because they were not available on the Canadian Nutrient File. Nutrient information was obtained from food manufacturers' data when possible or from the American database (20). The nutrient database includes >5000 food items and 40 nutrients. Folic acid supplementation of flour in Canada occurred after the data collection.

Foods were classified into 51 food groups for the purposes of describing types of foods in the following manner: fruits were classified as citrus and noncitrus fruits (due to differences in vitamin C content). Vegetables were categorized according to specific nutrient contribution by each subgroup (lettuce/cabbage/greens, other dark green vegetables, dark yellow/orange vegetables, tomatoes, potatoes and non-dark green vegetables). Dairy products were grouped as milk, cheese, yogurt, cream and ice cream/pudding. The meat group was classified according to the type of meat (beef, pork, poultry, bacon/sausages/lunchmeats, fish/seafood, organ meats, lamb and other meats). Grain products were categorized as breads, pasta/rice/grains, cereals and mixed dishes. The alcohol group included beer, alcoholic coolers, liquor and wine. Other foods were broken into clear categories such as sugar/syrup/gelatin, carbonated beverages, candies/chocolates. These food groups were used to determine the main contributors to nutrient intake (carbohydrate, fat, folate and vitamin C) by smoking status. The percentage of subjects consuming the food on the day of the intake and the average amount of that food eaten by consumers were analyzed and compared using χ^2 and t tests.

To determine whether subjects in the two smoking categories met the recommendations for food groups based on Canada's Food Guide to Healthy Eating (21), foods were categorized into the following food groups: grains, dairy, meat, and fruits and vegetables. Food portions were determined using food density (g/mL), and all foods with very similar densities within a category were divided by the same weight of a standard portion size to obtain units of portion size (e.g., cooked rice or pasta = 70 g in the grain products food group; corn/other vegetables = 85 g in the vegetables and fruit group). In addition, the Good Health Eating Guide Resource (22) was consulted to determine weights for some foods and also to establish how many portions of each food group went into each of the mixed foods. Mixed food groups were broken down into constituents for contribution to the four food groups (e.g., one cheese pizza = 1 grain product and 0.2 milk product).

Data were collected on supplement use on the day of the recall. Supplement composition was determined using the Health Canada Drug Product Database (23), product labels or by contacting the company. When adequate information was not available to identify brand or amount of nutrient present in the supplement, default values were assigned on the basis of the modal value for the supplement. For vitamin B complex preparations, the lowest values found in any identified supplements were used.

Nutrients examined in this analysis include calcium (mg), iron (mg), zinc (mg), folate (μg), vitamin A [retinol equivalents (RE)], vitamin C (mg) and fiber (g) as well as total fat, saturated fat, monounsaturated fat and alcohol, which are expressed as percentage of energy. Carotenoid data are not available in the Canadian Nutrient file. These nutrients were chosen because the mean percentage of energy from fat and saturated fat are generally above the Nutrition Recommendations of 30 and 10%, respectively (24); vitamin C is a nutrient of concern for those who smoke (25), whereas calcium, iron and folate are often below recommended levels in Canadians (14,24,26). Zinc was also assessed because of its role in limiting free radical–induced oxidative damage (27).

The distribution of each nutrient was examined for normality, and appropriate transformations (log and square root) were performed for nutrients with skewed distributions (28). However, an appropriate transformation was not found for alcohol. Using the subsample with 2 d of intake, inter- (between) and intra- (within) subject variability were estimated separately for men and women by ANOVA (29). Using this measure of variation, the entire study population distribution was adjusted for within-subject variability using the NRC method (30). Differences in nutrient intake by smoking status were assessed separately for men and women using the general linear method of ANOVA, adjusting for education. Multiple comparisons were corrected for using Scheffé's method (29). Possible effect modification by level of education and age was examined by including interaction terms for smoking and education and smoking and age.

A comparison of the day-to-day variability between people who

TABLE 1

Demographic characteristics of subjects by smoking status

	Men (n = 571)		Women (n = 970)	
	Smokers (n = 127)	Nonsmokers (n = 444)	Smokers (n = 181)	Nonsmokers (n = 789)
Age,[1] y	42 ± 11	44 ± 11	44 ± 10	44 ± 11
Education level,[2] n (%)				
≤High school	67 (53%)	154 (35%)	106 (59%)	340 (43%)
Preuniversity/Trade	29 (23%)	106 (24%)	45 (25%)	206 (26%)
University	31 (24%)	184 (41%)	30 (16%)	243 (31%)
BMI,[1] kg/m2	26.4 ± 4.3	26.8 ± 4.0	24.9 ± 4.6	25.5 ± 5.1

1 Values are means ± SD.
2 P = 0.001 (χ^2 analysis).

smoked and people who do not smoke was examined by computing intra- (within) to inter- (between) subject variability ratio for energy, calcium (mg), folate (μg), vitamin A (RE), vitamin C (mg), zinc (mg) and iron (mg).

The percentage meeting the National Academy of Science Recommendations for calcium (adequate intake, AI), iron, zinc, folate and vitamin C (estimated average requirement, EAR) was examined (25,31–33) by smoking status.

To assess underreporting of food intake, the ratio of reported energy intake (EI) to estimated energy requirements (estimated basal metabolic rate, BMR_{est}) was calculated separately for men and women by smoking status. BMR was calculated from the reported height and weight using the FAO/WHO/UNU formula (34) and is reported as BMR_{est}. All analyses were performed using SAS (version 6.12, Cary, NC).

RESULTS

There were no significant differences by smoking status in age or BMI among men and women. However, those who smoked had less education than those who did not smoke (P < 0.001) (Table 1).

Total energy intake did not differ by smoking status (Table 2). However, people reporting smoking consumed more total fat and saturated fat and significantly less folate, vitamin C and fiber than those who did not report smoking. There were no significant differences in calcium, zinc or vitamin A intakes by smoking status. Although most patterns of intake were very similar in men and women, men who smoked consumed more monounsaturated fat and women who smoked consumed less iron than people who did not smoke. The percentage of subjects consuming alcohol did not differ between the two smoking groups. Alcohol consumption among women who reported drinking alcohol was higher in those who reported smoking (Wilcoxon test, $P < 0.01$). There was no interaction of smoking by education level on nutrient intake. There were no interactions by age and smoking status for most nutrients with the exception of folate intake, which was higher among nonsmoking women in the 35–49 and 50–65 y age groups; among young women, however, there was no association of smoking status with folate intake.

The mean EI/BMR_{est} for men who smoked and did not smoke was 1.44 ± 0.61 and 1.44 ± 0.58, respectively, indicating little if any underreporting. The mean EI/BMR_{est} for females who smoked vs. those who did not smoke was 1.23 ± 0.62 vs. 1.28 ± 0.53, respectively, indicating underreporting in both groups. The EI/BMR_{est} ratio was similar across BMI categories (<20, ≥20–25, ≥25–<27 and ≥27 kg/m^2).

Food groups. Food choices differed by smoking status (Table 3). Because men and women reported similar food group choices contributing to carbohydrate, fat, vitamin C and folate intakes, results are reported by smoking status alone. The order in which foods appear in the table is the order in which each food contributed to the overall nutrient intake of the study sample. The frequency of consumption on the day of recall and mean intake of each food by the consumers of that food are reported. The differences in food group intake for primary sources of carbohydrate indicated that those who did not smoke were more likely to consume pasta, cakes/cookies, noncitrus fruits, cereals and milk. The portion sizes of cereals were larger for smokers. Other differences were apparent in food sources of folate and vitamin C, indicating better food choices among people who do not smoke. Although, overall, the most important contributors to folate and vitamin C were fruits and vegetables in both groups, significantly fewer smokers reported consuming different categories of fruits and veg-

TABLE 2

Nutrient intakes stratified by men and women smoking status[1,2]

	Men (n = 571)		Women (n = 970)	
Nutrient	Smokers (n = 127)	Nonsmokers (n = 444)	Smokers (n = 181)	Nonsmokers (n = 789)
Energy, kcal	2544 ± 810	2562 ± 826	1650 ± 541	1726 ± 463
kJ	10,634 ± 3386	10,709 ± 3453	6897 ± 2261	7215 ± 1935
Total fat, % of total energy	31.2 ± 7.09	29.5 ± 6.68*	29.5 ± 6.70	28.5 ± 5.90*
Saturated fat, % of total energy	10.3 ± 3.10	9.39 ± 2.87*	9.85 ± 2.95	9.09 ± 2.69*
Monounsaturated fat, % of total energy	12.1 ± 3.06	11.3 ± 3.32*	11.0 ± 2.99	10.6 ± 2.57
Calcium, mg/d	943 ± 491	976 ± 517	693 ± 346	733 ± 334
Iron, mg/d	16.9 ± 6.73	18.0 ± 6.16	11.6 ± 4.59	12.6 ± 3.85*
Zinc, mg/d	13.6 ± 6.52	13.4 ± 4.95	9.23 ± 5.18	9.30 ± 3.74
Folate, μg/d	254 ± 108	299 ± 130*	197 ± 112	225 ± 91*
Vitamin A,[3] RE/d	1622 ± 968	1745 ± 1115	1601 ± 1923	1971 ± 1953
Vitamin C, mg/d	120 ± 107	152 ± 117*	95 ± 79	130 ± 87*
Fiber, g/d	13.7 ± 6.43	17.5 ± 8.76*	11.5 ± 6.92	14.0 ± 6.87*

1 Values are means ± SD (adjusted for within-subject variability by sex).
2 $P \leq 0.05$ (comparison of smokers vs. nonsmokers stratified by sex, ANOVA with Scheffé's test).
3 RE, retinol equivalents.

TABLE 3

Food groups contributing to intakes of carbohydrate, fat, folate and vitamin C by smokers and nonsmokers[1]

	Smokers (n = 308)			Nonsmokers (n = 1233)		
Nutrient	Food group	Freq[2]	Amount[3]	Food group	Freq[2]	Amount[3]
		%	*g/d*		%	*g/d*
Carbohydrate	Breads	87.3	98.1 ± 72.8	Breads	86.6	110.0 ± 78.0*
	Carbonated beverages	42.9	720.1 ± 540.6	Pasta/rice/grains	40.6**	231.4 ± 215.4
	Sugar/syrups/jams/ gelatin/cocoa mixes	61.7	45.8 ± 119.9	Cakes/cookies/pies/ granola bars	48.1**	81.6 ± 86.8
	Pasta/rice/grains	27.0	227.2 ± 173.2	Noncitrus fruits	60.0**	191.8 ± 162.3
	Cakes/cookies/pies/ granola bars	38.6	77.1 ± 81.6	Cereals	36.9**	85.0 ± 94.4*
	Potatoes boiled/mashed	29.2	198.1 ± 149.6	Carbonated beverages	36.7*	525.2 ± 350.6***
	Milk/chocolate milk	70.5	326.6 ± 322.4	Milk/chocolate milk	78.8**	299.0 ± 333.2
	Cereals	22.7	114.8 ± 134.5	Potatoes boiled/mashed	28.2	200.7 ± 165.1
Fat	Beef/Veal	32.5	153.0 ± 127.3	Cakes/cookies/pies/ granola bars	48.1**	81.6 ± 86.8
	Margarine/butter/ lard	63.6	12.6 ± 16.5	Breads	86.6	98.2 ± 73.0*
	Cheese	38.6	77.1 ± 73.7	Margarine/butter/lard	57.6	11.5 ± 31.3
	Sausages/bacon/ lunch meats	32.5	153.0 ± 127.3	Beef/veal	27.5	133.9 ± 118.4
	Breads	87.3	110.0 ± 78.0	Cheese	48.1**	81.6 ± 86.8
	Cakes/cookies/pies/ granola bars	38.6	77.1 ± 73.7	Sausages/lunchmeat/ bacon	27.5	133.9 ± 118.4
	Milk/chocolate milk	70.5	326.6 ± 322.4	Mixed meat/poultry/ fish dishes	15.9	223.3 ± 220.2
	Mixed meat/poultry/ fish dishes	15.6	183.0 ± 134.5	Milk/chocolate milk	78.8*	299.0 ± 333.2
Folate	Breads	87.3	98.2 ± 72.8*	Citrus fruit juice	35.4**	300.0 ± 231.1
	Lettuce/greens/cabbage	30.5	87.1 ± 101.6	Lettuce/greens/cabbage	38.9*	81.0 ± 82.8
	Citrus fruit juice	22.1	315.2 ± 300.0	Breads	86.6	109.7 ± 78.0
	Other non-dark green vegetables	52.9	90.0 ± 120.5	Other non-dark green vegetables	63.3**	83.0 ± 88.8
	Hamburger/pizzas	9.74	224.8 ± 219.2*	Legumes/nuts/seeds	28.1*	45.6 ± 66.7
	Milk/chocolate milk	70.5	326.6 ± 322.4	Other dark green vegetables	32.5*	69.6 ± 70.8
	Coffee/Tea	87.3**	1106.7 ± 905.5*	Milk/chocolate milk	78.8**	299.0 ± 333.2
	Tomatoes/juice/sauce	38.6	147.0 ± 166.8	Noncitrus fruits	28.1*	45.6 ± 66.8
Vitamin C	Citrus fruit juice	22.1	315.2 ± 256.8	Citrus fruit juice	35.4**	299.8 ± 230.1
	Citrus fruits	10.7	214.0 ± 142.1	Citrus fruits	20.2**	203.7 ± 151.1
	Noncitrus fruits	35.4	169.3 ± 144.8	Noncitrus fruits	60.0**	191.8 ± 162.3
	Other dark green vegetables	26.0	64.4 ± 65.1	Other dark green vegetables	32.5*	69.6 ± 70.8
	Tomatoes/juice/sauce	7.47	397.4 ± 364.4	Fruit drinks/juice drinks	35.4**	299.8 ± 230.1
	Fruit drinks/juice drinks	22.1	315.2 ± 256.8	Noncitrus fruit juice	32.5*	69.6 ± 70.8
	Noncitrus fruit juice	26.0	64.4 ± 65.1	Tomatoes/juice/sauce	9.08	348.8 ± 311.9
	Potatoes boiled/mashed	29.2	198.1 ± 149.6	Dark yellow/orange vegetables	39.5	89.0 ± 90.7

[1] Values are mean ± SD. Significantly different from smokers *** $P < 0.001$ ** $P < 0.01$ * $P = 0.05$ (χ^2 analysis or Student's t test). Please note: For some foods, * appear in the smokers' category. This is because the food did not appear in first 8 foods in the non-smokers group but statistical testing was done.
[2] Freq (%) refers to the number of subjects consuming the particular food on the day of recall.
[3] Amount (g/d) refers to the mean intake among consumers of that food.

etables on the day of the recall and they were more likely to consume carbonated beverages, coffee and tea.

The average number of servings of vegetables and fruit fell below the minimum suggested number of 5 servings/d for people of both sexes who smoke (**Table 4**). Only 30% of people who smoke compared with 48% of people who do not smoke ($\chi^2 < 0.001$) met the minimum suggested number of portions for fruits and vegetables.

Variability in eating pattern. Day-to-day variability in nutrient intake was compared to evaluate whether people who smoke had more variable intakes of nutrients. Intra/intersubject ratios were generally >1 for all nutrients examined (Table

TABLE 4

Average number of servings of food groups from Canada's Food Guide to Healthy Eating among men and women stratified by smoking status[1,2]

	Men (n = 571)		Women (n = 970)	
Food groups	Smokers (n = 127)	Nonsmokers (n = 444)	Smokers (n = 181)	Nonsmokers (n = 789)
Grain products	6.2 ± 4.0	7.2 ± 4.6*	4.1 ± 2.7	5.1 ± 2.9*
Vegetables and fruit	4.0 ± 3.7	5.6 ± 4.1*	3.7 ± 3.6	4.8 ± 3.5*
Milk products	1.8 ± 1.8	1.8 ± 1.9	1.3 ± 1.3	1.5 ± 2.1
Meat and alternatives	3.4 ± 2.9	3.4 ± 2.7	2.1 ± 2.1	2.0 ± 1.8

1 Values are means ± SD.
2 $P \leq 0.05$ (comparison of smokers vs. nonsmokers stratified by sex. ANOVA with Scheffé's test).

TABLE 6

Percentage of men and women stratified by smoking status meeting recommendations for calcium, iron, zinc, folate and vitamin C[1]

	Men (n = 571)		Women (n = 970)	
Nutrient	Smokers (n = 127)	Nonsmokers (n = 444)	Smokers (n = 181)	Nonsmokers (n = 789)
	%			
Calcium, *mg*	33.1	33.0	17.1	15.8
Iron, *mg*	98.4	99.6	87.3	93.4**
Zinc, *mg*	75.6	77.3	70.7	77.5
Folate, *μg*	25.2	35.6*	8.3	12.8
Vitamin C, *mg*	36.2	72.7***	39.2	77.2***

1 Adjusted for within subject variability before calculating the prevalence of adequate intakes. Significantly different from smokers: *** $P < 0.001$ ** $p < 0.01$ * $P < 0.05$ (χ^2 analysis).

5). There were no distinct patterns in variability by smoking status.

Comparison of nutrient intake with Dietary Reference Intake. To examine whether people who smoke met the recommended levels of intake despite lower intakes of some nutrients, we analyzed the percentage of men and women meeting the Dietary Reference Intake for calcium (AI), folate, vitamin C, iron and zinc (EAR) by smoking status (**Table 6**) (25,31–33). A greater percentage of people who smoke failed to meet the EAR for smokers for vitamin C ($\chi^2 < 0.001$). Most men met the EAR for iron, irrespective of smoking status (98 vs. 99.5%), whereas for women, a smaller percentage of those who smoked met the EAR for iron (87% of those who smoke vs. 93% of those who do not smoke, $\chi^2 < 0.01$). Most people in both smoking categories met the EAR for zinc. Most women, irrespective of smoking status, had mean intakes below the EAR for folate. Stratification by education level did not modify these relationships.

Supplement use. Overall, 38.5% of subjects reported using dietary supplements. People who smoked were less likely to take dietary supplements (21.3 vs. 29.7% among men, $\chi^2 < 0.001$ and 37 vs. 43.5% among women, $\chi^2 < 0.001$). Women who reported not smoking were more likely to take calcium supplements than women who reported smoking (18 vs. 10%, $\chi^2 < 0.05$).

TABLE 5

Ratio of intra- and intersubject variability among men and women stratified by smoking status

	Men (n = 571)		Women (n = 970)	
Nutrient	Smokers (n = 127)	Nonsmokers (n = 444)	Smokers (n = 181)	Nonsmokers (n = 789)
Energy	1.19	1.05	1.06	1.69
Calcium	0.98	0.96	0.98	1.19
Iron	2.93	1.27	1.35	1.59
Zinc	1.62	1.99	0.84	1.84
Folate	0.82	1.47	1.13	1.41
Vitamin C	0.69	1.43	0.86	1.34

DISCUSSION

Our results suggest important dietary differences between those who smoke and those who do not. Those who smoke had relatively higher intakes of fat and saturated fat, and lower intakes of folate, vitamin C and fiber. Food choices by smoking group support the observed nutrient differences.

Several studies have reported that antioxidants such as ascorbic acid may attenuate adverse health effects associated with cigarette smoking by scavenging the free radicals produced by tobacco smoke (2,13). However, the intake of antioxidants by smokers is low, placing them at higher risk of oxidative stress (9,35,36). High intake of saturated fat raises total cholesterol and LDL cholesterol levels and is a risk factor for coronary heart disease (37). People who smoke tend to have high intakes of saturated fat and also to have increased levels of VLDL cholesterol and low HDL cholesterol levels (38). In addition, low folate intake is a risk factor for coronary heart disease and certain forms of cancer (39). On the basis of our results, we find that people who smoke have slightly higher intakes of total fat and saturated fat (9%) and lower intakes of folate (14%), vitamin C (24%) and fiber (23%). This is consistent with those reported in other populations (3,6). Although the differences may appear small, such dietary differences are predicted to be associated with higher levels of cardiovascular disease risk and decreased life expectancy (40). Consequently, in addition to the toxic effects of smoke, those who smoke are at increased risk of developing chronic diseases related to diet.

Although fruits and vegetables were among the most important contributors to folate and vitamin C, a smaller proportion of smokers consumed these foods, leading to lower mean intakes of these two vitamins. This effect was consistent among several food groupings of fruits and vegetables, which is consistent with other studies (3,41,42). The average number of servings of fruits and vegetables was below the minimum recommended 5 servings/d for people of both sexes who smoked. Possible reasons for lower consumption of fruits and vegetables include changes in taste acuity induced by smoking that could influence food choices (2). Finally, several studies suggest that those who smoke and those who do not have different health priorities and habits (43–45).

People who do not smoke were more likely to use supplements, particularly nonsmoking women who were more likely to take calcium supplements than women who smoke supporting other studies indicating a healthier lifestyle among those who do not smoke (46,47).

Diet may be a confounder when studying the relationship between smoking and chronic disease. Those who smoke have been reported to have higher intakes of saturated fat and in addition, to have unfavorable lipid and lipoprotein levels (38) so that the effects of smoking and diet are acting in the same direction. Therefore, failure to control for the confounding effect of diet when examining the relationship between smoking and chronic diseases may result in overestimation of relative risk.

Two methodological issues not addressed in earlier studies on diet and smoking status include EI:BMR_{est} and intra- and intersubject variability that were examined in this study. In our study, the mean EI/BMR_{est} values for men and women were similar to those reported in NHANES III and other studies (48,49). Although men appear to report adequate intakes, the mean EI/BMR_{est} among women was ~1.25, below the cut-off value of 1.35, indicating underreporting (50). The lower EI/BMR_{est} values for women appear to be a problem in surveys (51). The similar EI/BMR_{est} values among those who smoke and do not smoke provide evidence that underreporting was similar in the two smoking groups.

People who smoke did not report higher variability in nutrient intakes. The lack of difference in day-to-day variation indicates that the diet of those who smoke is no more variable than that of those who do not smoke.

Previous studies reporting on differences in BMI by smoking group have found differing results, with some reporting lower BMI among smokers and others, including our results, not showing any differences in BMI (9,52–56). There is similar disagreement in the literature concerning whether energy intakes are higher among smokers or not (6,10,53).

The extent to which we can generalize these results to the Canadian population is limited by the low response rate achieved. Response rates to health surveys appear to be dropping (57,58). The sample, however, appeared to be representative of the sociodemographic profile of Canadians.

In conclusion, those who smoke consumed a less healthy diet than those who do not smoke. The finding that nutrient and food group intake varied by smoking status has public health implications because the less healthy dietary patterns of those who smoke place them at an even greater risk for developing chronic disease than those who do not smoke. Studies examining smoking disease relationships should control for the confounding effect of diet, given these consistent findings for nutrient intakes from both food and supplement sources.

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Appendix 9

Acceptance letter from Journal of Nutrition-

Implications of day-to-day variability on measurement of usual food and nutrient intake. Palaniappan, U., Cue, R.I., Payette, H., Gray-Donald, K. J. Nutr. Vol. 133:232-235, 2003.

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Sent: Thursday, October 24, 2002 8:33 AM
Subject: Journal of Nutrition -- Manuscript Decision

RE: NUTRITION/2002/006015
Implications of day-to-day variability on measurement of
usual food and nutrient intake
K. GRAY-DONALD

Dear Dr. GRAY-DONALD:

As a follow-up to previous correspondence, The Journal of Nutrition is pleased to inform you that the manuscript entitled "Implications of day-to-day variability on measurement of
usual food and nutrient intake" has been accepted for publication. You will be sent page proofs in 4-6 weeks. Please proofread, correct, and return them within 48 hours of receipt.

Again, thank you for submitting your manuscript to The Journal of Nutrition.

Sincerely yours,

Editor, The Journal of Nutrition
Associate Professor
Cornell University

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Appendix 10

Reprint

Implications of day-to-day variability on measurement of usual food and nutrient intake. Palaniappan, U., Cue, R.I., Payette, H., Gray-Donald, K. J. Nutr. Vol. 133:232-235, 2003.

Implications of Day-to-Day Variability on Measurements of Usual Food and Nutrient Intakes[1,2]

(Manuscript received 8 June 2002. Initial review completed 10 July 2002. Revision accepted 18 October 2002.)

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ABSTRACT **Day-to-day variability in dietary intake makes it difficult to measure accurately the "usual" intake of foods and nutrients. The objectives of the present study were to estimate within- and between-subject variability for foods and nutrients by adjusted and unadjusted models and to assess the number of days required to assess nutrient and food group intakes accurately by two different methods. Adult men and women aged 18–65 y ($n = 1543$) in the Food Habits of Canadians Study provided a 24-h recall. A repeat interview was conducted in a subsample to estimate components of variability. Within- and between-subject variability were determined by mixed model procedure (crude and adjusted for age, gender, education, smoking, family size and season). The number of days required to obtain various degrees of accuracy was ascertained by two methods, one that uses the variance ratio for groups and one that considers within-subject variability alone for individuals. Variance ratios were higher using the adjusted compared with the unadjusted method (e.g., for men, energy 1.07 vs. 0.49). More days were required to reflect usual intake with accuracy using the adjusted model (energy 5 vs. 2 d), indicating the need to control for confounders to obtain reliable estimates of intakes.** J. Nutr. 133: 232–235, 2003.

KEY WORDS: • within-person variability • between-person variability • 24-h recall • dietary methodology

An increasing number of studies point to dietary intake as a risk factor for numerous chronic diseases (1). Accurate measurement of usual intake, which refers to long-term average daily nutrient intake of an individual (2), is required to make links between diet and disease. Because dietary intake of an individual is not constant from day to day (3), an understanding of variability in food intake is required to estimate usual intake. Variability in food intake arises both because each individual differs in the types and amounts of food consumed from one day to the next (within- or intra-subject variability) (4) and because individuals differ from each other in their food intakes (between- or inter-subject variability) (5,6). Variability in dietary intake influences the number of days required to estimate food and nutrient intakes accurately. The number of days required to obtain reliable estimates of food and nutrient intakes for individuals (4,7) varies from that required to classify individuals correctly into groups for analytical purposes (8,9).

A number of studies have examined within- and between-subject variability for different nutrients (7,8,10,11); however, less work has been done on variability in food intakes (12,13). With increasing interest in the association between foods and disease risk (14,15), a clearer understanding of variability in food intakes is important.

When ≥2 d of intake data are available, both between- and within-subject variability can be determined by ANOVA (7,8,16–19). Mixed models that take into account both fixed and random effects are now available (20). These models can be used to control for other factors that may influence variability.

The objectives of the present study are to compare ratios of within- to between-subject variability for foods and nutrients by the mixed model procedure, adjusting for several factors with the mixed model procedure unadjusted for other factors, and to estimate the number of days required to classify subjects correctly into groups using within- and between-subject variances and the number of days required to assess usual intakes for individuals with accuracy using within-subject variability alone in the calculation.

SUBJECTS AND METHODS

Dietary data used in the study are from the Food Habits of Canadians Survey, the most recent national survey in Canada, conducted between September 1997 and August 1998. A description of the sample design and selection is provided elsewhere (21). Briefly, a sample of 1543 noninstitutionalized adults aged 18–65 y was randomly selected from five regions of Canada, including the Atlantic provinces, Quebec, Ontario, the Prairie provinces and British Columbia, using a multistage random sampling strategy (21). They were interviewed between September 1997 and August 1998. Pregnant and lactating women and those who did not speak English or French were excluded. The final sample included 572 men and 971 women. For the present study, two subjects who did not report their level of education were excluded resulting in 571 men and 970 women. A repeat interview was conducted on 29% of subjects to estimate within-subject variability in nutrient intake. Systematic sampling was used for this purpose; the second person initially interviewed and every third person thereafter were selected, providing a subsample of 446 subjects.

Information on height, weight, smoking status and educational

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level was collected by questionnaire. Dietary intake was recorded by dietitians using the 24-h recall method in a face-to-face interview. Detailed descriptions of all foods and beverages consumed during the 24-h period before the interview, including the quantity, cooking method and brand names were recorded. Quantities were estimated using standard graduated glasses, bowls, spoons and a ruler. Supplement intakes were not considered for the present analyses. Nutrient intakes were analyzed using the Candat nutrient analysis program (Godin London Inc., London, Canada) and the 1997 Canadian Nutrient File.

Nutrients examined in this analysis included the macronutrients, fat, protein and carbohydrate, and the micronutrients, calcium, iron, folate, vitamin A and vitamin C. Carotene and vitamin E were not assessed because data are not available for these nutrients for many foods in the Canadian nutrient file.

Foods including meat, vegetables, fruits (including juice), green leafy vegetables (lettuce/spinach/cabbage), milk and bread were examined as were the four food groups based on Canada's Food Guide to Healthy Eating (22). These latter groups did not include mixed dishes from different food groups in which foods were entered as a mixed dish. For mixed foods, when specific amounts for each ingredient were described, it was possible to categorize into specific food groups. Total grams of the food grouping consumed was used as a measure of intake. The frequency of consumption of foods was examined in the subsample with 2 d of intake to provide information on variability in food intake.

The distribution of each nutrient was examined for normality, and appropriate transformations (log and square root) were performed for nutrients with skewed distributions (23). An appropriate transformation could not be found for Vitamin A.

Within- and between-subject variability were estimated by the mixed model procedure for men and women in two ways, i.e., one that was unadjusted for the fixed effects and the other adjusted for the fixed effects of gender, age, education, smoking, season and size of family. It should be noted that in the analyses, means and variances are considered separately. Mixed model procedures also enable examining variances by gender in addition to adjusting for the fixed effect means of gender, age, smoking, education, family size and season. An analysis of heterogeneity of variances yielded variances attributed to men and women separately in both models. Thus, the results presented (which it should be noted, are variances and variance ratios) are stratified by gender. The above analyses were performed using both untransformed and transformed data but because similar ratios were obtained for all nutrients, the results for untransformed data are reported. The mixed model procedure permits the use of data for subjects with either 1 or 2 d of intake; data from both days of intake were used for estimating within-subject variability, whereas one day's intake was used for estimating between-subject variability. The above analyses were performed using the mixed model procedure (Proc Mixed) of SAS (version 6.12, 1996, Cary, NC).

Within- and between-subject variances obtained by the mixed model procedure that adjusted for factors were used to determine the number of days required to obtain reliable estimates of food and nutrient intake by two different methods, one using both within- and between-subject variances and the other using only the within-subject variability. The first method allows estimation of the number of days required to obtain a specified level of correlation between observed and true intakes and is obtained by the formula,

$$d = [r^2/(1 - r^2)] \times s_w^2/s_b^2$$

where d is the number of days, r represents the unobservable correlation between observed and true mean nutrient intakes of subjects, and s_w^2/s_b^2 is the within/between-subject variance ratio (8). A higher value of r indicates a higher proportion of subjects correctly classified and a lower proportion misclassified (8). If the ratio of variances is low, then fewer days of observation are required to classify subjects correctly (8,9), which may be because of low within-subject variability or high between-subject variability.

For some purposes, it may be necessary to assess actual intake of individuals with a given level of confidence (7). The number of days of observation required for a given level of confidence (7) can be calculated as follows: $d = (Z_\alpha\, CV_0/D_0)^2$ where d is the number of days required per person, Z_α is the normal deviate, e.g., 1.96, CV_0 is the within-subject variation, calculated as square root of within-subject variance (SD)/mean intake and D_0 is the specified limit as a percentage of long-term intake (24). Using this calculation, the number of days needed for the observed estimate of a person's intake to lie within a specified percentage of the true mean, 95% of the time can be obtained (24). All analyses were performed using SAS (version 6.12, 1996, Cary, NC).

RESULTS

The subsample obtained for the repeat interview was very similar to the total sample with regard to age, education level, smoking status, family size and body mass index for both men and women (data not shown).

Within- to between-subject variability ratios (s_w^2/s_b^2) obtained for the selected nutrients using the mixed model procedure that adjusted for other factors tended to be higher than the unadjusted model (1.07 vs. 0.49 and 2.04 vs. 1.76 for energy in men and women, respectively) (**Table 1**). The higher ratios obtained using the adjusted mixed model procedure occurred because adjusting tends to reduce between-subject variability.

Using both within- and between-subject variances in the computation for estimating the number of days, ~2–6 d were required to estimate nutrient intakes with good accuracy ($r = 0.8$) (**Table 2**). Using within-subject variability alone to estimate the accuracy of individual measurements, many more days were required to estimate nutrient intakes within 20 or 30% of usual intake. Comparison of both methods indicates that more repeat observations are required to obtain estimates of usual nutrient intakes for individuals than are required to place subjects in groups relative to each other.

Variability in food and nutrient intake is a measure of how frequently a food is consumed and how much of the food is consumed. Examination of frequency of consumption of foods in the subsample indicated that except for green leafy vegetables, fruits and milk, only 5% or less reported not consuming any of the major food groups or foods on both days of interview (data not shown).

Variability ratios (s_w^2/s_b^2) for food groupings were computed by the mixed model procedures described previously for nutrients (**Table 3**). The within/between- subject ratios for most food/food groups tended to be slightly higher by the mixed model procedure that adjusted for other variables (1.15 vs.

TABLE 1

Intra- to intersubject variance ratios (s_w^2/s_b^2) by gender for selected nutrients assessed by two different methods

	Men *n* = 571		Women *n* = 970	
Nutrient	Proc mixed[1]	Proc mixed[2]	Proc mixed[1]	Proc mixed[2]
Energy, *kJ*	1.07	0.49	2.04	1.76
Protein, *g*	1.53	0.79	3.24	2.98
Fat, *g*	0.99	0.62	2.95	2.56
Carbohydrate, *g*	1.39	0.76	1.58	1.42
Iron, *mg*	2.04	1.04	2.29	2.03
Calcium, *mg*	1.16	0.92	1.23	1.18
Folate, *µg*	1.51	1.21	1.95	1.77
Vitamin C, *mg*	1.03	0.93	1.43	1.34

1 Adjusted for fixed effects of gender, age, education, smoking, size of family and season.

2 Unadjusted for fixed effects.

TABLE 2

Number of days of observation required for specific nutrients using two different methods[1]

Nutrient	Gender	CV (%)		Attenuation factor[2]			Specified limit (% of long term intake)[3]		
		Intra	Inter	0.9	0.8	0.7	10	20	30
Energy, *kJ*	M	28.3	27.4	5	2	1	30	8	3
	F	33.1	23.2	9	4	2	42	11	5
Protein, *g*	M	39.7	32.1	7	3	2	61	15	7
	F	34.6	25.6	14	6	3	46	12	5
Fat, *g*	M	42.2	42.4	4	2	1	68	17	8
	F	50.8	29.6	13	5	3	99	28	11
Carbohydrate, *g*	M	32.0	27.1	6	3	1	39	10	4
	F	34.4	27.3	7	3	2	46	11	5
Iron, *mg*	M	38.4	26.9	9	4	2	57	14	6
	F	39.0	25.8	10	4	2	58	15	7
Calcium, *mg*	M	46.2	42.9	5	2	1	82	21	9
	F	44.3	44.5	5	2	1	75	19	8
Folate, *μg*	M	44.2	36.8	6	3	2	75	19	8
	F	50.2	36.8	8	4	2	97	24	11
Vitamin C, *mg*	M	67.4	66.3	4	2	1	175	44	19
	F	64.8	54.3	6	3	1	161	40	18

1 n = 571 men, 970 women.

2 Attenuation factor is the correlation between observed and true mean nutrient intakes and number of days, $n = [r^2/(1-r^2)] \times (s_w^2/s_b^2)$ where r is the unobservable correlation coefficient between observed and true mean nutrient intakes of individuals and s_w^2/s_b^2 is the within subject/between subject variance ratio (8).

3 Number of days, $n = [(1.96 \times CVw)/D_0]^2$ where D_0 is the specified % of the true mean and CVw is the within-person coefficient of variation (7, 24).

0.96 and 2.07 vs. 1.87 for grain products among men and women, respectively), indicating that, as for nutrients, adjustment tended to reduce the between-subject variability, thereby increasing the ratio. The variance ratios were generally higher for food groupings than for nutrients, with the exception of fruits (including juices) and milk food groups. These higher variance ratios mean that more days of food intake would be required than those estimated for nutrients.

TABLE 3

Intra- to intersubject variance ratios (s_w^2/s_b^2) by gender for different food groups assessed by two different methods

Food group	Men (n = 571)		Women (n = 970)	
	Proc mixed[1]	Proc mixed[2]	Proc mixed[1]	Proc mixed[2]
Canada's Food Guide to Healthy Eating Food Groups				
Grain products	1.15	0.96	2.07	1.87
Meat and alternatives	2.84	1.71	4.89	4.52
Milk products	1.32	1.23	0.96	0.96
Vegetables and fruit	1.63	1.33	1.71	1.58
Foods				
Meat	1.83	1.30	3.44	3.19
Vegetables (all types)	7.99	7.19	3.78	3.60
Green leafy vegetables	2.19	2.26	3.82	3.61
Fruits (includes juice)	1.17	0.98	1.35	1.25
Milk	1.33	1.23	0.69	0.69
Bread	4.74	2.96	5.66	4.55

1 Adjusted for the fixed effects of gender, age, education, smoking, size of family and season.

2 Unadjusted for fixed effects.

The mixed model procedure that permits controlling for variables that may influence variability indicated that gender, age and education were significant fixed factors explaining variability in the mean intake of most foods and nutrients; smoking was a significant fixed factor explaining variability in the mean carbohydrate, iron and folate intakes; the fixed effect factor household size explained variability in the mean intakes of iron and folate, indicating that these factors have to be recorded and controlled for in dietary analyses.

DISCUSSION

The need for adjusting within/between-subject variability for differences between subjects in terms of basic demographic factors such as age is clear. The ratios tended to be higher with the adjusted model compared with the unadjusted model for most nutrients and foods/food groups. The higher ratios among men for energy and macronutrients with the adjusted mixed model procedure indicated that fewer days would be obtained if unadjusted values were used, which could then result in unreliable estimates of intakes. Within/between-subject variance ratios were generally lower for nutrients compared with foods; food groups based on Canada's Food Guide to Healthy Eating had lower ratios than specific foods. The higher variability for foods makes it difficult to obtain reliable estimates of food intake from few repeated observations.

Adjusting for several factors when estimating variance ratios results in a reduction in between-subject variance. This may be due to differences in total intake because of age, sex, smoking status or physical activity. The resulting higher variance ratio indicates that more days are needed to obtain reliable estimates of nutrient intakes. Not adjusting for these factors and thus estimating a lower number of days required could result in the study having insufficient power to detect differences in intakes when these variables are controlled in multivariate analyses.

In the present study, gender, age, smoking, education, season and size of family contributed to variability in the intakes of most foods and nutrients. Similar to other studies, gender, age and smoking contributed to variability in nutrient intakes (7,25,26). It has been reported that there are differences in consumption of certain foods by level of education and family size (25,27–29). As reported in other studies, season did not contribute to variability in the present study (11,30).

The within- to between-subject variability ratios were generally > 1 as reported in other studies (7,8,10–12). The ratios for energy, protein, carbohydrate, calcium, vitamin C, iron, (7,8) grains, vegetable and fruit food groups (12) were similar to those reported for similar populations. The variance ratio for fat was similar to that reported in literature among men (7); however, the ratio was higher for women. For women, the within-subject variability was higher than for men and the between-subject variability lower, possibly reflecting inconsistent use of low fat products or less regular consumption of fat-containing foods. The number of days required to estimate usual intakes for carbohydrate and calcium was similar to that reported in other studies for similar populations using within/between variance methodology (8).

Nutrients had lower within- to between-subject variability ratios compared with foods possibly because nutrients come from many food sources. Among foods, there was greater variability in the intake of specific foods compared with whole food groups. It is possible that 2 d of measured intake for each individual is not sufficient to obtain a true picture of variability in some less routinely eaten foods.

A question often asked at the design stage pertains to the number of days of observation required to assess usual intakes of individuals and groups (7,9). In our analyses, considerably more days were required to obtain reliable estimates of intakes for individuals compared with relative ranking of subjects into groups. If the objective is to obtain accurate estimates of individuals for counseling purposes (7), then the method involving the use of within-subject variability must be considered due to the large day-to-day variation in dietary intakes of each individual. Studies have indicated that most nutrients have high within-subject variability, resulting in a greater number of days to estimate intakes reliably for individuals (7,24,9). The food frequency method may be an option for specific foods (7); however, food-frequency questionnaires have been estimated to measure nutrient intakes only as accurately as 2–3 repeat 24-h recalls (31).

A possible limitation of the present study was that the day of the week effect (3,24) was not considered. Attention was given to avoid conducting a repeat interview on the same day of the week for each subject; however, the choice of days was not necessarily a weekday and a weekend day. Interviews for the same subject were not done on consecutive days to avoid misleading correlations associated with consecutive days of dietary assessment (3).

In conclusion, within/between-subject ratios for foods and nutrients tended to be higher with adjustment compared with the unadjusted model, indicating the need to adjust for confounding variables when calculating the number of days to obtain reliable estimates of nutrient intakes.

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