

A five-country evaluation of nutrition labelling policies:
consumer use, understanding, and knowledge of processed foods

by
Jasmin Bhawra

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EXAMINING COMMITTEE MEMBERSHIP

The following served on the Examining Committee for this thesis. The decision of the Examining Committee is by majority vote.

External Examiner

DR. RACHEL ENGLER-STRINGER
Associate Professor
Community Health & Epidemiology
University of Saskatchewan

Supervisor

DR. DAVID HAMMOND
Professor
School of Public Health & Health Systems
University of Waterloo

Internal Member

DR. SHARON I. KIRKPATRICK
Associate Professor
School of Public Health & Health Systems
University of Waterloo

Internal Member

DR. MARISSA G. HALL
Assistant Professor
Department of Health Behavior
Gillings School of Global Public Health
University of North Carolina

Internal-external Member

DR. GEOFFREY FONG
Professor
Department of Psychology
University of Waterloo

AUTHOR'S DECLARATION

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

STATEMENT OF CONTRIBUTIONS

This thesis consists in part of four manuscripts that have been submitted for publication. Exceptions to sole authorship:

Bhawra J, Kirkpatrick SI, Hall MG, Vanderlee L, Hammond D. Initial development and evaluation of the Food Processing Knowledge score: a functional test of nutrition knowledge based on level of food processing. *Journal of the Academy of Nutrition and Dietetics*, 2020. [Under Review.]

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As lead author of these four manuscripts, I was responsible for conceptualizing the research questions, conducting the analyses, and drafting and submitting manuscripts. My co-authors provided guidance throughout the process and provided feedback on draft manuscripts. Dr. David Hammond provided significant direction and editorial assistance throughout.

Under Dr. David Hammond's supervision, I also prepared the remaining chapters in this thesis, which were not written for publication.

ABSTRACT

Background: Poor dietary intake is a critical risk factor for non-communicable diseases – the world’s leading cause of premature death and disability. Globally, consumption of highly processed foods has increased in recent decades. Population-health interventions, such as nutrition labelling, have the potential to promote healthy eating behaviours. Nutrition Facts tables (NFts) and front-of-package (FOP) labelling systems provide consumers with essential nutrition information at the point-of-purchase to aid healthy decision-making and encourage healthier product reformulation. An increasing number of countries are implementing FOP labelling systems, ranging from ‘high in’ labels in Chile to Health Star Ratings in Australia. There is a need to examine consumers’ knowledge of levels of food processing, as well as awareness, understanding, and use of nutrition labels to better understand the impact of labelling policies.

Objectives: This dissertation explored patterns and correlates of nutrition label awareness, understanding, and use, as well as functional nutrition knowledge across five countries with different nutrition labeling systems. Canada and the US currently have NFts only, which were compared to NFt and FOP labelling systems in Australia (voluntary Health Star Rating FOP labels), the UK (voluntary multiple Traffic Light FOP labels) and Mexico (mandatory Guideline Daily Amount FOP labels). The four primary aims of this study were to: 1) assess face and content validity of a new functional nutrition knowledge measure based on level of food processing – the Food Processing Knowledge (FoodProK) score; 2) determine functional nutrition knowledge levels (FoodProK scores) and associated correlates; 3) identify and compare patterns and correlates of self-reported versus functional label understanding; and 4) explore patterns and correlates of label awareness and use across countries.

Methods: This dissertation consisted of four sub-studies: Study 1 developed and tested a new functional measure of nutrition knowledge which was based on respondents' ability to understand and apply the concept of food processing in a functional task; Study 2 examined patterns and correlates of functional nutrition knowledge across countries; Study 3 explored self-reported (NFt, FOP label) and functional (NFt) label understanding across countries; and Study 4 examined patterns of NFt and FOP label use and awareness across countries. Cross-sectional data from the 2018 International Food Policy Study were used. Respondents aged ≥ 18 years ($n = 22,824$) from Australia ($n = 4103$), Canada ($n = 4397$), Mexico ($n = 4135$), the UK ($n = 5549$), and the US ($n =$

4640) were recruited through Nielsen Consumer Insights Global Panel and their partners' panels. Respondents completed web-based surveys answering questions about food policies, dietary behaviours, health literacy, and other factors related to food environment. The primary outcomes were functional nutrition knowledge; self-reported label (NFt, FOP) awareness, understanding, and use; and functional NFt understanding. Sociodemographic factors (age, sex, ethnicity, country, education level, income adequacy), body mass index, dietary behaviours (dietary practices, diet modification efforts, food shopping role), and knowledge-related characteristics (health literacy, FoodProK score) were included in all analyses.

In Study 1, content validity of the newly developed FoodProK score was examined by surveying Registered Dietitians in Canada (n = 64). Dietitians completed the FoodProK measure, which required rating the healthiness of three food products in four categories (fruit, dairy, grain, meat). Thereafter, dietitians answered several open-ended survey questions about the measure. One-way repeated-measure ANOVA models tested whether dietitians' product ratings were significantly different between products and food categories. Multiple linear regression models were fitted to examine between-country differences in functional nutrition knowledge in Study 2. Studies 3 and 4 also used multiple linear regression models to assess correlates of label understanding and use/awareness, respectively. All analyses adjusted for sociodemographic, dietary behaviours, and knowledge-related characteristics. Interaction terms with country and sociodemographic characteristics were tested to examine how patterns differed across countries.

Results:

Study 1 – Overall, 70.3% of dietitians scored 7 and above on the 8-point FoodProK measure. The majority of dietitians rated food products in congruence with level of processing (85.9% of dietitians correctly ordered products in the fruit and dairy categories; 73.4% correctly ordered grain products). The meat category was an exception, with approximately half of dietitians (54.7%) rating meat products in accordance with level of processing. Open-ended responses showed dietitians did not perceive meaningful differences between the processed meat products. Overall, 80% of dietitians reported level of processing as an important indicator of the healthiness of foods. Preliminary content validity evidence suggests knowledge of food processing levels as one indicator of general nutrition knowledge.

Study 2 –The highest FoodProK scores were reported in Canada (mean: 5.1) and Australia (5.0), followed by the UK (4.8), Mexico (4.7), and the US (4.6). Health literacy and self-rated nutrition knowledge were positively associated with FoodProK scores ($p<.0001$). FoodProK scores were higher among those who reported specific dietary practices such as vegetarianism ($p<.0001$); made efforts to consume less sodium, trans fats, sugars, processed foods, or calories ($p<.0001$); respondents classified as having ‘adequate health literacy’ ($p<.0001$); respondents who self-reported being ‘very knowledgeable’ or ‘somewhat knowledgeable’ about nutrition ($p<.0001$); those who were 60+ years old ($p=0.0023$), women ($p<.0001$), and respondents who belonged to the ‘majority’ ethnic group in their respective countries ($p<.0001$). Education, income adequacy, and food shopping role were not significantly associated with FoodProK scores.

Study 3 – Self-reported and functional NfT understanding was highest in the US and Canada, followed by Australia, the UK, and Mexico. Functional and self-reported NfT understanding were weakly correlated ($r_s=0.18$, $p<.0001$). In adjusted analyses, functional NfT understanding was higher among women ($p<.0001$), ‘majority’ ethnic groups ($p<0.0001$), respondents with higher education levels ($p<.0001$), and those making efforts to consume less sodium, sugar, fat, calories or processed food ($p<.0001$). Similar correlates were significant for self-reported NfT and FOP label understanding, with some differences in diet behaviour correlates between self-reported and functional NfT understanding. Self-reported FOP label understanding was higher for interpretative labelling systems in Australia (Health Star Ratings) and the UK (Traffic Lights) compared with Mexico’s Guideline Daily Amounts ($p<.0001$). Mean self-reported FOP label understanding was higher than NfT understanding, with the exception of Mexico where self-reported NfT understanding was higher.

Study 4 - Respondents from the US, Canada, and Australia reported significantly higher NfT use and awareness than respondents in Mexico and the UK. Mexican respondents reported the highest level of FOP label awareness, followed by the UK and Australia, whereas UK respondents reported the highest FOP label use followed by Mexico and Australia. In countries with both NfT and FOP labelling systems, use and awareness was higher for NfTs in Australia and Mexico, with UK respondents reporting higher FOP label than NfT use and awareness. Correlates of NfT and FOP label use were similar, with the exception of health literacy where NfT use was higher among respondents with ‘adequate literacy,’ but FOP use was lower among this group compared to those

with a ‘high likelihood of limited literacy.’ Food processing knowledge, sex, and ethnicity were only significantly associated with NFt use.

Conclusions: Cross-country differences in labelling outcomes provide an opportunity to examine differences in nutrition labelling policies across countries. Nutrition labels requiring greater numerical skills (i.e., NFt, GDA) were more difficult for consumers to understand than interpretive FOP labels, and mandatory labelling policies (NFt, GDA) had the highest levels of awareness. These findings highlight the importance of mandatory FOP labelling policies to maximize reach, particularly among consumers with lower literacy, nutrition knowledge, and education who reported using nutrition labels less. This study also provides further evidence for the use of functional measures of knowledge and label understanding for multi-country, population-based studies. Overall, these findings support the need for mandatory labelling policies and national health promotion efforts that are accessible to all populations to minimize nutrition-related health disparities.

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“She believed she could, so she did.”— R.S. Grey

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LIST OF ABBREVIATIONS

BMI	Body Mass Index
CIHR	Canadian Institutes of Health Research
FoodProK	Food Processing Knowledge
FOP	Front-of-package
GDA	Guideline Daily Amount
HSR	Health Star Rating
IFPS	International Food Policy Study
NCD	Non-Communicable Disease
NFt	Nutrition Facts table
SAHL	Short Assessment of Health Literacy
SES	Socioeconomic Status
TOFHLA	Test of Functional Health Literacy in Adults
UK	United Kingdom
US	United States
WHO	World Health Organization

Chapter 1: Introduction

1.1 The role of food environment in shaping dietary behaviour

The World Health Organization (WHO) has identified non-communicable diseases (NCDs) as the world's leading cause of premature death and disability, with more than 36 million people dying annually from cardiovascular disease, cancers, chronic respiratory diseases, and type 2 diabetes.^{1,2} Dietary intake is a shared risk factor for many of these NCDs: five out of the nine voluntary global targets to reduce NCD risk in the *Global Action Plan for the Prevention and Control of NCDs 2013-2020* focus on nutrition or diet-related behaviour.¹ An estimated 1.8% of total disease burden can be linked to inadequate fruit and vegetable intake,^{3,4} and in many countries, recommended fruit and vegetable intake guidelines are not being met by youth or adults.³⁻⁷

In addition, consumption of highly processed foods – including ultra-processed foods – have increased globally.⁸⁻¹⁰ Ultra-processed foods are “formulations of food substances often modified by chemical processes and then assembled into ready-to-consume hyper-palatable food and drink products using flavours, colours, emulsifiers, and a myriad of other cosmetic additives.”⁹ These foods typically contain high amounts of sodium, sugar, saturated or trans fats.¹¹⁻¹³ The high energy density and relatively low nutrient content of ultra-processed foods contributes to poor diet quality^{8,9,12,14,15} and increased overall risk of morbidity.¹⁴⁻¹⁸ The health risks of ultra-processed foods are especially alarming considering that these foods constitute more than half of consumers' total energy intakes in high-income countries such as Canada, the United States (US), and the United Kingdom (UK),^{9,11,19,20} and between one-fifth to one-third of energy intake in middle-income countries such as Mexico and Brazil.^{9,21-23}

Overall, diet is influenced by a myriad of factors that work together to influence consumers' access to food, purchasing and consumption patterns, and consequently their vulnerability to diet-related disease outcomes.²⁴⁻²⁷ These factors include individual (e.g., dietary preferences, purchasing behaviours) and meso-level determinants (e.g., household income, family/cultural meal practices), built environment (e.g., proximity to grocery and other food outlets), and broader environmental contexts (e.g., media and marketing of foods, nutrition and health policies).

The environmental contexts in which people live can exert direct or indirect influence on their health behaviours, thus form a critical point of intervention for population health problems such as poor diet.^{24,26} Globally, governments have adopted numerous policy measures to improve food environments to support healthy eating.

1.2 Population health interventions targeting nutrition

Given the strong influence of social and physical food environments, interventions which solely target individual dietary behaviours have limited effectiveness compared to population-level interventions.^{5,28-30} Population health interventions address the “interrelated conditions and factors that influence the health of populations over the life course.”³⁰ Measures that educate the public and seek to increase nutrition knowledge – such as food labelling policy – are important population health interventions due to their wide reach and potential for impact.^{5,24,31,32}

Consumers gather information about the foods they purchase from a wide variety of sources, ranging from family and cultural knowledge, school-based curricula, to media and advertising.^{24,26,27} However, the credibility and accuracy of nutrition information varies, complicating consumers’ ability to navigate the increasingly processed food environment.^{1,5,33,34} Hence, one of the primary objectives of governmental population health initiatives, such as Canada’s Healthy Eating Strategy, is to enhance mandatory food labels to “make the healthier choice the easier choice for all.”³³

Given the association between level of food processing and healthfulness,^{8,9,14,15} nutrition labelling on packaged foods – which tend to be highly processed – are important educational tools to aid consumer decision-making and influence healthy product reformulation.^{35,36} An increasing number of countries, including Brazil and Canada, have started to shift away from prescriptive quantitative food group recommendations towards dietary guidance that emphasizes how to eat, in addition to what to eat, with integration of messaging related to limiting consumption of highly processed foods.^{33,34,38} Many countries specifically note the importance of limiting intake of foods high in saturated or trans fats, added sugars, and sodium in their dietary guidelines.^{33,34,37-41} These messages are distilled into back- and front-of-package (FOP) nutrition labelling systems and inform which nutrients are highlighted for consumers on food packaging.

Nutrition labels may influence changes in consumers' purchasing patterns, and over time, their dietary intake.^{35,42-52} Educational campaigns which accompany labelling policy and national dietary guidelines contribute to increasing nutrition knowledge among consumers.⁵²⁻⁵⁵ The following section describes nutrition literacy and knowledge, as well as associated measures.

1.3 Defining and measuring health literacy, nutrition literacy, and nutrition knowledge

1.3.1 Health literacy

The four competencies of health literacy include the ability to access, understand, appraise, and apply health information.⁵⁶ Health literacy is influenced by an individual's knowledge, competence, and motivation regarding health.⁵⁶ There is lack of consensus on the definition of health literacy across disciplines; as a result, a variety of measures are used to assess health literacy.^{56,57} Some studies have developed measures specific to their study goals,⁵⁸ such as tailored e-Health⁵⁹ or mental health literacy assessment tools.⁶⁰ Generalized measures have also been developed for application across health fields, including the Short Assessment of Health Literacy (SAHL) tool^{61,62} and Test of Functional Health Literacy in Adults (TOFHLA),^{63,64} that are used across a range of studies. The SAHL tool is focused on assessing adults' ability to read and understand common medical terms.⁶² TOFHLA measures various components of literacy, including reading, comprehension, and numeracy by showing respondents health-related materials (e.g., prescription bottle label) in a healthcare setting.^{63,64} These tools have been tested among English-speaking adults; however, their application is limited among minority or non-English speaking populations.⁵⁷

The Newest Vital Sign⁵⁸ is an objective test which assesses consumers' ability to read, understand, and apply information from a Nutrition Facts table (NFt).⁶⁵ The Newest Vital Sign captures the four competencies described in the Sorensen et al. (2012) model⁵⁶ and is one of the few measures that has been broadly tested across a variety of age and ethnic groups in different countries including Canada, the US, Australia, and the UK.^{58,65-71}

1.3.2 Nutrition literacy and knowledge

Nutrition literacy is considered a form of health literacy, which reflects consumers' "ability to access, interpret, and use nutrition information."⁷² Nutrition literacy is intrinsically connected to nutrition knowledge. Literacy is primarily concerned with the ability to critically apply information using relevant skills (i.e., numeracy), whereas knowledge is concerned with awareness and understanding of specific information.⁷² Practical food skills are related more closely to *food literacy*, which is not discussed here.⁷³

Miller et al. (2015) define nutrition knowledge as "knowledge of concepts and processes related to nutrition and health, including knowledge of diet and health, diet and disease, foods representing major sources of nutrients, and dietary guidelines and recommendations."⁷⁴ Following consultation with nutrition professionals, Gibbs and Chapman-Novakofski (2012) identified knowledge of macronutrients, portion sizes, and basic math skills necessary for understanding food labels as core components of nutrition knowledge.⁷⁵

Knowledge is a fundamental factor in health promotion and health behaviour change theories.⁷⁶ Knowledge is considered a prerequisite for intentional health-related behaviour;⁷⁶ however, the extent of influence that knowledge can exert on behaviour depends on the type of knowledge being assessed. In the psychology literature, knowledge is classified as declarative (i.e., awareness of facts or information) or procedural (i.e., knowing how to apply information).⁷⁷ Declarative knowledge must precede procedural knowledge for behaviour change to occur. The influence of knowledge on dietary behaviours, such as purchasing and consumption patterns, is largely determined by nutrition knowledge (declarative) and food skills (procedural), as well as a range of other factors including individual motivation, goals, and the broader food environment (i.e., if it is conducive to the application of knowledge).⁷⁷

A variety of measures are used to assess nutrition literacy and knowledge. This variability is due, in part, to the use of distinct definitions.⁷⁴ Some studies use measures of health literacy for assessment of nutrition literacy because the core components – ability to read and comprehend information – are expected to be associated with food label understanding and use.⁵⁸ Similar to

health literacy, there are a range of tools to measure nutrition literacy or knowledge, as measurement has been study- or context-specific.^{58,72,78}

A systematic review conducted by Yuen et al. (2018) found 13 instruments to measure nutrition literacy ranging from six to 64 items.⁷⁸ These included the Newest Vital Sign, English and Spanish versions of the Nutrition Literacy Assessment Instrument,⁷⁹ and Nutrition Literacy Scale.⁸⁰ The Nutrition Literacy Assessment was developed to test nutrition literacy among adults with chronic disease. Six domains of nutrition literacy are assessed, including nutrition and health, energy sources in food, food label numeracy, household food measurement, food groups, and consumer skills.⁷⁹ Measures such as the Nutrition Literacy Scale, are less comprehensive and ask respondents to fill in the blanks for a series of nutrition statements missing key terms in order to assess nutrition literacy.⁷⁸ Other tools identified in the systematic review were adapted for specific populations.⁷⁸

Nutrition knowledge, which is a component of some nutrition literacy measures, can be assessed using distinct tools depending on the study goal or purpose. Bradette-Laplante et al. (2017) developed a validated nutrition knowledge measure for a Canadian population comprised of 38-items.⁸¹ Subsections include familiarity with Canada's Food Guide (i.e., food groups, portion sizes) and general nutrition knowledge (i.e., knowledge of a specific food or food/nutrient-disease relationship).⁸¹ Other examples of objective nutrition knowledge assessment tools include the Nutrition Knowledge Questionnaire for Athletes⁸² and General Nutrition Knowledge Questionnaire⁸³ which assess knowledge about dietary recommendations, sources of nutrients, and diet-disease relationships. However, there does not appear to be a consistently used tool with validity evidence for nutrition knowledge, as unique studies develop measures specific to their research interests and subpopulations.

Given lack of consensus in the literature about nutrition knowledge assessment, subjective measures, such as self-rated knowledge, are often used. However, functional nutrition knowledge tests demonstrate that consumers tend to overestimate their ability to understand quantitative nutrition information – a challenge given the tendency for nutrition policy approaches including labelling (e.g., NFls) to rely upon numeric data such as nutrient amounts per serving.⁸⁴⁻⁸⁹ Hence, while subjective knowledge measures may be informative and often correlated with nutrition-related decisions and behaviours,³⁴ 'functional' nutrition knowledge measures are considered more

accurate.⁹⁰ Therefore, in addition to self-reported nutrition knowledge, this study uses another approach which assesses consumers' ability to discern the healthiness of foods based on level of processing. The following section describes the role of food processing in nutrition knowledge assessment.

1.3.3 Level of food processing as a nutrition knowledge measure

National dietary guidelines have been shifting away from specific recommendations regarding number of servings per food group to communicating the basic principles of healthy eating, such as avoiding highly processed foods and increasing whole food consumption.^{33,37-41} Given the growing emphasis within country-specific dietary guidelines on reducing highly processed food consumption, consumers' ability to understand and apply principles related to level of food processing could serve as a proxy measure of general nutrition knowledge. Tools that assess consumers' ability to identify and rate foods based on their level of processing measure nutrition knowledge more holistically than other measures focused on specific nutrients, as well as consumers' ability to integrate a variety of information. Existing nutrition knowledge assessment tools, such as the General Nutrition Knowledge Questionnaire,⁸³ include subsections where respondents choose the healthiest choice between different foods, and take into consideration the recommended food groups, nutritive value, as well as level of processing.^{78,91,92} However a shortcoming of most functional measures is that they tend to focus on awareness of country-specific dietary guidelines, and consequently, are unsuitable for use across contexts.^{72,78}

In order to address this gap, a new measure of nutrition knowledge – the Food Processing Knowledge (FoodProK) score – was developed based on the internationally recognized NOVA classification system for level of food processing.^{9,19} This measure, described in greater detail in Chapter 2, was used alongside self-reported nutrition knowledge in this study.

1.4 The importance of labelling policy in a complex food environment

The processed food environment poses numerous challenges for healthy eating, as constant food innovation makes it difficult for consumers to interpret levels of food processing, further muddling the boundaries between 'healthy' vs. junk foods.^{8,74,78,93,94} Food labelling is a policy focused on providing the public with nutrition information to help navigate an increasingly processed food

environment.³¹ Food labels refer to the information placed by both government and industry on packaged foods, including nutrition labels that aim to communicate nutrient content. The WHO has identified food labelling as an important strategy to facilitate healthy choices.⁵ Nutrition labels aim to increase consumers' understanding of the nutritive value of food products, which may contribute to increased nutrition knowledge.^{32,74} The literature suggests that nutrition knowledge may improve motivation and decision accuracy in applying label information,^{74,92,94,95} and ultimately influence dietary behaviours.^{74,92,96,97}

The effectiveness and influence of labelling policy is, in part, determined by the type, design, and whether it is voluntary or mandatory in a jurisdiction.^{90,98,99} Voluntary industry labels and claims consistently highlight the presence of 'positive' nutrients or reductions in 'negative' nutrients on packaged foods as part of product promotion.^{90,100} Voluntary nutrition claims and symbols are more likely to appear on processed food products in an effort to market innovations in food manufacturing.¹⁰⁰ On the other hand, government-mandated labels provide important objective information on nutrient composition through NFts, ingredients lists, nutrition and health claims, as well as front-of-package (FOP) nutrient summaries depending on the jurisdiction.^{34,36,101,102} NFts and FOP labels are the focus of this dissertation and are described in greater detail below.

1.5 Nutrition label types

1.5.1 Nutrition Facts Tables

1.5.1.1 Description

NFts are typically panels found at the back or side of packages that display nutritional information about a food product.^{98,101,102} NFts are mandatory in seven countries and among European Union members, with other nations applying NFts voluntarily.¹⁰² In the US, over 98% of packaged foods have NFts, and in the European Union, 84% of packaged foods have these labels.^{102,103} All countries require energy, proteins, total fats, and carbohydrates to be displayed when a nutrition label is used, while other vitamins and minerals remain optional or vary by country.^{98,102}

The NFt generally organizes information based on serving size and allows consumers to determine the total caloric and nutritive value of the food, as well as how much a particular serving of that

food will contribute to their recommended daily intake of a nutrient. However, there is currently no international guidance on nutrient thresholds. Many jurisdictions base their guidelines on recommendations from the Joint Food and Agriculture Organization/WHO expert consultations that outline human energy and nutrient requirements for good health.¹⁰⁴⁻¹⁰⁷ The WHO nutrient criteria are based on proportion of total energy intake (energy [en] 2000kcal/day; saturated fat <10en%; trans fats <1en%; sodium 2000mg/day = 1mg/kcal; added sugars <10en%); however, they do not provide specific guidance on threshold amounts for “too high” or “too low.”¹⁰⁴⁻¹⁰⁷ Three commonly used reference units on NFts are: i) per 100g/mL; ii) per serving; and iii) per recommended daily amount.⁹⁸ These reference units are printed adjacent to the nutrients present in a product to aid consumers in navigating and applying nutrition information.⁹⁸

NFts are found only on packaged food; thus, raw produce, meat, and dairy are among the exceptions in many jurisdictions. Government regulations may also exempt specific types of foods (i.e., spices, coffee, tea) as well as food sold at specific events (i.e., farmers markets, fundraising events) from requiring NFts.^{98,101}

1.5.1.2 Evidence of impact

Research has shown that NFts are one of the most commonly used sources of nutrition information, particularly among consumers making a dietary change.^{34,42,108-110} Most consumers are able to understand the basic nutrition information on labels;¹¹¹⁻¹¹⁴ however, comprehension accuracy decreases for more complex tasks.^{112,115-121} Poor NFt understanding has been observed across countries, with studies using both self-reported measures and functional tests of label understanding identifying issues with numeracy, as consumers struggle to interpret and apply label information.^{85,120-125} For example, while two-thirds of consumers in an American study reported looking at calorie information, the majority of respondents were not able to identify how it fit in the broader context of their daily caloric requirements, with 88% incorrectly estimating their daily energy needs.^{34,108} Similarly, a Canadian study among youth and young adults found that participants were able to define per cent daily value; however, they reported difficulty applying this information and understanding serving size information on NFts.⁸⁵ Nutrition knowledge and health literacy may influence consumers’ understanding of labels. Studies have used varied definitions and measures of health literacy and knowledge which has contributed to differences in

study findings, with some studies finding a positive relationship between health literacy and nutrition label use,^{58,121} and others noting an inverse¹²⁶ or no relationship.^{127,128} A systematic review of self-reported nutrition knowledge measures found positive associations with frequency of nutrition label use.^{74,129-133} In 18 out of 28 studies, consumers with high nutrition knowledge reported better comprehension of nutrition labels than those with lower nutrition knowledge levels.⁷⁴ Nutrition knowledge was consistently related to label understanding – or *how well* consumers felt they were able to use food labels.^{74,134}

Cross-sectional studies point to NfT use being associated with improved dietary intake, including decreased consumption of energy-dense, nutrient-poor foods,¹³⁵⁻¹³⁸ calories, and nutrients of public health concern (i.e., saturated fat, salt, sugar).⁴²⁻⁴⁵ However, it is difficult to ascertain the direction of these study findings, as it is possible that healthier consumers may also be more likely to use NfTs. These relationships are further nuanced by the fact that there are differences in NfT understanding and use based on sociodemographic characteristics.

Studies indicate that consumers with lower education and income are less likely to understand and therefore use NfTs.^{118,139} Moreover, males and younger consumers have been reported as less likely to use NfTs than their counterparts.^{45,114,121,140} Sociodemographic groups reporting lower label understanding and use, as well as poorer nutrition knowledge or literacy, are also considered more vulnerable to poor diet and nutrition-related chronic disease.^{5-7,141}

Textual and graphic descriptors on nutrition labels have been found to help consumers with lower literacy comprehend nutrition information and place foods into the broader diet context.^{90,119} Hence, in response to concerns about NfTs, FOP labels have been proposed as a policy solution for providing simple and interpretive nutrition information in a noticeable location on food packages.^{36,90,142}

1.5.2 Front-of-package labelling systems

1.5.2.1 Description


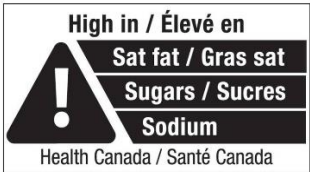
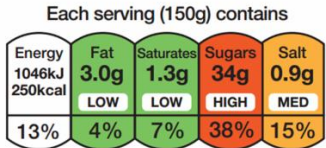
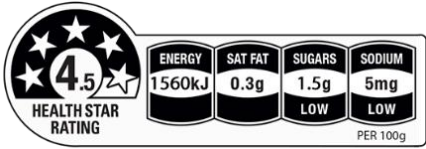
There is no single definition of what constitutes FOP labels; however, all FOP labelling systems condense the nutritional information from NFts in a simple and interpretive manner.^{36,90} FOP labelling schemes vary in presentation (e.g., shape, colour, size), health or nutrition message, and nutrient focus.^{36,98,143,144} The two main types of FOP labelling systems are nutrient-specific and summary-indicator systems.

Nutrient-specific labels display the content of select nutrients from the NFt. They highlight ‘negative’ nutrients (i.e., sodium, saturated fat, sugar) and/or ‘positive’ nutrients (i.e., fibre, potassium, vitamins).^{36,90} The FOP Guideline Daily Amount (GDA) system used in Mexico is an example of a reductive, nutrient-specific system which displays calories, total sugar, saturated fat, and sodium in a product. ‘High-in’ symbols in Chile are an interpretive, nutrient-specific system which signal high calories, sugar, saturated fat, and sugar in packaged products.^{145,146} The multiple Traffic Lights system in the UK and Ecuador is also an interpretative, nutrient-specific system which uses color coding to indicate high/medium/low amounts of total fat, saturated fat, total sugar and sodium in a product.^{147,148}

Summary-indicator systems are interpretative, and summarize nutrient content information and product healthfulness using algorithms which take multiple nutrients into consideration to provide a score or ordinal ranking of the overall product.^{36,90} An example of a summary-indicator system is France’s voluntary FOP system, NutriScore, which uses 5-level color coding and letter grades to guide consumers about the healthiness of a product. The score takes into account ‘positive’ nutrient content (i.e., fibre, protein), as well as nutrients of concern (i.e., saturated fat, sugar, sodium), to calculate a score and assign a letter (A to E) and corresponding colour (dark green to dark orange), with ‘A’/dark green indicating best nutritional quality.¹⁴⁹ Health Star Ratings (HSR) in Australia are also a summary-indicator system which assign 0.5 to 5 stars to a food product, with high star ratings corresponding with healthier options.¹⁵⁰ In some summary-indicator systems, nutrient-specific information is also included, such as the HSR, which displays total calories, serving size, sodium, sugar, and saturated fat.¹⁵⁰

FOP labelling systems differ based on the types of symbols (i.e., stars, stop signs) and number of levels. For example, the HSR uses 9 levels communicated via the number of stars, whereas Traffic Light labels typically use 3 levels communicated via the colours green, amber, and red.^{147,150} FOP labelling systems also differ in the amount of quantitative nutrient information, which may enhance or distract from FOP symbols. Whereas the GDA system in Mexico is based almost exclusively on quantitative nutrient amounts, others, such as ‘high-in’ labels in Chile, contain little or no quantitative information.^{145,146} **Table 1** summarizes the FOP labelling systems used in the five countries included in this study, and Appendix A provides a more detailed description of each system and associated advantages and disadvantages.

Table 1: Summary of FOP Labelling Systems

FOP Label	System	Number of indicator levels	Symbol	Image Example
Guideline Daily Amounts	Nutrient-specific	0	None	 <p>Each 36 g serving contains</p> <p>Energy 713 kJ 10% Sugars 14 g 16% Fat 8.9 g 13% Saturates 2.9 g 14.5% Sodium 106 mg 7%</p> <p>of a child's guideline daily allowance (5 years and older)</p>
‘High in’ systems	Nutrient-specific	2	‘Stop’ sign or ‘high-in’ symbol	 <p>High in / Élevé en Sat fat / Gras sat Sugars / Sucres Sodium Health Canada / Santé Canada</p>
Traffic light systems	Nutrient-specific	3	Colour scale	 <p>Each serving (150g) contains</p> <p>Energy 1046kJ 250kcal 13% Fat 3.0g 4% Saturates 1.3g 7% Sugars 34g 38% Salt 0.9g 15%</p> <p>of an adult's reference intake Typical values (as sold) per 100g: 697kJ/ 167kcal</p>
Health Star Ratings	Summary + Nutrient-specific	9	Stars	 <p>HEALTH STAR RATING 4.5</p> <p>ENERGY 1560kJ SAT FAT 0.3g SUGARS 1.5g SODIUM 5mg PER 100g</p>

Adapted from Hammond et al., 2018⁹⁰

1.5.2.2 Evidence of impact

Over 100 studies have been conducted on FOP labelling.⁹⁰ The study designs include pre-implementation research, which test the efficacy of FOP labelling in experimental settings, as well as post-implementation research assessing the impact of voluntary or mandatory FOP labelling policies across jurisdictions.⁹⁰ Below, a brief summary of pre- and post-implementation research is provided.

Pre-implementation research

A recent literature review by Hammond et al. (2018) uncovered 94 pre-implementation studies testing comprehension, effectiveness, and preference for a range of FOP label designs.⁹⁰ Eye-tracking studies from Uruguay, Europe, and the US found that FOP labels increased consumers' attention to nutrition information compared to NFTs or no label conditions, and reduced response time in answering questions about the nutrient content in food products.^{134,151-156}

'Pre-implementation' experimental research has also demonstrated higher self-reported and functional understanding of FOP labels compared with NFTs among adults.^{46,111,118,134,142,155-159} FOP label comprehension further varies by design. In Canada, Germany, and Ireland, Traffic Light systems have ranked high for ease of understanding among consumers.^{151,157,160} When shown multiple FOP label formats, consumers indicated a preference for colour-coded labels such as Traffic Lights^{157,161-164} compared with NFTs or GDA labels.^{90,151,161-164} Several studies which included the HSR have shown these labels as easier to understand compared with the Traffic Light system, in particular.^{165,166} In other studies which included 'high-in' symbols, these labels were reported as easiest to use in nutrient search tasks, followed by Traffic Lights and GDA.^{152,167-170} GDA labels have ranked relatively lower in consumer understanding compared to the other FOP labelling systems. One study found GDA and multiple Traffic Light labels to be equally understood,¹¹⁶ however, research to date indicates that consumers find the GDA only slightly more helpful than calorie information alone.^{124,151} Generally, qualitative studies demonstrated consumers' preference for simple, directive information on labels with minimal text.^{110,171-175}

Pre-implementation research commonly assesses FOP label comprehension via consumers' ability to identify the "healthiest" foods when provided with a range of options, or via hypothetical

product selection tasks. Consistent with consumers self-reported preferences, simplified, interpretative label formats have been found to be more successful at promoting healthy food choices in hypothetical settings compared to more complex label formats.^{152,161,166,167,169} Most studies examining the influence of FOP labels on purchase intentions found that they led to healthier product selections compared to control conditions,^{152,167,176-178} with few studies finding no significant effects.^{167,179-182}

For example, in a Canadian experimental marketplace study of consumers' perceptions of beverage healthiness, HSR and single Traffic Lights were more effective than numeric labels and control conditions (no labels) in helping consumers select beverages with less sugar.¹⁸³ A study in New Zealand in which participants scanned product barcodes on real shopping trips using a smartphone app, found that participants who were assigned the Traffic Lights or HSR conditions purchased significantly healthier packaged foods than those in the NFt control condition.⁴⁶ A similar study in Australia using a smartphone app compared HSR, Traffic Lights, GDA, and modified NFts with 'warning' text.¹⁶⁵ Only the warning text condition led to significantly healthier packaged food purchases compared with the NFt-only control.¹⁶⁵

Pre-implementation studies are useful for determining effective FOP label design features and consumer preferences before policy implementation. There is relatively less post-implementation evidence on FOP labelling systems as mandatory policies, in particular, are relatively recent in most jurisdictions.⁹⁰

Post-implementation research

A recent literature review found 23 post-implementation studies, which demonstrated varied effectiveness of FOP labelling policies based on whether they were voluntary or mandatory.⁹⁰ Under a voluntary policy, food manufacturers may choose to only apply FOP labels to healthier foods to avoid highlighting nutrient-poor products. This is evidenced in countries such as Australia and New Zealand, where only 31% and 21% of eligible packaged products, respectively, were found carrying voluntary HSR labels in 2017-2018.^{52,184}

Following HSR implementation in 2014, a five-year evaluation was conducted by an independent consulting firm to assess uptake, use, and impact of the HSR system. The evaluation found that

83% of Australians and 76% of New Zealanders reported being aware of HSR labels when prompted – an increase compared to 2015 data which showed 57% and 38% awareness among Australians and New Zealanders, respectively.⁵² When unprompted, 20% of Australians and 16% of New Zealanders reported recognizing the HSR label compared to approximately 3% recognition in 2015.⁵² When asked about ease of use, 77% of Australians reported the HSR made healthier products easier to identify.⁵² In New Zealand, ease of use was assessed based on the 2018 HSR System Campaign, and 66% of consumers who saw the campaign agreed that HSR made healthier products easier to identify compared to 56% among consumers who had not seen the campaign.⁵² Approximately 23% of consumers reported changing their purchasing behaviour by selecting products with more stars, with 68% of all consumers correctly identifying products with more stars as healthier.⁵² The evaluation also found evidence of healthier product reformulation as a result of HSR labels, with 79% of products in New Zealand being reformulated since HSR implementation in 2014, and reductions in energy and saturated fat in Australian food products.⁵²

Studies from the UK, where multiple Traffic Lights and GDA labelling systems are voluntary, found that 14% of foods in an analysis of 2021 products displayed the GDA, and only 8% displayed the recommended Traffic Lights in 2012.¹⁸⁵ Interviews with UK adults demonstrated that consumers were confused by the varied voluntary labelling systems.¹⁸⁶ There is limited research on awareness, understanding, and use of these voluntary labelling systems, as the majority of studies have used surveys and experimental tasks to assess effectiveness of FOP labels such as Traffic Lights compared to other systems.^{32,134,159,187} A pan-European study conducted across six countries found that 79% of UK respondents were aware of both the GDA and Traffic Lights, with 40% reporting use of the GDA label.¹⁸⁷ Across the study sample, respondents' ratings for ease of understanding of GDA labels was between 5.3-7.1 out of 10, which corresponded to 'average' or 'fairly well.'¹⁸⁷ UK respondents rated their average understanding around 7 out of 10, and over 80% of respondents from the UK were able to identify the healthier option between two products irrespective of whether the GDA or Traffic Lights were shown.¹⁸⁷ One study found that Traffic Light labels increased nutrition knowledge among consumers;¹⁰² however, another study found that Traffic Light labels did not significantly increase the healthiness of consumers' food purchases.¹⁸⁸

Research suggests higher awareness and use of FOP labels in countries with mandatory labelling policies, including ‘high-in’ labels in Chile and multiple Traffic Light labels in Bolivia, Ecuador, Iran, and Sri Lanka.¹⁸⁹⁻¹⁹² However, given that there are few examples of mandatory FOP labelling policies, pre-implementation studies to date have been important for identifying the potential effectiveness of different labelling systems.^{36,90,193-196} Mandatory labelling policies can prevent food manufacturers from disguising ‘less desirable’ nutrients and provide a balanced picture of both ‘positive’ nutrients and ‘negative’ nutrients of health concern.⁹⁰ Standardized formats allow consumers to easily compare nutrient facts with any nutrition or health claims also made on food packaging.^{98,101} Mandatory labelling policies may also provide greater impetus for food manufacturers to improve the nutritive value of their products.^{98,101}

Evidence regarding Chile’s mandatory ‘high in’ labels for calories, sugar, sodium, and saturated fat provides some insight into consumer preferences and impact. Six-months post-implementation, 92% of Chilean adults rated the labelling system as ‘good’ or ‘very good.’¹⁹³ The vast majority (92%) also reported that the labels influenced their food choices, 68% reported choosing foods with fewer ‘high-in’ symbols, 10% reported not buying foods with these labels, and 14% reported buying less of a product due to the label.¹⁹³ Another Chilean study which assessed adolescents’ and mothers’ perceptions before and after the FOP labelling system became mandatory found that a greater proportion of mothers considered nutrition information to be the most important aspect informing food purchases (28% in 2016 pre-implementation versus 35% in 2017 post-implementation), with no changes among adolescents.¹⁹³ When respondents were asked how they determined the healthiness of a food, 26% of mothers and 23% of adolescents reported basing this decision on the absence of a ‘high in’ FOP label in 2017.¹⁹³

The FOP Traffic Lights system is mandatory in Ecuador, and research has shown high awareness of these labels among children, youth, and adults.^{197,198} Use has been found to vary widely based on age, sex, ethnicity, and consumers’ interest in health,^{196,197} with studies finding lower use among children, adolescents, and adult males compared to adolescents and adult women interested in health.¹⁹⁷ One study found approximately 32% of women from the dominant Mestiza population in Ecuador reported using Traffic Lights information compared to 5% of Indigenous women.¹⁹⁶ Poor understanding of these labels has been associated with low use, with 50% of Mestiza and approximately 33% of Indigenous women exhibiting label understanding.¹⁹⁶ Another cross-

sectional study found approximately 28% of Ecuadorians in an urban supermarket-based study were observed using the Traffic Light labels.¹⁹⁸ A study of carbonated soft drink purchasing between 2013 to 2015 following mandatory Traffic Light label implementation in Ecuador in 2013, found that high sugar drink purchases decreased over time, and purchases of low- and non-sugar beverages increased.⁵¹ Relatively less post-implementation research has been conducted in other countries that recently implemented mandatory Traffic Light labels, with studies suggesting low awareness and uptake in countries such as Iran^{199,200} where traditional foods are exempt from carrying the label.¹⁹⁰

Overall, there is promising evidence that FOP label use not only improves consumer awareness and understanding, but also impacts purchasing behaviour.^{46,47,90,128,167,183,201-203} However, it is important to note that label reading, use, and resultant dietary choices are inevitably affected by many other factors. Evidence indicates that the varied impact of FOP labelling can be attributed, in part, to sociodemographic differences in understanding and use. Literature on NfTs suggests that these labels are poorly understood by consumers with lower education and income compared to higher socioeconomic status (SES) groups.^{118,139} While FOP labelling systems intend to reduce the gap in understanding between groups with differing SES and literacy levels,¹⁸⁹ some studies have found differences in FOP label preference, comprehension and use based on sociodemographic characteristics.

1.5.3 Disparities in nutrition labelling policy uptake

When implementing population-health policies such as nutrition labelling, it is important to consider potential differences in uptake based on consumers' literacy levels, SES, and sociodemographic characteristics. Research has found lower NfT use among lower education, income, and literacy groups,^{118,121,123,139} which is troubling given that lower SES groups are also more vulnerable to poor dietary patterns and nutrition-related chronic disease due to other barriers in accessing healthy foods.^{1,6,7,141}

Studies to date have shown that females, older consumers, and those with higher education and income report greater nutrition label understanding and use than males, younger, and lower SES consumers, respectively.^{45,90,114,118,119,121,140,204} Similarly, the sociodemographic groups reporting higher label use are also more likely have higher nutrition knowledge based on both self-report

and functional tests of knowledge.²⁰⁵⁻²¹⁰ Very few studies have explored label use differences by ethnicity; however, existing evidence suggests that label use tends to be higher among non-Indigenous or majority populations compared with Indigenous, minority, or immigrant groups.^{95,163,196,211}

Relatively little post-implementation research has been conducted on FOP labelling policies, with studies to date indicating FOP labels as easier to understand than NFts,^{111,118,142,158} particularly among consumers with lower education and income.^{46,118,134,139,156,157,159,212} Some studies have explored relationships between SES and FOP label preferences;^{163,171,172,214,215} however, there is limited research on sociodemographic differences in understanding and use of FOP labels specifically. A recent HSR evaluation study in Australia found that males, respondents with a university education, Indigenous Peoples, those with a body mass index (BMI) between 18.5-24.9, households with incomes over \$50,000 AUD, and households where a language other than English was spoken, were more likely to be influenced by HSR labels than their counterparts.⁵² Other studies have found that older adults and those with higher BMIs reported lower awareness of HSR compared to younger adults and respondents with lower BMIs, respectively.^{89,216}

GDA labels have been found to be poorly understood, particularly among lower income and education groups.^{32,90,154,167,217-219} In general, studies have found that consumers with lower health literacy or nutrition knowledge indicate a preference for color-coded FOP label formats such as Traffic Lights.^{157,161-164,220}

1.6 Rationale

The global trend in processed food consumption is of concern as it has contributed to rising NCD prevalence. Evidence demonstrates that nutrition labelling policies are important educational tools to improve awareness and understanding of the nutritive value of packaged foods, and to encourage healthier product reformulation by the food industry.^{35,36} NFts have been effective among some subpopulations;^{34,42,108-110} however, prominent disparities in NFt understanding and use have led to the development of FOP labelling policies.^{36,90,118,139,142} While FOP labels have been implemented as voluntary or mandatory policies across jurisdictions,⁹⁰ there is currently limited

post-implementation evidence assessing their uptake and effectiveness across countries and subpopulations.

Research focused on FOP nutrition labelling suggests that these labels are easier for consumers to understand than NFts; therefore, they have greater potential to modify dietary behaviour.^{111,118,142,158} Evidence has shown that specific subgroups (e.g., consumers with high literacy or education) tend to benefit more from NFts;^{95,118,121,123,139} however, it is unclear whether the same subgroup associations hold for FOP labels. Moreover, a limited number of studies have explored the influence of consumers' diet-related goals or practices on nutrition label awareness and use.^{58,74,92,95,221,222} While FOP labels may be subject to fewer subgroup differences in uptake than NFts, patterns and correlates of nutrition label use – including comparisons between label types across countries, health literacy, and sociodemographic subgroups – are yet to be explored.

Several studies have assessed consumer understanding of front- and back-of-package nutrition labelling systems across multiple countries,^{32,111,117,134,159,166,173} although the lack of post-implementation research comparing mandatory vs. voluntary policies across countries is a significant gap in evidence. Cross-country comparisons are especially important given that different jurisdictions can learn from one another without having to implement and test various label designs. National evaluations can contribute to best practice guidelines to inform nutrition labelling policy more broadly. Moreover, cross-country studies are necessary to explore the impact and uptake of labels among different subgroups, as this data can enable labelling policies and campaigns to be effectively tailored to the needs of citizens.

To date, most FOP labelling systems such as HSR (Australia) and Traffic Lights (UK) have been implemented on a voluntary basis. However, more countries have been mandating FOP labelling policies. In Canada, FOP 'high-in' symbols will be mandatory for packaged products containing high levels of sodium, sugar, or saturated fat by 2021,²²³ and Mexico has now mandated the use of 'high-in' symbols on ultra-processed foods.²²⁴ In order to support successful implementation of mandatory FOP labelling policies, research is needed to evaluate the extent to which FOP labels are more effective than NFts, and whether certain label types perform better than others.

In addition to sparse post-implementation research on labelling systems, patterns and correlates of nutrition knowledge, as well as its role in labelling behaviours, are poorly understood. Nutrition

knowledge differences may further exacerbate existing disparities in label use, thus warrant special attention. Subjective measures, such as self-rated knowledge, are often used in studies focused on nutrition knowledge. On the other hand, current functional measures which may be a stronger indicator of knowledge tend to focus on awareness of country-specific dietary guidelines, and consequently are unsuitable for use across geographic contexts with different dietary guidelines.^{38,81,96,208,225} As a result, the same nutrition knowledge measure is seldom used across studies, which creates challenges for comparing nutrition knowledge levels – as well as corresponding determinants of knowledge – across studies, geographic contexts, and populations.^{78,226}

This study uses cross-sectional International Food Policy Study (IFPS) data to compare different nutrition labelling systems and obtain a greater understanding of *who* is benefiting most from this population-level intervention. This study also explores disparities across subgroups in terms of label understanding, use, awareness, and nutrition knowledge. Thus, this study contributes to the evidence base of differential effects of varied labelling policies on subgroups, including by age, sex, ethnicity, education, income, BMI, and health literacy. This study also contributes a new functional measure of nutrition knowledge based on level of food processing, which can be used in large population-based studies to enable cross-country comparisons – unlike longer, more complex measures – to shed light on consumer nutrition knowledge patterns.

Many countries do not consistently collect population-based data on nutrition knowledge or nutrition label awareness, understanding, and use; hence, this study importantly contributes to the generation of data necessary for long-term evaluation efforts. An assessment of relevant correlates of these outcomes is critical for ongoing policy development and health promotion efforts in each of the five countries surveyed.

1.7 Research Objectives and Questions

This dissertation explores patterns and correlates of nutrition knowledge and label awareness, understanding, and use across five countries (Australia, Canada, Mexico, UK, US), with a specific focus on the role of consumer dietary behaviours and sociodemographic characteristics.

1.7.1. Study 1 – Development and evaluation of the Food Processing Knowledge score: a functional test of consumer nutrition knowledge based on level of food processing

The objective of Study 1 was to assess face and content validity of a new functional measure of nutrition knowledge, the FoodProK score. This study addressed the following research questions:

1. To what extent do subject matter experts (Registered Dietitians) perceive level of food processing as an appropriate indicator of the general nutritional quality of foods?
2. a) How do experts perform on the FoodProK score?
b) What are potential areas of improvement for the FoodProK score?
3. Is the FoodProK considered a reasonable measure for general nutrition knowledge for consumers?

1.7.2 Study 2 – Patterns and correlates of nutrition knowledge across five countries in the 2018 International Food Policy Study

The objective of Study 2 was to determine nutrition knowledge levels and associated correlates across countries. This study addressed the following research questions:

1. Do self-reported and functional nutrition knowledge (as measured by the FoodProK score) differ across countries?
2. How does nutrition knowledge differ across sociodemographic groups, behavioural characteristics, BMI, and health literacy levels?
3. What is the association between self-reported and functional measures of nutrition knowledge?

1.7.3 Study 3 – Correlates of self-reported and functional understanding of nutrition labels across five countries: Findings from the 2018 International Food Policy Study

The objective of Study 3 was to assess patterns and correlates of nutrition label understanding across countries. This study addressed the following research questions:

1. What are the levels of self-reported (NFt, FOP label) and functional (NFt) label understanding across countries?
2. Does self-reported FOP label understanding vary by label type (i.e., HSR vs. GDA)?
3. Is self-reported label understanding associated with functional label understanding and consumers' nutrition knowledge?
4. Does label understanding vary by consumers' dietary behaviours or sociodemographic characteristics?

1.7.4 Study 4 – A five-country study of front- and back-of-package nutrition label awareness and use: patterns and correlates from the 2018 International Food Policy Study

The objective of Study 4 was to explore correlates of nutrition label awareness and use, as well as associations between labelling behaviours and functional nutrition knowledge. Associated research questions include:

1. What are the levels of NFt and FOP label use and awareness across countries?
2. a) How does NFt and FOP label use and awareness differ across sociodemographic groups and behavioural characteristics?
b) Is functional nutrition knowledge associated with NFt and FOP label use and awareness?
3. Is NFt or FOP label use higher among consumers with specific sociodemographic (age, sex, ethnicity, education, income adequacy) and knowledge-related characteristics (health literacy status, FoodProK) in the three countries with both label types (Australia, Mexico, UK)?

1.8 Conceptual Framework

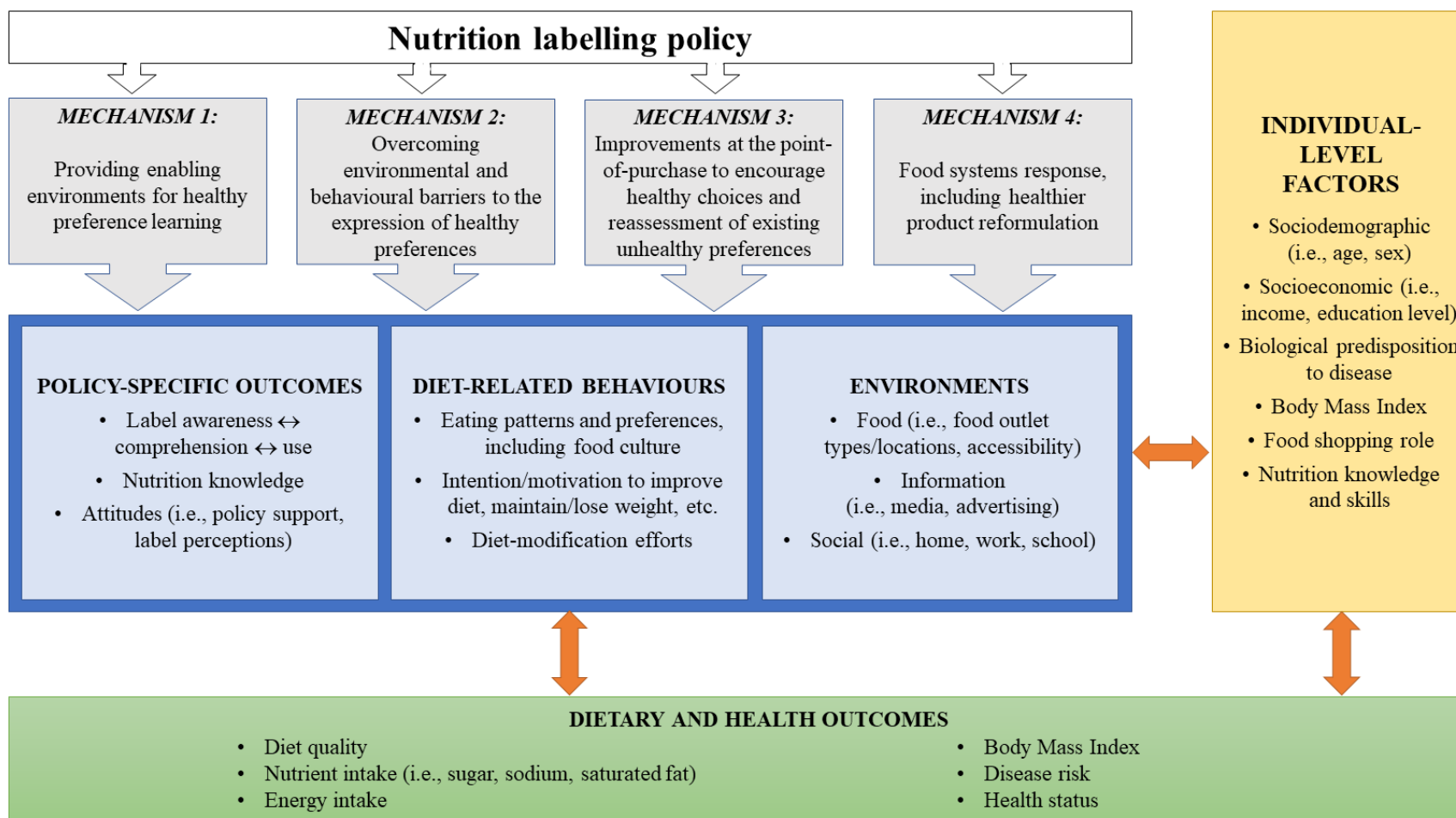
This study draws upon two key conceptual frameworks: the Glanz et al. (2005) Model of Community Nutrition Environments²⁴ and the Hawkes et al. (2015) Framework of Theory of Change.²²⁷ The Model of Community Nutrition Environments²⁴ highlights the interaction between government/industry policies, nutrition and information environments, and individual-level factors to influence eating behaviours. The Hawkes et al. (2015) framework introduces potential mechanisms (i.e., pathways) through which nutrition labelling policies influence environments, and may lead to different dietary and health outcomes. These mechanisms apply to various food policies, including labelling and taxation, and reiterate that food policies should not only aim to make “the healthy choice the easy choice, but also the preferred choice” by consumers.²²⁷

Figure 1 illustrates how nutrition labelling policy, in particular, may act via four key mechanisms to influence changes in three domains: policy-specific outcomes, diet-related behaviours, and environments. Policy-specific outcomes refer to the psychosocial impacts of nutrition labelling policy (i.e., changes in label awareness/understanding/use, nutrition knowledge, or attitudes). Diet-related behaviours include consumers’ eating patterns, as well as intentions to modify diet. Environments include the broader contexts (food, information, social) which may be influenced by policy. These domains interact with each other, and can also play a role in dietary and related health outcomes. Individual-level factors also act on these domains and dietary and health outcomes.

This dissertation focuses on consumers’ nutrition knowledge and labelling behaviours (label awareness, understanding, and use), and explores the association between multiple individual-level factors with these policy-specific outcomes. Nutrition knowledge is both an individual-level factor – as consumers possess prior knowledge from numerous sources – as well as a policy-specific outcome, as one of the aims of nutrition labelling policy is to improve consumer knowledge. Prior knowledge can influence current label understanding and use, as well as food purchasing and consumer patterns.^{24-27,74,84,129-135,226} Mechanisms 1 (providing enabling environments for health preference learning) and 3 (improvements at the point-of-purchase to encourage healthy choices and reassessment of existing unhealthy preferences) are tied to improvements in nutrition knowledge, as shifts in eating preferences may be facilitated by

knowledge of healthier eating practices. As noted under policy-specific outcomes, nutrition label awareness, comprehension, and use, are all connected. Attention to labels can lead to understanding, which may influence consumers' decision-making processes regarding healthier food purchasing and consumption. Alternatively, a greater understanding of labels or nutrition may prompt increased attention or use of labels.^{74,111,228}

Figure 1: Nutrition Labelling Policy Conceptual Framework



Chapter 2: General Methods

2.1 Study design

The International Food Policy Study (IFPS) is a 5-year prospective cohort study conducted in Australia, Canada, Mexico, the UK, and the US. This study aims to evaluate the impact of national-level policies (i.e., food labelling policy, food marketing restrictions, sugar taxation). Given that the timing of policy implementation is not in the control of researchers, cross-country data collection and a quasi-experimental design enable examination of dietary patterns and policy-relevant behaviours within and between countries over time.

Each country differs on nutrition labelling policies and is also at different stages with respect to implementation. Exposure to a policy in a given group (country) can be compared with control groups, which are represented by countries that have not implemented particular policies. The prospective cohort design requires the same individuals to be measured on the same key outcome variables before and after policy implementation.^{1,2} Appendix A provides an overview of the different FOP labelling policies in each of the five countries.

This dissertation used cross-sectional data from the 2018 wave of the IFPS. Respondents aged ≥ 18 years completed web-based surveys in November-December 2018 answering questions about a range of dietary behaviours, food environment, and policy-specific questions. Surveys were conducted in English in Australia and the UK; Spanish in Mexico; English or French in Canada; and English or Spanish in the US. The median time to complete the survey across countries was 40 minutes. More details about the IFPS can be found elsewhere.¹

In addition, a sub-study was conducted to aid the development and assessment of a new functional measure of nutrition knowledge. Registered Dietitians in Canada were recruited as subject matter experts in January 2020 to provide feedback on the new measure. The survey was created using Survey Gizmo, an online platform which enabled survey administration via desktops, laptops, tablets, and smartphone devices. Respondents for the IFPS and associated sub-study provided consent prior to survey completion. The study was reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 21460 for IFPS and #36005 for the sub-study).

2.2 Sample description, recruitment, and selection criteria

IFPS respondents were recruited through the Nielsen Consumer Insights Global Panel and their partners' panels via email invitations sent to a random sample of panelists, targeting for age and country criteria. The sample was stratified within each province/state/region, by sex (male/female) and age, with sample size proportional to population size in each of the age/sex groups. Nielsen panels are recruited using both probability and non-probability sampling methods in each country. To account for differential response rates, Nielsen modified sampling proportions to place greater weight on subgroups with lower response rates. Nielsen provided a diverse sample matching the population distribution of socioeconomic factors in each country, including respondents with lower income and education. The Nielsen panel provided consistent recruitment and sampling methodology across all countries.¹

IFPS respondents received remuneration (points-based or monetary rewards in accordance with the panel's incentive structure) to increase response rates and decrease response bias in subgroups underrepresented in surveys, including disadvantaged subgroups.³⁻⁵ The 2018 IFPS wave had a total of 22,824 respondents, including 4,397 from Canada, 4,640 from the US, 4,135 from Mexico, 5,549 from the UK, and 4,103 from Australia. A total of 7.7% of invited respondents accessed the study, and 6.5% completed all surveys.¹

Dietitians were recruited using convenience sampling via an online survey link shared in the bi-monthly Registered Dietitians of Canada newsletter. Eligible participants were Registered Dietitians (assessed via self-report) and at least 18 years of age. No incentives were provided; however, respondents were notified that results would be shared following study completion.

2.3 Measures

2.3.1 Sociodemographic variables

Potential determinants of nutrition label use or nutrition knowledge were identified based on a review of previous literature. Sociodemographic and socioeconomic measures controlled for in all analyses included age, sex, ethnicity, education, income adequacy, country, and BMI.

Participants were asked about their *age*, "How old are you?" and grouped into the categories 18-29, 30-44, 45-59, and 60+ years old.

Sex was determined by asking, “What sex were you assigned at birth, meaning on your original birth certificate?” with response options ‘male’ and ‘female.’ Gender was not used in this study because less than 1% of respondents (n = 113) reported a gender different than biological sex, which was insufficient for providing robust estimates in modelling.

Ethnicity was treated as a binary variable to enable between-country comparisons, with respondents categorized as ‘majority’ in Mexico if they identified themselves as ‘Indigenous,’ and ‘majority’ in Australia, Canada, the UK and the US if they identified themselves as ‘white,’ predominantly English-speaking, or non-Indigenous based on country-specific ethnicity questions.^{1,6-9}

Education level was categorized in accordance with country-specific criteria, in which respondents were classified as having ‘low’ (high school completion or lower), ‘medium’ (some post-secondary school qualifications, including some university), or ‘high’ (university degree or higher) levels of education.^{1,6,7,10-12}

Income adequacy was used instead of household income to ensure relevance of this measure across countries. Respondents were asked, “Thinking about your total monthly income, how difficult or easy is it for you to make ends meet?” with Likert scale response options ‘very difficult,’ ‘difficult,’ ‘neither easy nor difficult,’ ‘easy,’ and ‘very easy.’¹³

Country of residence was a core categorical variable that was used to compare patterns for respondents across the five countries included in this study.

BMI was calculated using self-reported height and weight. Respondents were asked, “How tall are you without shoes?” and “How much do you weigh without clothes or shoes?” Responses in centimetres were converted to metres (for height), and stones or pounds were converted to kilograms (for weight). Categorization of BMI followed World Health Organization criteria,¹⁴ with self-reported height and weight used to classify respondents based on BMI <18.5 kg/m², 18.50 to <25 kg/m², 25 to <30 kg/m², and ≥30 kg/m². Respondents with missing or incomplete height or weight data were classified as ‘missing.’

2.3.2 Dietary behaviour variables

Diet modification efforts, specific dietary practices, and food shopping role are expected to influence nutrition label use as individuals with specific diet-related goals, preferences, and greater involvement in household food purchasing are expected to be more interested in labels.¹⁵⁻¹⁸

Diet Modification Efforts were measured by asking, “Have you made an effort to consume more or less of the following in the past year?” Respondents answered ‘consume less,’ ‘consume more,’ and ‘no effort made’ to a list of nutrients and food categories. This study focused on efforts in five categories that have received increasing attention in policies such as dietary guidelines within the five countries: ‘trans fats,’ ‘sugars/added sugars,’ ‘salt/sodium,’ ‘calories,’ and ‘processed foods.’¹⁹⁻²⁴ A value of -1 was assigned for responses to ‘consume less,’ +1 for responses to ‘consume more,’ and 0 for ‘no effort made’ in the five categories. Five points were added to the sum of the five categories to create a scale ranging from 0 to 10, with 0 representing ‘consume less’ responses to all categories, 10 representing ‘consume more’ responses to all categories, and the range between reflecting all other response combinations.

Dietary Practices were measured by asking, “Would you describe yourself as: (select all that apply) ‘vegetarian,’ ‘vegan,’ ‘pescatarian,’ ‘following a religious practice for eating (please specify),’ or ‘none of the above.’ This variable was recoded as binary (no specific dietary practices = 0; one or more dietary practices = 1). The dietary modification efforts and practices questions were adapted from the Canada Foundation for Dietetic Research Tracking Nutrition Trends survey.²⁵

Food Shopping Role was measured by asking, “Do you do most of the food shopping in your household?”²⁶ ‘Yes,’ ‘no,’ and ‘share equally with other(s)’ were the response options. This variable was treated as binary (‘yes’ = 1, ‘no’ = 0).

2.3.3 Knowledge-related variables

Health Literacy was measured using an adapted version of the Newest Vital Sign, which asks respondents six questions regarding an ice cream container NFt. The Newest Vital Sign was self-administered as part of the online IFPS survey, and country-specific NFts were shown. This exercise measured respondents’ ability to make mathematical calculations (numeracy), read and apply information from the NFt (prose literacy), and understand the information on the label

(document literacy). A score between 0-6 was calculated based on the number of correct answers. A score of 0-1 suggested ‘high likelihood (50% or more) of limited literacy;’ a score of 2-3 indicated ‘possibility of limited literacy;’ and a score of 4-6 indicated ‘high likelihood of adequate literacy.’²⁷⁻³¹













Self-Reported Nutrition Knowledge was measured by asking, “How would you rate your nutrition knowledge?” with response options ranging from ‘not at all knowledgeable,’ ‘a little knowledgeable,’ ‘somewhat knowledgeable,’ ‘very knowledgeable,’ and ‘extremely knowledgeable.’²⁵ This variable was treated as continuous in analyses (range =1-5).

Functional Nutrition Knowledge was assessed using the FoodProK score, a new measure based on consumer knowledge of level of processing. Respondents viewed and rated images of three food products (along with NFts and ingredient lists) within each of four categories: fruits (apple, apple juice, apple sauce), meat (chicken breast, deli chicken slices, chicken nuggets), dairy (1 per cent milk, cheese block, processed cheese slices), and grains (oats, cereal, cereal bar). Products in each category were selected based on availability in multiple international contexts and to represent varied levels of processing. Potential food products were identified via an online search, and availability of the shortlisted products was verified by IFPS co-investigators from each of the five countries. Each category included a food in Group 1 (“minimally processed/whole foods”), Group 3 (“processed”), and Group 4 (“ultra-processed”) of the NOVA classification system (**Table 2**). NOVA Group 2 foods were not included because they are processed culinary ingredients extracted from whole foods (i.e., oils, flours, sugars).³² Three reviewers with nutrition training independently categorized the 12 foods according to the NOVA classification system for level of food processing (**Table 3**), with no discrepancies identified across reviewers. Branding on food packages was removed digitally and fictional product names were added to minimize the potential for bias based on brand familiarity. The 12 product images with their corresponding NFts and ingredients lists were displayed one at a time, in random order. For each product, respondents were asked, “Overall, how healthy is this food product?” and answered using a scale of 0 to 10, with 0 representing ‘not healthy at all’ to 10 indicating ‘extremely healthy.’

Table 2: NOVA Food Processing Classification System Definitions

Group 1 Foods	Minimally processed, whole foods (e.g., fruit, skim milk)
Group 2 Foods	Processed culinary ingredients extracted from whole foods that are not primarily consumed on their own, but used in the preparation of meals with Group 1 products (e.g., oils, flours, sugars)
Group 3 Foods	Processed food products manufactured by adding Group 2 foods to increase durability and palatability (e.g., canned vegetables, cheese, etc.)
Group 4 Foods	Ultra processed foods that contain little/no whole foods.

Table 3: Food products included in the Food Processing Knowledge score based on NOVA food groups

NOVA Food Classification	Fruit products	Meat products	Dairy products	Grain products
Minimally processed (group 1)	<p>Apple</p> 	<p>Chicken breast</p> 	<p>1% milk</p> 	<p>Oats</p> 
Processed (group 3)	<p>Apple sauce</p> 	<p>Deli meat</p> 	<p>Cheese block</p> 	<p>Cereal</p> 
Ultra-processed (group 4)	<p>Apple juice</p> 	<p>Chicken nuggets</p> 	<p>Processed cheese slices</p> 	<p>Cereal bar</p> 

FoodProK scores were calculated based on the concordance of healthiness ratings within each food category with the rankings based on the NOVA classification, with less processed foods representing higher healthiness. For each category, respondents received a score of 2 if their food product ratings corresponded with the order of NOVA food processing groups (e.g., apple > apple sauce > apple juice). If 2 of 3 products in a given category were ranked in accordance with

NOVA's rankings (e.g., apple > apple juice > apple sauce), respondents received a score of 1. Zero was assigned if the respondent's rankings did not align with those based on NOVA. Scores were summed across the four food categories to create the total FoodProK score, ranging from 0 to 8.

2.3.4 Nutrition labelling outcome variables

For the following measures, a country-specific label image was shown on the screen. All countries were shown NFt images. Australia, Mexico, and the UK were also shown FOP labels specific to their country. All of the following variables were coded as continuous in analyses. These survey questions were adapted from the 2014 Food and Drug Agency Health and Diet Survey.³³

NFt and FOP Label Awareness was measured by showing respondents a label and asking, "Have you seen this type of food label on packages or in stores?" Response options include 'never,' 'rarely,' 'sometimes,' 'often,' and 'all the time.'

NFt and FOP Label Understanding was measured by showing respondents a label and asking, "Do you find this information..." 'very hard to understand,' 'hard to understand,' 'neither hard or easy to understand,' 'easy to understand,' and 'very easy to understand.'

NFt and FOP Label Use was measured by showing respondents a label and asking, "How often do you use this type of food label when deciding to buy a food product?" with response options 'never,' 'rarely,' 'sometimes,' 'often,' and 'all the time.'

2.3.5 Dietitians survey

After rating the healthiness of 12 products presently individually, dietitians were asked: "In general, which of the following foods is healthier?" using a multiple-choice format. This question was asked to compare the two processed food products in each category (i.e., apple sauce vs. apple juice, cheese block vs. processed cheese slices, cereal vs. cereal bar, deli chicken slices vs. chicken nuggets), with the option of indicating 'no difference' for each comparison. Dietitians were further asked to explain their choice and what the main difference was between the two foods in each

category. Responses were coded as ‘correct’ if the less processed food in each category was selected.

Following the FoodProK scoring task, dietitians were asked about the appropriateness of this measure for assessing the general nutritional quality of foods. To assess face validity, dietitians were asked the open-ended question, “When you were rating each of the foods, what were the main factors that you considered in your rating?” The importance of processing was assessed by asking, “Overall, how important is level of processing to the healthiness of foods?” with five-point Likert-scale responses ranging from ‘very important’ to ‘not important.’

Dietitians were also asked, “In your opinion, is level of processing (e.g., “fresh” unprocessed vs. ultra-processed foods) a reasonable indicator of the general nutrition level of different foods?”, with the response options ‘yes,’ ‘no,’ and a follow-up asking them to explain why or why not. Lastly, dietitians were asked, “Were any of the food rating task questions confusing or unclear?” with response options ‘yes,’ or ‘no,’ and a follow-up question prompting an explanation.

2.4 Data Analysis

Descriptive statistics were used in all studies to assess food product healthiness ratings (study 1), FoodProK scores (study 1 and 2), and nutrition label understanding (study 3), use and awareness (study 4). In study 1, one-way repeated-measures ANOVA tests were conducted to assess differences in mean food product ratings. Pairwise comparisons between food products in each category were tested, adjusting for multiple comparisons using the Bonferroni correction. A total of four tests were run to assess whether mean ratings significantly differed for the three products within each food category. A sample size calculation was conducted to ensure sufficient power to detect a 1-point difference in FoodProK scores. Analyses were conducted using SPSS Statistical Software (Version 26.0; IBM Corp., Armonk, NY; 2018). A thematic analysis was conducted for open-ended survey data, which consisted of reviewing all responses and creating new variables representing common factors that dietitians considered when completing food product ratings. Responses were coded according to whether particular factors were mentioned, and feedback was summarized with sample quotations.

Multiple linear regression models were fitted to examine between-country differences in nutrition knowledge (FoodProK score) in study 2, and correlates of label understanding (study 3), awareness

and use (study 4) using SAS Studio (SAS Institute, Cary, NC). All analyses adjusted for sociodemographic, behavioural, and knowledge-related characteristics. Regression models included an ‘indicator’ or ‘class’ variable for country to test the ‘main’ effect of country on outcomes. Two-way interactions between country and sociodemographic characteristics (i.e., country*income adequacy) were tested to examine how patterns differed across countries. Multiple comparisons were conducted to assess all pairwise contrasts for categorical variables. The Benjamini-Hochberg procedure was applied to decrease the false detection rate following multiple exploratory tests.³⁴ All statistically significant pairwise contrasts are reported after applying the Benjamini-Hochberg procedure, assuming a false discovery rate of 10%.

Lastly, generalized linear mixed models in study 4 tested awareness of NfT vs. FOP labels, and use of NfT vs. FOP labels in Australia, Mexico, and the UK. A repeated-measures analysis was used to account for the correlated data within individuals for these measures. Each model included two-way interactions between country and all sociodemographic, dietary behaviours, and knowledge-related covariates to assess whether awareness/use differed for NfT vs. FOP labels among these subgroups. Values of $p < 0.05$ were considered statistically significant for all regression and repeated-measures analyses.

Spearman’s rank correlation tests were conducted to gain a better understanding of the correlation between self-reported (label awareness/understanding/use, nutrition knowledge) and functional outcome variables (Newest Vital Sign, FoodProK), as well as between labelling outcomes (NfT and FOP label awareness/understanding/use). Post-stratification survey weights were constructed for each country based on population totals by age, sex, region, ethnicity (except Canada), and education (except Mexico) using census data in each country,¹ and applied to all analyses.

Response options ‘don’t know’ and ‘refuse to answer’ were provided for all survey questions and recoded as missing. BMI had a large number of cases with missing height and weight data, hence a separate category for ‘missing’ was created and retained as a response category for analyses. Missing data were systematically removed for each variable. With the exception of BMI, respondents with missing data were not different with respect to nutrition knowledge or nutrition labelling outcomes compared with the rest of the sample. Analyses were conducted using data for respondents who had complete data for all variables.

Chapter 3: Results

3.1 Study 1 – Initial development and evaluation of the Food Processing Knowledge score: a functional test of nutrition knowledge based on level of food processing

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Authors: Bhawra J,¹ Kirkpatrick SI,¹ Hall MG,¹ Vanderlee L,³ Hammond D.¹

¹School of Public Health & Health Systems, University of Waterloo, Waterloo, Ontario, Canada

²Gillings School of Global Public Health and Lineberger Comprehensive Cancer Center, University of North Carolina, Chapel Hill, North Carolina, United States

³École de Nutrition, Centre nutrition, santé et société (Centre NUTRISS), Institut sur la nutrition et les aliments fonctionnels (INAF), Université Laval, Québec, Canada

3.1.1 Abstract

Background: Existing nutrition knowledge measures tend to be lengthy or tailored for specific contexts, making them unsuitable for population-based surveys. Given the growing emphasis within country-specific dietary guidelines on reducing consumption of highly processed foods, consumers' ability to understand and apply principles related to level of food processing could serve as a proxy measure of general nutrition knowledge.

Objective: To examine the content validity of the Food Processing Knowledge (FoodProK) score based on subject matter expert consultation with Registered Dietitians.

Methods: Registered Dietitians in Canada (n=64) completed an online survey, including the FoodProK, in January 2020. Participants rated the 'healthiness' of 12 food products from four categories (fruit, meat, dairy, and grains) on a scale from 1 to 10. FoodProK scores were assigned based on concordance of ratings within each food category with rankings according to the NOVA system, with less processed foods representing higher healthiness. For each category, one-way repeated-measures ANOVA models tested whether the three product ratings were significantly different from one another. Descriptive statistics compared ratings and FoodProK scores across categories. Open-ended feedback was solicited to assess face validity of the score.

Results: Dietitians' FoodProK scores were strongly associated with level of food processing. Almost one in three dietitians received perfect FoodProK scores, and the mean score was 7.0 of 8.0 possible points. Within each category, the three foods received significantly different healthiness ratings, in the same order as the NOVA system ($p < .001$ for all contrasts). Open-ended responses showed dietitians did not perceive meaningful differences between the processed meat products, suggesting the need to change one of the products in the meat category. Overall, 80% of dietitians reported level of processing as an important indicator of the healthiness of foods.

Conclusions: Level of food processing represents a promising framework for assessing general nutrition knowledge in population-based surveys.

Keywords: nutrition knowledge, food rating task, content validity, validity evidence, healthy food perceptions

3.1.2 Introduction

Nutrition knowledge is integral to consumers' ability to identify and select foods that contribute to a healthy diet.¹⁻⁴ Consumers obtain nutrition knowledge from numerous sources, including educational campaigns, media, and cultural and social contexts.^{2, 5-7} With rising rates of diet-related non-communicable diseases,⁸⁻¹⁰ understanding nutrition knowledge and its role in health behaviours is increasingly important. Nutrition knowledge is a complex phenomenon that can encompass a wide variety of constructs, including knowledge of dietary recommendations, ability to understand quantitative information, and food preparation skills.¹¹⁻¹⁴ Existing measures of nutrition knowledge range from single-item questions about one's perceived level of knowledge, to elaborate scales that focus on different combinations of these constructs.¹¹⁻¹⁵

Given the lack of consensus in the literature about nutrition knowledge assessment, subjective, self-rated measures of nutrition knowledge are commonly used. However, research has shown that consumers tend to overestimate their ability to understand quantitative nutrition information on such subjective measures, as demonstrated by lower scores on functional tasks compared to self-reported knowledge.¹⁶⁻²⁰ 'Functional' nutrition knowledge measures are considered to provide more accurate assessment,^{14, 16-19} and studies using these measures have demonstrated associations between nutrition knowledge and diet-related decisions and behaviours.²¹⁻²⁶ Currently, many functional measures assess knowledge of dietary recommendations which are specific to national contexts, and therefore not applicable to other countries with different dietary guidelines.^{12, 26-28} As a result, the same nutrition knowledge measure is seldom used across studies, which creates challenges for comparing nutrition knowledge levels – as well as corresponding determinants of knowledge – across studies, geographic contexts, and populations.^{15, 29}

The wide variety of knowledge measures used in the literature also reflects differences in perceptions of what constitutes a 'healthy food' within the nutrition community.^{15, 30, 31} In the midst of this complexity, an increasing number of countries, including Brazil and Canada, have started to shift away from prescriptive quantitative food group recommendations towards dietary guidance that emphasizes how to eat, in addition to what to eat, with integration of messaging related to limiting consumption of highly or ultra-processed foods.³²⁻³⁴ Many countries specifically note the

importance of limiting intake of foods high in saturated or trans fats, added sugars, and sodium in their dietary guidelines.³²⁻³⁸

The focus on type of processing follows a global dietary shift towards greater consumption of highly processed foods in recent decades.³⁹⁻⁴¹ Ultra-processed foods constitute more than half of total energy intake in high-income countries such as Canada, the United States, and the United Kingdom.^{40,42-44} The high energy density and relatively low nutrient content of ultra-processed foods contributes to poor diet quality,^{39,40,45-47} which is associated with serious health consequences, including non-communicable disease^{44,47,48} and increased risk of morbidity.^{45,46,49-51} To support inquiries of this nature, researchers have developed classification systems, such as NOVA, which differentiate foods based on the type, extent, and purpose of processing.^{40,42} NOVA has been used in over 17 countries to aid in the development of dietary guidelines and nutrient profiling systems, and to assess associations with diet-related health outcomes.⁴⁰ More specifically, NOVA has been used as an indicator of food product healthiness, as unprocessed and minimally processed foods are considered to have higher nutritional value and contribute to healthier diets compared with highly processed foods.^{39,40,42,44,46,48}

Due to its relative simplicity as a general indicator of a food's nutritional quality, a focus on level of processing provides a potential means of evaluating consumer nutrition knowledge in population health surveys. Additionally, a measure with this focus could enable cross-country comparisons that are not possible with current measures. To this end, we developed the Food Processing Knowledge (FoodProK) score, a 12-item food rating task to measure nutrition knowledge based on consumers' ability to understand and apply principles related to level of processing. The current study examined the content validity of the FoodProK score based on subject matter expert consultation with Registered Dietitians, and the extent to which experts perceived level of food processing as an appropriate indicator of the general nutritional quality of foods.

3.1.3 Methods

Sample





Dietitians were recruited using convenience sampling in January 2020 via an online survey link included in the bi-monthly Registered Dietitians of Canada newsletter. Eligible participants

were Registered Dietitians in Canada (assessed via self-report) and at least 18 years of age. Respondents provided informed consent before completing the online survey via desktops/laptops or smartphones. There were no incentives provided; however, respondents were notified that results would be shared following study completion. The study was reviewed by and obtained clearance from a University of Waterloo Research Ethics Board (ORE #36005).

Food rating task and calculation of the FoodProk score

As part of ascertaining content validity of the FoodProK, respondents completed the 12-item measure and provided feedback on the extent to which the measure was relevant and appropriate as a proxy for the general nutritional quality of foods. First, respondents viewed and rated images of three food products within four categories (fruits, meat, dairy, and grains). These categories were selected based on the food groups which commonly appear in national dietary guidelines, such as Canada’s Food Guide and the United States’ Dietary Guidelines. Food product selection entailed shortlisting specific product options from the four food groups which represented different levels of food processing. Products in each category were reviewed and selected by the authors based on consensus. The final product shortlist was determined based on availability in multiple international contexts, and to represent varied levels of processing. In particular, each category included a food in Group 1 (“un/minimally processed”/“whole food”), Group 3 (“processed”), and Group 4 (“ultra-processed”) based on the NOVA classification system (Table 1). Three reviewers with nutrition training independently categorized the 12 foods according to NOVA, with no discrepancies identified across reviewers.

Table 1: Food products rated by dietitians in the Food Processing Knowledge score based on levels of food processing from the NOVA food classification system

NOVA Food Classification	Fruit products	Meat products	Dairy products	Grain products
Minimally processed (group 1)	<p>Apple</p> 	<p>Chicken breast</p> 	<p>1% milk</p> 	<p>Oats</p> 

**Processed
(group 3)**



**Ultra-processed
(group 4)**



Note: NOVA Group 2 foods, are defined as processed culinary ingredients extracted from whole foods (i.e., oils, flours, sugars), were not included as they are typically used in meal preparation rather than consumed on their own.

The 12 product images and corresponding Nutrition Facts tables (NFTs) and ingredient lists were displayed on the screen one at a time, in random order. While viewing each product, respondents were asked, “Overall, how healthy is this food product?” using a scale between 0 to 10, with 0 representing ‘not healthy at all’ and 10 indicating ‘extremely healthy.’ Branding on food packages was removed and generic product names were used to minimize the potential for bias based on brand familiarity.

FoodProK scores were calculated based on the concordance of healthiness ratings within each food category with the rankings based on the NOVA classification, with less processed foods representing higher healthiness. Respondents received a full score of 2 if their food product ratings corresponded with the order of NOVA food processing groups (e.g., apple > apple sauce > apple juice). If the respondent ranked 2 of 3 products in a given category in accordance with NOVA (e.g., apple > apple juice > apple sauce), they received a score of 1. Zero was assigned if the respondent’s rankings did not align with those based on NOVA. Scores were summed across the four food categories to create the total FoodProK score, ranging from 0 to 8.

Capturing open-ended feedback for the FoodProK score

Following the FoodProK scoring task, dietitians were queried about the appropriateness of this measure for assessing the general nutritional quality of foods. To assess face validity, dietitians were asked the open-ended question, “When you were rating each of the foods, what were the main factors that you considered in your rating?” The importance of processing was assessed by

asking, “Overall, how important is level of processing to the healthiness of foods?” with five-point Likert-scale responses ranging from ‘very important’ to ‘not important.’ Dietitians were also asked, “In your opinion, is level of processing (e.g., “fresh” unprocessed vs. ultra-processed foods) a reasonable indicator of the general nutrition level of different foods?”, with the response options ‘yes,’ ‘no,’ and a follow-up asking them to explain why or why not. Lastly, dietitians were asked, “Were any of the food rating task questions confusing or unclear?” with response options ‘yes,’ or ‘no,’ and a follow-up question prompting an explanation. Respondents were not given the option to return to previous survey questions. This survey feature ensured that respondents could not modify answers based on later survey questions which may have suggested the importance of food processing in the rating task.

Comparing food rating task performance with alternate question formats

After rating the healthiness of 12 products presented individually, dietitians were asked: “In general, which of the following foods is healthier?” using a multiple-choice format. This question was asked to compare the two processed food products in each category (i.e., apple sauce vs. apple juice, cheese block vs. processed cheese slices, cereal vs. cereal bar, deli chicken slices vs. chicken nuggets), with the option of indicating ‘no difference’ for each comparison. Dietitians were further asked to explain their choice and what the main difference was between the two foods in each category. Responses were coded as ‘correct’ if the less processed food in each category was selected.

Statistical Analyses

Descriptive statistics were used to summarize the sample profile, food product ratings, and overall FoodProK score. A one-way repeated-measures (within subject) ANOVA was conducted to test for differences in mean food product ratings. Pairwise comparisons between food products in each category were tested, adjusting for multiple comparisons using the Bonferroni correction. A total of four tests were run to assess whether the mean ratings significantly differed for the three products within each food category (fruit, grain, dairy, meat). Analyses were conducted using SPSS Statistical Software (Version 26.0; IBM Corp., Armonk, NY; 2018). Values of $p < 0.05$ were considered statistically significant.

A sample size calculation was conducted to ensure sufficient power to detect a 1-point difference in FoodProK scores. Mean scores for the ‘processed’ product in each food category (apple sauce, deli chicken slices, cheese block, cereal) and standard deviation were input into a two-tailed test. Sample sizes of 57 respondents would provide 80% power to detect a difference of 1-unit in mean product ratings, where the mean rating for deli chicken slices is 4.27 and standard deviation is 1.94, with a significance level of 0.05 for a two-tailed test.

To analyze the open-ended data, the first author reviewed all of the responses and created new variables representing common factors that the dietitians considered when completing the food product ratings. Participants’ responses were coded according to whether they mentioned a particular factor. Other relevant open-ended comments were summarized, highlighting several example quotations.

3.1.4 Results

Sample profile

A total of 81 dietitians responded to the survey. After excluding those with incomplete surveys (n=17), 64 were included in the analysis. A total of 55 (85.9%) indicated their role involved educating patients or the public about nutrition. Dietitians reported a mean of 13.1 years professional experience (SD=11.3) and median of 10 years. The survey took a median of 15 minutes to complete.

Performance on the FoodProK score

Table 2 shows mean ratings for each food product, as well as results from the one-way repeated-measures ANOVA tests. To illustrate congruence of the dietitians’ rankings with those based on the NOVA system, the proportion of respondents who correctly ordered two versus all three food products in a given category are shown.

Dietitians’ mean ratings for individual food products corresponded with NOVA groups within each of the four food categories, with 85.9%, 85.9%, and 73.4% correctly ordering food products based on level of processing in the fruit, dairy, and grain categories, respectively. The meat category was an exception, with approximately half of respondents (54.7%) correctly rating the healthiness of meat products based on the NOVA classification system.

Of a possible maximum of two points, the mean scores for the fruit and dairy categories were 1.86 (SD = 0.35), 1.73 (SD = 0.44) for grains, and 1.55 (SD = 0.50) for the meat category. The mean total FoodProK score was 7.00 out of 8 (SD = 0.82). Overall, 39.1% received 7 out of 8, and 31.2% of respondents received a perfect FoodProK score of 8.

Table 2: Registered Dietitians’ mean food product ratings based on perceived healthiness and performance on the Food Processing Knowledge score (n=64)

	Mean rating (SD)	F-statistic, p-value	β (by product), p-value	Category score= 1 2 of 3 products in correct order % (n)	Category score= 2 All 3 products in correct order % (n)
Fruit category					
Apple	9.61 (0.68)		9.61, p<0.001		
Apple sauce	7.50 (1.83)	F=425.64, p<0.001	7.50, p<0.001	14.1% (9)	85.9% (55)
Apple juice	2.38 (1.84)		2.38, p<0.001		
Dairy category					
1% milk	8.92 (1.06)		8.92, p<0.001		
Cheese block	6.89 (1.52)	F=271.38, p<0.001	6.89, p<0.001	14.1% (9)	85.9% (55)
Processed cheese slices	3.39 (2.08)		3.39, p<0.001		
Grain category					
Oats	9.00 (1.07)		9.00, p<0.001		
Cereal	7.05 (1.57)	F=231.84, p<0.001	7.05, p<0.001	26.6% (17)	73.4% (47)
Cereal bar	3.41 (1.74)		3.41, p<0.001		
Meat category					
Chicken breast	9.02 (1.11)		9.02, p<0.001		
Deli chicken slices	4.27 (1.94)	F=285.89, p<0.001	4.27, p<0.001	45.3% (29)	54.7% (35)
Chicken nuggets	3.41 (1.87)		3.41, p<0.001		

Notes: All food products within each category are listed in order of least to most processed. No dietitian received a score of 0 in any of the food categories. “Correct” ordering refers to ratings that correspond with NOVA classification of processing, where Group 1 foods are rated highest, Group 4 foods are rated lowest, and Group 3 foods are rated between Group 1 and 4 foods.

Food rating task vs. multiple choice

The majority of respondents who selected the correct response in the multiple-choice question also rated the individual food products in the same order (e.g., higher rating for apple sauce than apple juice), with the exception of the grain and meat categories. Based on the multiple-choice format, when asked which grain product was healthier, 30.6% reported no difference between cereal and cereal bar, with 11.3% selecting “don’t know.” In the meat category, 49.3% of respondents reported no difference between deli chicken slices and chicken nuggets, and 9.9% selected “don’t know” in response to the multiple-choice question.

Open-ended feedback on FoodProK scoring task

When asked to explain their food product ratings, respondents commented on core nutrient differences. In the fruit category, respondents noted higher fibre content and satiety, as well as lower sugar content in apple sauce compared with apple juice. When comparing the dairy products, respondents commented that the cheese block had fewer additives, less sodium, and overall processing than the cheese slices. In the grain category, respondents noted there was less sodium, sugar, and additives in cereal compared to the cereal bar. Those who selected ‘no difference’ between the two grain products commented that specific product details were required to assess which product was healthier. For example, one dietitian said, “This depends on the product. Many cereals are over-processed and full of added sugar and salt! Some bars have a decent amount of protein and not as much added sugar. Again - this varies greatly.” With respect to the meat category, respondents noted that deli chicken slices contained less total/saturated fat and fewer ingredients compared to the nuggets, with several respondents commenting on differences in sodium, carbohydrates, and calories. Respondents who said there was no difference between these products commented that both were highly processed and contained a lot of sodium.

When rating each of the foods, the main factors respondents reported considering were the nutritional value of the food products (i.e., presence of ‘positive’ and ‘negative’ nutrients), degree of processing, and ingredient lists (**Table 3**).

Table 3: Factors considered in rating the healthiness of 12 food products included in the Food Processing Knowledge score by Registered Dietitians in Canada (n = 64)

Factor	Frequency (n)
'Negative' nutrient amounts (i.e., sodium, saturated fat, sugar)	45
Degree of processing	32
'Positive' nutrient amounts (i.e., fibre, protein, vitamin/mineral content)	30
Ingredients lists	20
Whole food	9
Full nutrient profile	9
Congruence with dietary guidelines	5
Other (e.g., freshness, caloric content, plant vs. animal based)	5

Note: Each respondent provided a list of factors, therefore the frequency reflects the total number of times each factor was mentioned.

Approximately 80% of respondents reported level of processing as important to the healthiness of foods (3.1% 'slightly important,' 17.2% 'moderately important,' 39.1% 'important,' 40.6% 'very important'). Overall, 81% of respondents agreed level of processing is a reasonable indicator of the general healthiness of foods. When asked to explain their response, respondents noted that level of processing reflected amounts of negative nutrients such as salt, fat, and sugar, and that unprocessed foods have higher nutritive value; however, it is not the only factor that should be considered as many nutritious foods are also processed. One dietitian stated, "As foods are more heavily processed, they tend to contain higher levels of salt, sugar and saturated fat. Higher processed foods also tend to be lower in whole grains, vitamins and minerals (unless added during processing). This is an easy indicator (usually)." Lastly, 89% reported the FoodProK was not confusing or unclear. Among the 11% who indicated concerns with survey question clarity, feedback included issues with the use of the term "extremely healthy," and difficulty rating healthiness without specific guidelines.

3.1.5 Discussion

This study examined the content validity of the FoodProK score—a proxy measure of consumer nutrition knowledge based on level of food processing. Despite the wide range of factors that contribute to the nutritional profile of foods, dietitians rated the healthiness of 12 food products in congruence with the NOVA system, which confirmed the expected relationship between the FoodProK score and level of processing (i.e., more processed foods perceived as less healthy). In addition to completing the FoodProK measure, content validity was further assessed via open-ended feedback to determine whether level of food processing was a relevant indicator of the

general nutritional value of foods. The multiple-choice food ranking task question provided a point of comparison for individual product healthiness ratings in the FoodProK, and reiterated dietitians' mean food ratings based on level of processing.

While the FoodProK is intended for use among consumers, this initial assessment among dietitians was a critical first test to determine whether the premise of using level of food processing as a proxy of nutrition knowledge was relevant and appropriate. Moreover, prior to testing among consumers, the congruence of dietitians' food product ratings with the NOVA system was necessary for testing the scoring system.

A closer look at the FoodProK scores revealed a potential issue with the meat category, as only 55% of dietitians correctly ordered all meat products according to NOVA. Qualitative feedback demonstrated some dietitians did not perceive meaningful differences between the processed meat products due to high sodium content in both deli chicken slices and chicken nuggets. These findings suggest several improvements can be made to the next iteration of the FoodProK, including use of a different processed meat product to better illustrate the distinction between Group 3 and 4 NOVA categories.

More importantly, the findings highlight the complexity of food processing as a concept. Many dietitians provided responses such as, "it depends," indicating a simple rating task can not fully capture the nuances that dietitians considered when rating the healthiness of foods. This finding reiterates the importance of including NfTs and ingredient lists alongside food product images in the FoodProK, as this enabled respondents to make informed ratings.

It is also important to note that there is a lack of consensus in the nutrition community more broadly regarding what is a 'healthy food,'^{15,30,32} which further complicates the measurement and content validity testing of nutrition knowledge based on an understanding of product 'healthiness.' The FoodProK assesses only one component of nutrition knowledge and does not assess other important factors that determine diet quality, such as food purchasing and the frequency with which different foods are consumed. However, the design of the FoodProK is consistent with existing evidence that supports use of level of processing as an indicator of product healthiness.^{39,40,42,44,46,48,51} In addition, the use of 'level of processing' as a proxy measure of

nutrition knowledge is consistent with greater emphasis on food processing within national dietary guidelines, such as Brazil and Canada.^{11-15,32-34}

In an attempt to reflect some of the nuance in the concepts of healthiness and processing, the NOVA classification system was specifically selected because of its ability to distinguish among various levels of processing.^{40,42} Monteiro et al. (2019) argue that binary classification of products as processed/not processed is less useful given that most foods are processed in some way.⁴⁰ NOVA functions similar to other nutrient classification systems such as the Ofcom nutrient profiling model in the United Kingdom, which scores foods based on positive and negative nutrient content,⁵² and the Health Star Rating system in Australia, which assigns a star-rating to foods based on positive and negative nutrient content across different food categories.¹⁹ Irrespective of the system used, these nutrient profiling systems reflect the association between level of processing and healthfulness, as more highly processed foods have a greater proportion of ‘negative nutrients’ (i.e., sodium, sugars, fats) and therefore, receive lower scores.^{39,40,42,51}

Overall, the FoodProK score has the potential to serve as a general functional test of nutrition knowledge across contexts due to the use of food products that can be found in multiple settings, and adaptability of NFts to country-specific guidelines. Use of such a measure in large population-based studies can enable cross-country comparisons unlike longer, more complex measures to shed light on consumer nutrition knowledge patterns.

The findings of this study should be interpreted in light of several limitations. The study relied upon a convenience sample of Registered Dietitians, hence we cannot determine whether the sample is representative of the overall dietetic community. Open-ended questions were used to obtain qualitative feedback; however, in-person methods may have facilitated more detailed responses. While the NOVA system does not consider portion size,⁴² we addressed this limitation by providing images of NFts in the FoodProK scoring task. Finally, the current study only tested face and content validity among subject matter experts, but not among general consumers. Next steps include FoodProK testing and cognitive interviews among consumers in Canada and other geographic contexts, which span various age, sex, education, and literacy levels to assess whether similar issues in the FoodProK are identified, and if further modifications are required. Test-retest reliability, or other types of validity (e.g. convergent, criterion) were not assessed, thus further

psychometric testing in diverse samples is necessary to build validity evidence for the FoodProK score.

Finally, the development of the FoodProK is not intended to assess level of processing as the only or most important factor in diet quality. Overall quality of dietary intake can include a wide range of foods and is largely determined by the frequency with which these foods are consumed; however, for consumers to achieve this balance, they require some understanding of which foods should be consumed more or less frequently. The FoodProK assesses consumers' basic ability to evaluate foods based on the broad category of levels of processing. Nevertheless, the FoodProK should be assessed in conjunction with other measures nutrition knowledge, as well as dietary intake, to examine comparability with existing tools.

3.1.6 Conclusions

Level of food processing may provide a reasonable proxy for assessing basic consumer nutrition knowledge, particularly in population-based surveys that require brief assessment tools. The FoodProK may provide a basis for comparing nutrition knowledge across countries, although specific food products may need to be adapted for different national food markets. Finally, revision to the processed products used in the 'meat' category would likely enhance agreement between the FoodProK score and dietitian ratings.

3.2 Study 2 – Patterns and correlates of nutrition knowledge across five countries in the 2018 International Food Policy Study

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Authors: Bhawra J,¹ Kirkpatrick SI,¹ Hall MG,² Vanderlee L,³ White C,¹ Hammond D.¹

¹School of Public Health and Health Systems, University of Waterloo, Waterloo, Canada

²Department of Health Behavior, Gillings School of Global Public Health, and Lineberger Comprehensive Cancer Center, University of North Carolina, Chapel Hill, United States

³École de Nutrition, Centre nutrition, santé et société (Centre NUTRISS) and Institut sur la nutrition et les aliments fonctionnels (INAF), Université Laval, Québec, Canada

3.2.1 Abstract

Objective: To identify functional nutrition knowledge levels and associated correlates in five countries.

Design: Respondents completed web-based surveys in November-December 2018. Functional nutrition knowledge was measured using the Food Processing Knowledge (FoodProK) score.

Setting: Australia, Canada, Mexico, United Kingdom (UK), United States (US).

Participants: Adults, aged ≥ 18 years, were recruited through the Nielsen Consumer Insights Global Panel in Australia (n = 3997), Canada (n = 4170), Mexico (n = 4044), UK (n = 5363), and the US (n = 4527).

Analysis: Linear regression models examined associations between FoodProK score and consumer characteristics.

Results: FoodProK scores (maximum, 8 points) were highest in Canada (mean: 5.1) and Australia (5.0), followed by the UK (4.8), Mexico (4.7), and the US (4.6). Health literacy and self-rated nutrition knowledge were positively associated with FoodProK scores ($p < .001$). FoodProK scores were higher among those who reported vegetarian/other dietary practices ($p < .0001$); made efforts to consume less sodium, trans fats, or sugars ($p < .001$); 60+ years old ($p = 0.002$), female ($p < .001$), and 'majority' ethnic group respondents in their respective countries ($p < .001$).

Conclusions: Nutrition knowledge differences based on consumer characteristics highlight the need for accessible policies and interventions that support uptake of healthy eating efforts across populations to avoid exacerbating nutrition-related disparities.

Key words: nutrition knowledge, functional knowledge test, food processing knowledge

3.2.2 Introduction

Nutrition knowledge, which includes knowledge of concepts such as dietary guidelines and sources of various nutrients,^{1,2} is an important determinant of diet-related behaviour.³⁻⁷ In particular, nutrition knowledge can influence consumers' ability to identify and select healthy foods, as well as manage diet-related chronic diseases.⁸⁻¹¹ Nutrition knowledge is influenced by a myriad of factors, including sociodemographic characteristics and socioeconomic status. Research has shown that consumers who are older, female, and have higher income and education perform better on assessments of nutrition knowledge in cross-sectional studies.¹²⁻¹⁶ Moreover, nutrition information may be more accessible to consumers with higher literacy, thereby increasing nutrition knowledge.¹⁷⁻¹⁹ Knowledge is also influenced by interest in nutrition, as individuals with specific dietary goals or practices may seek out nutrition information to a greater extent than those without diet-related goals.^{20,21}

Consumers obtain nutrition knowledge from numerous sources, such as national nutrition policies, dietary guidelines, and food cultures that might influence uptake of or exposure to nutrition information.²²⁻²⁷ A variety of tools have been used to measure nutrition knowledge across countries.^{28,29} Indeed, most studies use unique tools tailored to specific study populations.^{1,7,14,15,30-34} The use of disparate tools creates challenges for comparing nutrition knowledge levels and corresponding determinants across studies, geographic contexts, and populations.^{28,35} This is a barrier to drawing upon diverse studies or conducting between-country studies to learn about the role of nutrition knowledge in dietary and health outcomes, and whether specific nutrition policies and interventions are more effective than others in increasing consumer nutrition knowledge. Overall, very few cross-country studies on nutrition knowledge have been conducted.^{13-15,36}

Furthermore, subjective measures, such as self-rated knowledge, are often used in studies focused on nutrition knowledge.²⁰ However, consumers tend to overestimate their ability to understand quantitative nutrition information, which poses a challenge given the tendency for nutrition policy approaches, including labelling, to rely upon numeric data such as amounts of nutrients per serving.^{2,37-40} Although functional tasks may be a stronger indicator of knowledge, such measures tend to focus on awareness of country-specific dietary guidelines, and consequently, are unsuitable for use across contexts.^{28,35}

The Food Processing Knowledge (FoodProK) score was developed to measure nutrition knowledge based on consumers' ability to understand and apply the concept of food processing in a functional task.⁴¹ Content validity testing conducted with Registered Dietitians in Canada indicated the FoodProK as a reasonable measure of consumer nutrition knowledge, however this tool has not yet been compared with others measures of nutrition knowledge.⁴¹ The focus on processing levels is consistent with increasing inclusion of messages related to minimizing processed food consumption in dietary guidelines.^{22-26,42} Given that processing is not specific to a given population or context, this measure can serve as an indicator of consumer nutrition knowledge that can be used across studies,⁴¹ lending to the interpretation of cross-country research in this area.

To this end, the current study sought to compare nutrition knowledge levels based on the FoodProK among adults in five countries: Australia, Canada, Mexico, the United Kingdom (UK) and the United States (US). In particular, this study aimed to identify between-country differences in functional nutrition knowledge levels based on processing, and assess correlates of functional nutrition knowledge, including sociodemographic and socioeconomic characteristics, body mass index (BMI), and dietary behaviors. We also examined correlations between FoodProK scores and other measures that may be used as proxies for nutrition knowledge, such as self-reported nutrition knowledge and health literacy, to assess how the FoodProK performs in comparison with these measures across countries.

3.2.3 Methods

Study Design and Participants

This study used cross-sectional data from the 2018 wave of the International Food Policy Study (IFPS).⁴³ Respondents aged ≥ 18 years were recruited through Nielsen Consumer Insights Global Panel and their partners' panels, and completed web-based surveys in November-December 2018. Of the 22,824 respondents who completed the IFPS survey, a subsample of 22,102 respondents from Australia (n=3,997), Canada (n=4,170), Mexico (n=4,044), the UK (n=5,363), and the US (n=4,527) were included in the study. Respondents were asked about a range of topics related to nutrition and the food environment, including food purchasing and preparation practices, nutrition knowledge, food security, and perceptions of national-level food policies. The median time to complete the survey across all countries was 40 minutes. The study













was reviewed by and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 30829). More details about IFPS can be found elsewhere.⁴³

Respondents with missing data for covariates of interest, including ethnicity (n=296), income adequacy (n=182), education (n=69), food shopping role (n=29), dietary efforts (n=122), FoodProK score (n=17), health literacy (n=29), and self-reported nutrition knowledge (n=153) were excluded from analyses. Respondents with missing data for these variables were not different with respect to FoodProK scores compared with the rest of the sample (data not shown). The final analytic sample was 22,102.

Measures

Food Processing Knowledge score. The FoodProK is a functional test of consumer nutrition knowledge based on level of processing.⁴¹ Respondents viewed and rated images of three food products within each of four categories: fruits (apple, apple juice, apple sauce), meat (chicken breast, deli chicken slices, chicken nuggets), dairy (1 per cent milk, cheese block, processed cheese slices), and grains (oats, cereal, cereal bar). Products in each category were selected based on availability in multiple international contexts and to represent varied levels of processing. In the development of the FoodProK, three reviewers with nutrition training independently categorized the 12 foods according to the NOVA classification system for processed foods, with no discrepancies identified across reviewers.⁴¹ Each category included a food in Group 1 (“un/minimally processed”/“whole food”), Group 3 (“processed”), and Group 4 (“ultra-processed”) of the NOVA system (**Table 1**). NOVA Group 2 foods were not included because they are processed culinary ingredients extracted from whole foods (i.e., oils, flours, sugars).⁴⁵ In the product images, branding on food packages was removed digitally and fictional product names were added to minimize the potential for bias based on brand familiarity. The 12 product images with their corresponding Nutrition Facts tables (NFts) and ingredients lists were displayed one at a time, in random order. For each product, respondents were asked, “Overall, how healthy is this food product?” and answered using a scale of 0 to 10, with 0 representing ‘not healthy at all’ to 10 indicating ‘extremely healthy.’

Table 1: Food Products included in the Food Processing Knowledge Score based on NOVA food groups

NOVA Food Classification	Fruit products	Meat products	Dairy products	Grain products
Minimally processed (group 1)	Apple 	Chicken breast 	1% milk 	Oats 
	Apple sauce 	Deli meat 	Cheese block 	Cereal 
Ultra-processed (group 4)	Apple juice 	Chicken nuggets 	Processed cheese slices 	Cereal bar 

FoodProK scores were calculated based on the concordance of healthiness ratings within each food category with the rankings based on the NOVA classification, with less processed foods representing higher healthiness. For each category, respondents received a score of 2 if their food product ratings corresponded with the order of NOVA food processing groups (e.g., apple > apple sauce > apple juice). If 2 of 3 products in a given category were ranked in accordance with NOVA's rankings (e.g., apple > apple juice > apple sauce), respondents received a score of 1. Zero was assigned if the respondent's rankings did not align with those based on NOVA. Scores were summed across the four food categories to create the total FoodProK score, ranging from 0 to 8.

Correlates were selected based on evidence regarding associations between sociodemographic, socioeconomic, behavioral, literacy, and knowledge-related variables with nutrition knowledge.

Health literacy and nutrition knowledge. Respondents with higher health literacy and self-reported nutrition knowledge were expected to score higher on a functional nutrition knowledge test.^{17,18,45} Health literacy was measured using an adapted version of the Newest Vital Sign (NVS), which asks respondents six questions regarding an NfT on an ice cream container. The adapted NVS was self-administered as part of the online IFPS survey, and country-specific NfTs were shown. This measure assesses respondents' ability to make mathematical calculations (numeracy), read and apply label information (prose literacy), and understand the label information (document literacy).⁴⁶ A score between 0 and 6 is calculated based on the number of correct answers. A score of 0-1 suggests 'high likelihood (50% or more) of limited literacy;' a score of 2-3 indicates 'possibility of limited literacy;' and a score of 4-6 indicates 'high likelihood of adequate literacy.'⁴⁷ This measure has been adapted and tested among a variety of age and ethnic groups in different countries including Canada, the US, Australia, and the UK, but has not yet been validated as a self-administered measure.⁴⁷⁻⁵⁴

The self-reported nutrition knowledge question was adapted from the Canadian Foundation for Dietetic Research (CFDR) Tracking Nutrition Trends survey,⁵⁵ and asked, "How would you rate your nutrition knowledge?", with response options ranging from 'not at all knowledgeable,' 'a little knowledgeable,' 'somewhat knowledgeable,' 'very knowledgeable,' to 'extremely knowledgeable.' This variable was treated as continuous in analyses (range =1-5).

Consumer dietary behaviours. Individuals engaging in efforts to modify their eating patterns, those practicing vegetarian or other specific dietary patterns, and those with a prominent food shopping role in their households, were hypothesized to be more interested in nutrition, and therefore, also have higher nutrition knowledge.^{20,21} Efforts to modify eating patterns were measured by asking, "Have you made an effort to consume more or less of the following in the past year?" Respondents were prompted to answer, 'consume less,' 'consume more,' or 'no effort made' for each of a list of nutrients and food categories.⁵⁵ The current analyses focused on efforts in five categories that have received increasing attention in policies such as dietary guidelines within the five countries: 'trans fats,' 'sugars/added sugars,' 'salt/sodium,' 'calories,' and 'processed foods.'²²⁻²⁶ A value of -1 was assigned for responses to 'consume less,' +1 for responses to 'consume more,' and 0 for 'no effort made' in the five categories. Modification efforts were recoded into a scale variable, with five points for all five categories summed to create a 0 to 10

scale, with 0 representing ‘consume less’ responses to all categories, 10 representing ‘consume more’ responses to all categories, and the range between reflecting all other response combinations. Respondents indicated whether they followed vegetarian and/or religious dietary practices by selecting one or more of the following options: ‘vegetarian,’ ‘vegan,’ ‘pescatarian,’ ‘following a religious practice for eating (please specify),’ or ‘none of the above.’ This variable was recoded as binary (no specific dietary practices = 0; one or more dietary practices = 1).⁵⁵ Food shopping role was captured using an adapted version of an item from the United States Department of Agriculture Eating and Health survey,⁵⁶ “Do you do most of the food shopping in your household?”, with response options ‘Yes,’ ‘no,’ or ‘share equally with other(s).’

Sociodemographic variables and body mass index. Differences in nutrition knowledge in relation to sociodemographic and socioeconomic characteristics may contribute to disparities in nutritional health.^{8,57-59} Sociodemographic covariates of interest included age group (18-29, 30-44, 45-59, and 60+ years), sex (female or male), country (Australia, Canada, Mexico, the UK, the US), education, ethnicity, and income adequacy. Of the 22,824 IFPS respondents, less than 1% (n=113) reported a gender different than their biological sex, which was insufficient for providing robust estimates in modelling. Hence, sex at birth was used as a binary covariate. Education level was categorized in accordance with country-specific criteria, classifying respondents as having ‘low’ (high school completion or lower), ‘medium’ (some post-secondary school qualifications, including some university), or ‘high’ (university degree or higher) levels of education.⁶⁰⁻⁶⁴ To enable between-country comparisons, ethnic identity was characterized as ‘majority’ in Mexico if they identified themselves as ‘Indigenous,’ and ‘majority’ in Australia, Canada, the UK and the US if they identified themselves as ‘white,’ predominantly English-speaking, or non-Indigenous based on country-specific ethnicity questions.^{62,64-66} Income adequacy was assessed by asking, “Thinking about your total monthly income, how difficult or easy is it for you to make ends meet?” with Likert scale response options ‘very difficult,’ ‘difficult,’ ‘neither easy nor difficult,’ ‘easy,’ and ‘very easy.’⁶⁷

Categorization of BMI followed World Health Organization criteria,⁶⁸ with self-reported height and weight used to classify respondents based on BMI <18.5 kg/m², 18.5 to 24.9 kg/m², 25.0 to 29.9 kg/m², and ≥30 kg/m². Response options ‘don’t know’ and ‘refuse to answer’ were provided for all survey questions and recoded as missing. Given the large number of cases with

missing height and weight data – including those who selected ‘don’t know’ or ‘refuse to answer’ – a separate category for ‘missing’ was created and retained as a response category for BMI in analyses.

Statistical Analysis

Statistical analyses were conducted using SAS Studio (SAS Institute, Cary, NC). Data were weighted with post-stratification sample weights constructed using a raking algorithm with population estimates from respective country-based censuses based on age group, sex at birth, region, ethnicity (except in Canada), and education (except in Mexico).⁴³ All reported estimates are weighted.

Descriptive statistics were used to summarize the sample profile, mean, and ranges for FoodProK score by country. A multivariable linear regression model was fitted to examine between-country differences in FoodProK scores. This model included an indicator variable for country, as well as 10 covariates, including the knowledge-related, behavioural, and sociodemographic variables described above. Multiple comparisons were conducted to assess all pairwise contrasts for categorical variables. A second model was run to test two-way interactions between country and the core sociodemographic variables age, sex, education, income adequacy, and ethnicity to identify potential differences in nutrition knowledge by country. Given most nutrition knowledge studies have been conducted in the US and Europe, the use of interaction terms allowed testing of whether the same sociodemographic associations are observed in other countries, with a focus on variables associated with nutrition knowledge previously.^{12,13,15-17,36} The Benjamini-Hochberg procedure was applied to decrease the false detection rate following multiple exploratory tests.⁶⁹ All statistically significant pairwise contrasts are reported after applying the Benjamini-Hochberg procedure, assuming a false discovery rate of 10%.

Content validity testing of the FoodProK score with subject matter experts indicated two items in the meat category – deli meat slices (processed), and chicken nuggets (ultra-processed) – were too similar to allow differentiation of healthiness.⁴¹ Hence, sensitivity tests were conducted to compare the performance of the original FoodProK score to a modified 7-point score excluding the deli meat product, as well as a 6-point score excluding the meat category entirely. Regression models were tested with all three versions of the FoodProK. Spearman’s rank correlation tests were also run with the original 8-point score and the revised 7- and 6-point scoring to examine

potential differences between countries and their association with other knowledge-related variables (self-reported nutrition knowledge, health literacy status).

3.2.4 Results

Sample Summary

Table 2 presents characteristics of respondents included in the analysis.

Table 2: Sample Characteristics (n = 22,102), International Food Policy Study, 2018

Characteristic	Australia (n=3997) % (n)	Canada (n=4170) % (n)	Mexico (n=4044) % (n)	United Kingdom (n=5363) % (n)	United States (n=4527) % (n)
Age Group					
18-29 years	21.2 (845)	19.2 (800)	29.8 (1204)	19.1 (1026)	20.7 (934)
30-44 years	26.5 (1060)	24.7 (1029)	32.3 (1305)	24.4 (1307)	25.2 (1141)
45-59 years	24.7 (988)	25.9 (1078)	28.5 (1155)	26.2 (1407)	25.7 (1165)
60+ years	27.6 (1104)	30.2 (1263)	9.4 (380)	30.3 (1623)	28.4 (1287)
Sex at Birth					
Male	49.0 (1959)	49.6 (2069)	47.6 (1925)	48.4 (2609)	48.4 (2192)
Female	51.0 (2038)	50.4 (2101)	52.4 (2119)	51.3 (2754)	51.6 (2336)
Ethnicity					
Majority	76.0 (3039)	79.6 (3320)	78.7 (3183)	89.1 (4776)	75.9 (3438)
Minority	24.0 (958)	20.4 (850)	21.3 (861)	10.9 (587)	24.1 (1089)
Education Level					
Low	42.0 (1682)	41.3 (1723)	19.5 (789)	48.6 (2605)	58.4 (2645)
Medium	32.6 (1302)	33.7 (1407)	13.2 (535)	23.1 (1240)	9.9 (445)
High	25.4 (1013)	25.0 (1040)	67.3 (2720)	28.3 (1518)	31.7 (1437)
Income Adequacy					
Very difficult to make ends meet	8.8 (353)	8.5 (353)	12.1 (490)	6.9 (367)	9.6 (435)
Difficult to make ends meet	19.2 (768)	19.7 (822)	31.8 (1286)	18.4 (985)	20.0 (905)
Neither easy nor difficult to make ends meet	37.6 (1502)	36.8 (1534)	38.7 (1564)	36.4 (1955)	33.9 (1535)
Easy to make ends meet	23.5 (939)	22.4 (935)	13.9 (564)	24.5 (1314)	21.8 (987)
Very easy to make ends meet	10.9 (435)	12.6 (525)	3.5 (141)	13.8 (742)	14.7 (665)
Body Mass Index					
<18.5	3.1 (123)	3.3 (136)	2.1 (85)	3.0 (162)	3.5 (157)
18.5-24.9	35.9 (1437)	33.6 (1400)	39.8 (1608)	34.7 (1861)	30.8 (1395)
25.0-29.9	26.4 (1054)	28.7 (1197)	29.9 (1207)	26.8 (1437)	27.8 (1259)
≥30.0	21.1 (842)	24.4 (1019)	15.5 (629)	16.8 (903)	27.3 (1235)
Missing	13.5 (541)	10.0 (418)	12.7 (515)	18.7 (1000)	10.6 (481)
Food Shopping Role					
Primary shopper	71.7 (2864)	72.0 (3000)	74.9 (3029)	74.2 (3981)	73.3 (3319)
Not primary shopper	7.1 (284)	6.0 (249)	5.1 (205)	4.7 (253)	6.6 (299)

Shared equally with others	21.2 (849)	22.0 (921)	20.0 (810)	21.1 (1129)	20.1 (909)
Dietary Practices					
No specific dietary practices	87.0 (3477)	90.3 (3765)	88.1 (3564)	87.0 (4665)	88.6 (4012)
One or more dietary practices (i.e., vegetarian, vegan, pescatarian, religious practices)	13.0 (520)	9.7 (405)	11.9 (480)	13.0 (698)	11.4 (515)
Dietary Efforts Score¹					
High likelihood of limited literacy (score 0-1)	26.7 (1040)	19.4 (810)	30.5 (1234)	31.8 (1707)	25.4 (1150)
Possibility of limited literacy (score 2-3)	24.7 (964)	23.2 (966)	31.2 (1261)	20.5 (1097)	20.2 (913)
Adequate literacy (score 4-6)	48.6 (1897)	57.4 (2394)	38.3 (1549)	47.7 (2559)	54.4 (2464)
Self-reported Nutrition Knowledge					
Not at all knowledgeable	5.6 (223)	4.1 (169)	2.8 (114)	9.4 (502)	5.8 (263)
A little knowledgeable	31.5 (1261)	30.1 (1256)	30.4 (1228)	39.4 (2111)	28.8 (1306)
Somewhat knowledgeable	41.4 (1653)	44.4 (1850)	53.0 (2141)	35.7 (1914)	41.2 (1864)
Very knowledgeable	17.4 (696)	18.2 (762)	12.2 (495)	12.6 (674)	18.7 (844)
Extremely knowledgeable	4.1 (164)	3.2 (133)	1.6 (66)	3.0 (161)	5.5 (250)

¹Mean and standard deviation reported for dietary efforts score.

Comparisons Across Countries and Correlates of FoodProK Scores

Within each country, the mean scores across food categories were similar, as demonstrated by the narrow range in scores (**Table 3**). Australia was an exception as it had the widest mean score range across categories (0.9-1.4), including the lowest dairy score and one of the highest mean scores for the fruit category. Within each food category, mean scores were similar across countries, with dairy scoring lowest across the five countries.

Table 3: Food Processing Knowledge Score by Country

	Fruit category mean (SD)	Grain category mean (SD)	Dairy category mean (SD)	Meat category mean (SD)	FoodProK score mean (SD)
Canada	1.3 (0.6)	1.3 (0.6)	1.2 (0.6)	1.3 (0.6)	5.1 (1.6)
Australia	1.4 (0.6)	1.3 (0.7)	0.9 (0.7)	1.3 (0.7)	5.0 (1.8)
United Kingdom	1.2 (0.6)	1.2 (0.7)	1.1 (0.7)	1.3 (0.7)	4.8 (1.9)
Mexico	1.4 (0.6)	1.1 (0.6)	1.0 (0.6)	1.3 (0.7)	4.7 (1.6)
United States	1.2 (0.7)	1.1 (0.7)	1.0 (0.6)	1.2 (0.7)	4.6 (1.8)
Five countries combined	1.3 (0.6)	1.2 (0.7)	1.0 (0.6)	1.3 (0.7)	4.8 (1.7)

Notes: Maximum total for each category is 2.0, and 8.0 for the Food Processing Knowledge (FoodProK) score. SD – Standard deviation.

Based on the linear regression analysis and after adjustment for false discoveries (**Table 4**), those classified as having ‘adequate health literacy’ or the ‘possibility of limited health literacy’ had higher FoodProK scores compared to respondents with a ‘high likelihood of limited literacy’

($\beta=1.28$; CI=1.21, 1.35; $p<.001$; $\beta=0.76$; CI=0.68, 0.84; $p<.001$). Self-reported nutrition knowledge was significantly associated with FoodProK score, as respondents who reported they were ‘very knowledgeable’ ($\beta=0.81$; CI=0.67, 0.96, $p<.001$), ‘somewhat knowledgeable’ ($\beta=0.75$; CI=0.61, 0.88; $p<.001$), and ‘a little knowledgeable’ ($\beta= 0.65$; CI= 0.52, 0.79; $p<.001$) scored higher on the FoodProK compared to those who reported that they were ‘not at all knowledgeable.’ Those who reported being ‘a little knowledgeable’ had lower FoodProK scores than those reporting being ‘somewhat knowledgeable’ ($\beta=-0.09$; CI=-0.15, -0.34; $p=0.002$) or ‘very knowledgeable’ ($\beta=-0.16$; CI=-0.23, -0.08; $p<0.001$). Respondents who stated they were ‘a little knowledgeable’ had significantly higher FoodProK scores than those who selected ‘extremely knowledgeable’ ($\beta=0.50$; CI=0.34, 0.66; $p<0.001$), and those who reported being ‘extremely knowledgeable’ had significantly lower FoodProK scores than those who reported being ‘somewhat knowledgeable’ ($\beta=-0.59$; CI=-0.75, -0.44; $p<0.001$) or ‘very knowledgeable’ about nutrition ($\beta=-0.66$; CI=-0.82, -0.50; $p<0.001$).

Respondents engaging in one or more specific dietary practices such as vegetarianism had significantly lower FoodProK scores ($\beta=-0.31$; CI=-0.39, -0.23; $p<.001$) than those with no specific dietary practices. Respondents who reported efforts to consume less sugar, sodium, trans fat, calories, or processed foods had significantly higher FoodProK scores ($\beta=-0.13$; CI=-0.14, -0.11; $p<.001$) compared to respondents not making efforts to modify their eating patterns in these areas. Food shopping role was not significantly associated with FoodProK score.

The oldest age group (60+ years) scored significantly higher on the FoodProK than the youngest age group (18-29 years) ($\beta=0.13$; CI=0.04, 0.21; $p=0.002$). Respondents aged 30-44 years ($\beta=-0.17$; CI=-0.24, -0.09; $p<0.001$) and 45-59 years ($\beta=-0.10$; CI=-0.17, -0.04; $p=0.002$) had significantly lower FoodProK scores than those in the 60+ years category. Females scored higher on the FoodProK than males ($\beta=0.26$; CI=0.21, 0.32; $p<0.001$). Education and income adequacy were not significantly associated with FoodProK score.

Respondents with a BMI <18.5 or missing BMI data had lower FoodProK scores than those with a BMI between 18.5-24.9 ($\beta=-0.19$; CI=-0.34, -0.04; $p=0.01$; $\beta=-0.32$; CI=-0.41, -0.23; $p<.001$). Moreover, respondents with BMIs between 25-29.9 ($\beta=0.18$; CI=0.03, 0.34; $p=0.02$) or ≥ 30 ($\beta=0.21$; CI=0.05, 0.36; $p=0.008$) had significantly higher FoodProK scores than those with

BMI's under 18.5, and those with missing BMI data had significantly lower FoodProK scores compared with respondents with BMI's between 25-29.9 ($\beta=-0.33$; CI=-0.42, -0.24; $p<0.001$) or ≥ 30 ($\beta=-0.31$; CI=-0.41, -0.21; $p<0.001$).

Table 4: Sociodemographic, behavioural, and knowledge-related correlates of the Food Processing Knowledge Score (n=22,102), International Food Policy Study, 2018

	Parameter estimate (β)	95% CI	p-value
<i>Country</i>			
Australia vs. Canada	0.07	-0.01, 0.14	0.08
Australia vs. Mexico	0.22	0.13, 0.30	*0.001
Australia vs. United Kingdom	0.09	0.01, 0.16	*0.02
Australia vs. United States	0.40	0.32, 0.48	*<.001
Canada vs. Mexico	0.15	0.06, 0.23	*<.001
Canada vs. United Kingdom	0.02	-0.05, 0.09	0.61
Canada vs. United States	0.33	0.25, 0.41	*<.001
Mexico vs. United Kingdom	-0.13	-0.21, -0.05	*0.002
Mexico vs. United States	0.18	0.10, 0.27	*<.001
United Kingdom vs. United States	0.31	0.23, 0.39	*<.001
<i>Age group</i>			
30-44 years vs. 60+ years	-0.17	-0.24, -0.09	*<.001
45-59 years vs. 60+ years	-0.10	-0.17, -0.04	*0.002
60+ years vs. 18-29 years	0.13	0.04, 0.21	*0.002
<i>Sex</i>			
Female vs. Male	0.26	0.21, 0.32	*<.001
<i>Ethnicity</i>			
Majority vs. Minority	0.19	0.11, 0.26	*<.001
<i>Education Level</i>			
Medium vs. Low	0.02	-0.05, 0.08	0.58
High vs. Medium	0.01	-0.05, 0.07	0.80
High vs. Low	0.03	-0.03, 0.08	0.40
<i>Income Adequacy</i>			
	-0.02	-0.04, 0.00	0.12
<i>Body Mass Index</i>			
<18.5 vs. 18.5-24.9	-0.19	-0.34, -0.04	*0.01
25.0-29.9 vs. <18.5	0.18	0.03, 0.34	*0.02
≥ 30.0 vs <18.5	0.21	0.05, 0.36	*0.008
Missing vs. 18.5-24.9	-0.32	-0.41, -0.23	*<.001
Missing vs. 25.0-29.9	-0.33	0.42, -0.24	*<.001
Missing vs. ≥ 30.0	-0.31	-0.41, -0.21	*<.001
<i>Food Shopping Role</i>			
Primary shopper vs. Not primary shopper	0.00	-0.12, 0.11	0.93

Primary shopper vs. Share equally with others	-0.06	-0.12, 0.00	0.05
Share equally with others vs. Not primary shopper	0.06	-0.06, 0.18	0.36
<i>Dietary Practices</i>			
One or more dietary practices (i.e., vegetarian, vegan, pescatarian, religious practices) vs. No specific dietary practices	-0.31	-0.39, -0.23	*<.001
<i>Dietary Efforts Score</i>			
	-0.13	-0.14, -0.11	*<.001
<i>Health Literacy</i>			
Possibility of limited literacy (score 2-3) vs. High likelihood of limited literacy (0-1)	0.76	0.68, 0.84	*<.001
Adequate literacy (score 4-6) vs. Possibility of limited literacy (score 2-3)	0.52	0.46, 0.58	*<.001
Adequate literacy (score 4-6) vs. High likelihood of limited literacy (0-1)	1.28	1.21, 1.35	*<.001
<i>Self-reported Nutrition Knowledge</i>			
A little knowledgeable vs. Not at all knowledgeable	0.65	0.52, 0.79	*<.001
A little knowledgeable vs. Somewhat knowledgeable	-0.09	-0.15, -0.34	*0.002
A little knowledgeable vs. Very knowledgeable	-0.16	-0.23, -0.08	*<.001
A little knowledgeable vs. Extremely knowledgeable	0.50	0.34, 0.66	*<.001
Somewhat knowledgeable vs. Not at all knowledgeable	0.75	0.61, 0.88	*<.001
Very knowledgeable vs. Not at all knowledgeable	0.81	0.67, 0.96	*<.001
Extremely knowledgeable vs. Somewhat knowledgeable	-0.59	-0.75, -0.44	*<.001
Extremely knowledgeable vs. Very knowledgeable	-0.66	-0.82, -0.50	*<.001

Notes: CI – Confidence Intervals. *Variables are significant ($p < 0.05$) after post hoc adjustment using Benjamini-Hochberg procedure. Only significant pairwise contrasts are shown for age group, body mass index, and self-reported nutrition knowledge. $R^2 = 0.24$.

Respondents from Australia, Canada, Mexico, and the UK scored significantly higher on the FoodProK compared to respondents from the US ($\beta=0.41$; CI=0.33, 0.49; $p < .001$; $\beta=0.33$; CI=0.25, 0.41; $p < .001$; $\beta=0.18$; CI=0.10, 0.27; $p < .001$; $\beta=0.31$; CI=0.23, 0.39; $p < .001$, respectively). Several other country contrasts were also significant. Respondents in Australia had significantly higher FoodProK scores than those in the UK ($\beta=0.09$; CI=0.01, 0.16; $p=0.02$) and Mexico ($\beta=0.22$; CI=0.13, 0.30; $p=0.001$), namely due to higher scores in the fruit and grain categories. Canadian respondents had significantly higher FoodProK scores than those in Mexico ($\beta=0.15$; CI=0.06, 0.23; $p < 0.001$). Respondents in Mexico had significantly lower FoodProK scores than the UK ($\beta=-0.12$; CI=-0.21, -0.05; $p=0.002$), with lower scores in the grain and dairy categories.

Two-way interactions were observed between country and age group, sex, and education level (**Figures 1-3**). Respondents aged 45-59 years ($\beta=-0.42$, CI=-0.65, -0.19, $p<0.001$) and ≥ 60 years in Mexico ($\beta=-0.38$, CI=-0.66, -0.10, $p=0.009$) had lower FoodProK scores than the corresponding age groups in the US. Similar patterns were observed for sex, as females had higher FoodProK scores than males in all countries, though to different degrees. Females in Australia ($\beta=-0.20$, CI=-0.36,-0.04, $p=0.012$), Canada ($\beta=-0.19$, CI=-0.34,-0.03, $p=0.016$), and Mexico ($\beta=-0.27$, CI=-0.42,-0.11, $p=0.001$) had significantly lower FoodProK scores than females in the US. Education was not significant in the main effects model, but those categorized as having high education levels in Australia ($\beta=-0.27$, CI=-0.46, -0.08, $p=0.004$) and Mexico ($\beta=-0.32$, CI=-0.49, -0.13, $p<0.001$) had significantly lower FoodProK scores than corresponding highly educated respondents in the US.

Figure 1: Age group and country interaction plot for Food Processing Knowledge (FoodProK) score

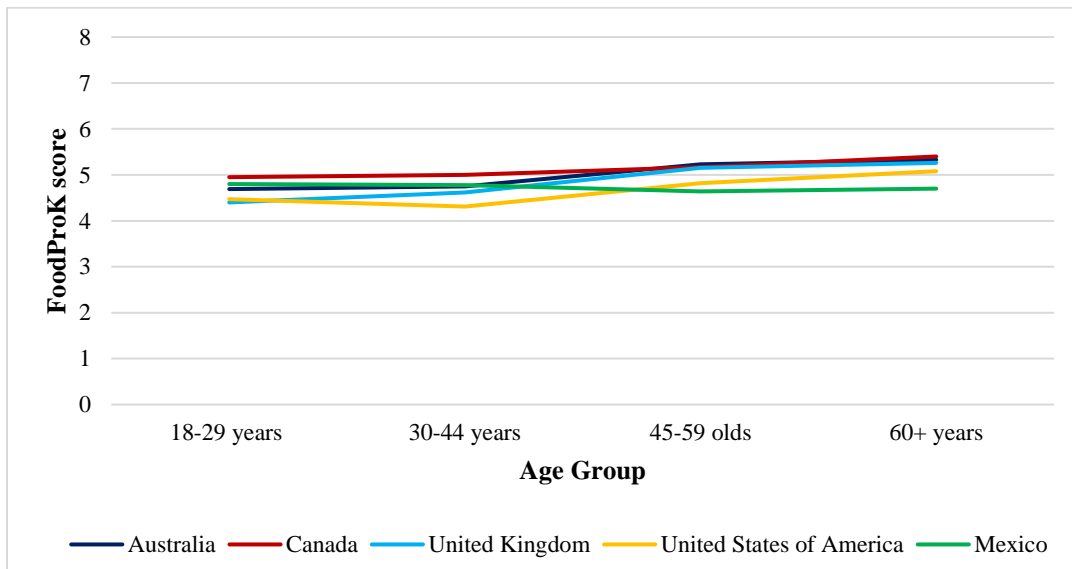


Figure 2: Sex and country interaction plot for Food Processing Knowledge (FoodProK) score

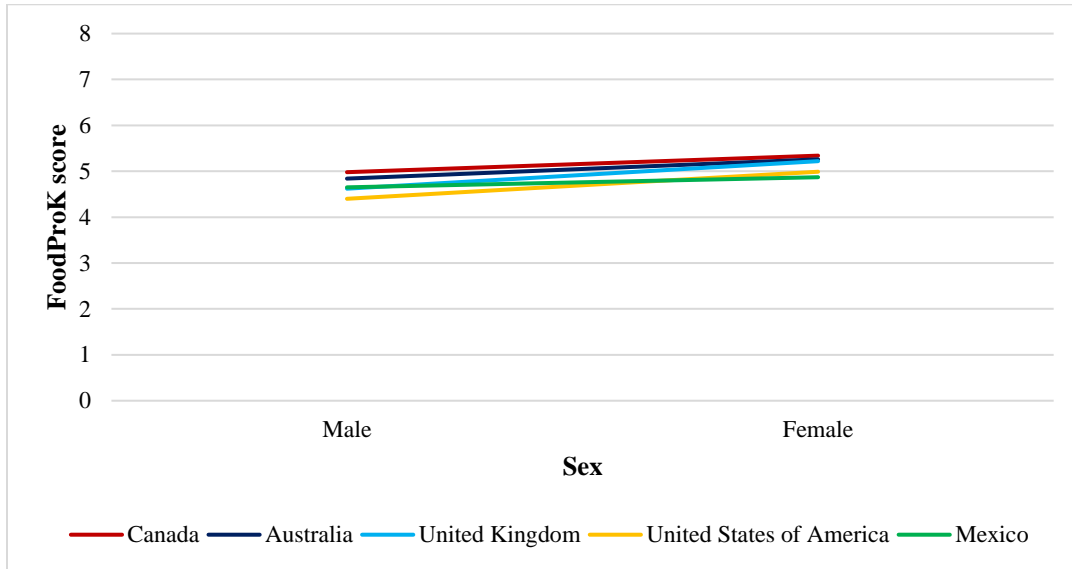
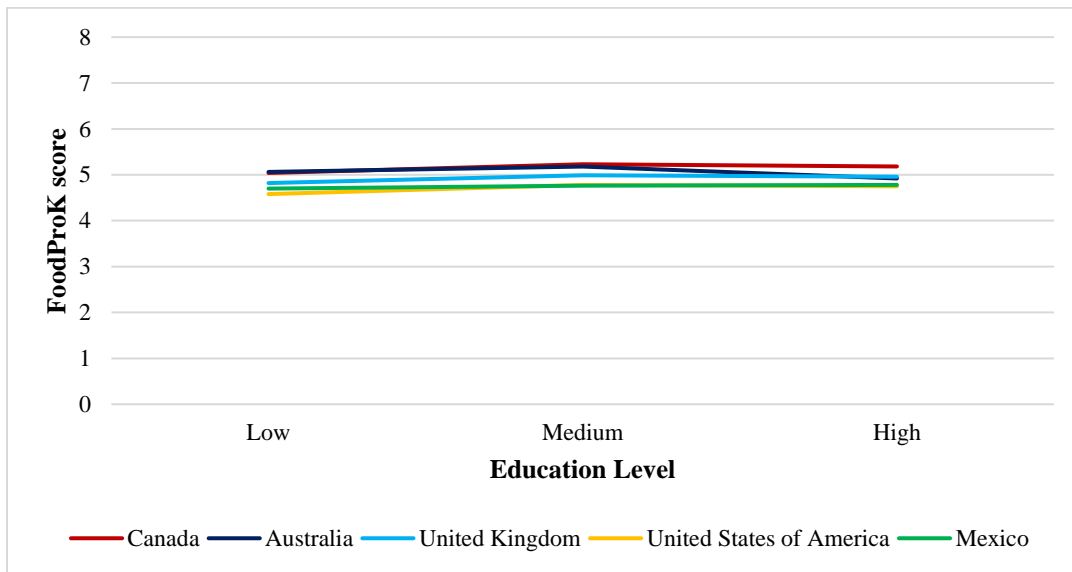


Figure 3: Education and country interaction plot for Food Processing Knowledge (FoodProK) score



Sensitivity Analyses

Sensitivity analyses indicated the FoodProK scoring method did not change the pattern of scores across countries or associations between scores and other variables. Irrespective of whether the FoodProK was in the original 8-point format, 7-point format dropping only deli meat, or 6-point format dropping the entire meat category, the same correlates were significant in the

regression model, with no meaningful differences in the parameter estimates. Further, the correlations between FoodProK, self-reported nutrition knowledge, and health literacy status were comparable regardless of the scoring approach.

FoodproK Scores and Relationships Between Knowledge-Related Variables

Health literacy and the FoodProK score were moderately correlated ($r_s = 0.37$, $p < 0.001$). There was a very weak, positive correlation between self-reported nutrition knowledge and each of health literacy ($r_s = 0.09$, $p < 0.001$) and the FoodProK score ($r_s = 0.09$, $p < 0.001$).

3.2.5 Discussion

The current study is one of the first to examine differences in nutrition knowledge levels across multiple countries. Based on understanding of levels of food processing, adults from Canada and Australia scored highest on the functional nutrition knowledge test, with adults in the US scoring the lowest. Differences across countries are likely due to a range of factors, including national dietary guidelines and nutrition policies that may influence consumers' access to and uptake of nutrition information based on the reach and effectiveness of these initiatives.⁷⁰ Country-specific dietary patterns or food culture may also play a role in nutrition knowledge among populations, particularly informal channels of nutrition education such as family food practices and cultural beliefs which contribute to consumers' implicit understanding of a food's nutritive quality/properties.⁷¹⁻⁷³ This 'prior' knowledge may reinforce messaging from national education campaigns, or on the contrary, conflict with cultural beliefs around healthy eating in some populations.⁷⁴⁻⁷⁷ The association between dietary practices and healthfulness is further complicated by the fact that the global food supply is highly processed; hence, foods previously considered 'healthy' may be less nutritious after going through the industrial food process.⁴⁴ Countries with the lowest FoodProK scores – Mexico and the US – also have among the highest levels of consumption of ultra-processed foods across countries.⁷⁸⁻⁸³ Lower scores in these countries may reflect lower levels of knowledge or different social norms in populations in which highly processed foods are ubiquitously available and consumed.

Although some differences in nutrition knowledge scores across countries were statistically significant, the magnitude of differences was modest. This may reflect similar content in national

nutrition guidelines and labelling policies with respect to the NfTs that appear on pre-packaged products, which were displayed to respondents as part of the FoodProK.^{22-26,84-87} Future research should focus on the impact of new national nutrition guidelines on nutrition knowledge, including evaluations of awareness, comprehension, use, and reach of such guidelines documents and associated campaigns. For example, a revised Canada Food Guide was released shortly after the IFPS data was collected in 2018, and now includes the specific recommendation to “limit highly processed foods,” including replacing sugary drinks in favour of fresh fruits.²² Studies assessing consumer awareness of this information and its potential impacts are necessary for understanding the extent to which such initiatives contribute to changes in nutrition knowledge.

Overall, cross-country studies of nutrition knowledge to enable comparisons of the current findings are lacking. Grunert et al. (2012) found that adults in the UK had significantly higher nutrition knowledge than respondents from four other European countries.¹³ The authors attributed this finding to the “history of health policies and nutrition-related initiatives,” as well as potential cultural differences among UK respondents compared with the other countries (p. 166).¹³ While specific policies are not described by Grunert et al. (2012),¹³ the UK was one of the first countries among the six included in the study to adopt dietary guidelines, which may have contributed to consumers’ general nutrition knowledge.⁸⁸ We are unaware of any other studies that have examined differences between the five countries included in the current study.

Respondents who reported efforts to modify their eating patterns, including efforts to consume less sodium, sugar, trans fat, processed foods, or calories, scored higher on the FoodProK. Individuals with specific diet-related goals likely have a greater interest in nutrition or may rely on labels and other sources of nutrition information more frequently.^{20,21} Respondents who engaged in dietary practices (i.e., vegetarianism) had significantly lower FoodProK scores than those without specific dietary practices, contrary to existing evidence suggesting that dietary preferences may drive individuals to improve their knowledge to support specific dietary choices.^{20,21} Few studies have used functional nutrition knowledge measures, hence this finding may differ in correlates based on the use of functional vs. self-reported measures. In addition, this study did not find an association between food shopping role and nutrition knowledge, which may reflect the fact that such tasks are gendered and based on the social organization of society rather than nutrition knowledge.⁸⁹⁻⁹¹

Sociodemographic differences in knowledge were also observed. Consistent with other literature, functional nutrition knowledge was higher with age and among females.^{13,15,16} Existing evidence points to behavioural and attitudinal differences between men and women, as well as different age groups, as a possible explanation for these differences. Women and older age groups appear to be more health conscious, and it is hypothesized that increased interest in healthy eating may result in increased nutrition knowledge due to intentional efforts to seek out nutrition information.^{13,92-94} Moreover, nutrition and food tend to be predominantly “female domains,”^{89,95,96} suggesting women may be more likely than men to be exposed to nutrition-related health information, increasing their opportunities to gain knowledge. In the current study, the observed two-way interactions suggest potential disparities in nutrition knowledge based on sociodemographic characteristics and education level. Specifically, respondents in particular age groups, women, and those with higher education levels from countries that had higher FoodProK scores than the US overall (i.e., Mexico, Australia) received lower FoodProK scores than corresponding age, sex, and education groups in the US. This finding highlights the importance of studying between-country differences in access, availability, and uptake of nutrition information and education.

The association between ethnicity and nutrition knowledge has not been extensively studied. This study found that the ‘majority’ ethnic group in each country had significantly higher FoodProK scores when controlling for other covariates. Some studies have used other measures of ethnicity such as citizenship status, showing lower nutrition knowledge levels among immigrant populations.^{36,97} This may be explained, in part, by acculturation, as immigrants in varying stages of assimilation may have different exposure to national dietary guidelines. The amount and type of cultural exposures, among other aspects of immigrant or ‘minority’ experiences, could potentially impact knowledge of country-specific guidance on healthy eating,⁹⁷⁻⁹⁹ as well as familiarity with foods in a new cultural context. Additionally, given racism that excludes some individuals from fully participating in economic and other systems, those not identifying as the ‘majority’ ethnic group in their respective countries may have had fewer opportunities to develop and apply nutrition knowledge and related skills, such as label reading.¹⁰⁰⁻¹⁰³ Overall, these factors may result in lower capacity to answer the FoodProK questions.

With respect to BMI, there were notably lower FoodProK scores among those with missing BMI data compared to the other categories, and higher FoodProK scores when comparing the highest BMI categories to the lowest <18.5 group. Generally, the literature is inconclusive with respect to associations between BMI and nutrition knowledge.^{5,104-107} Furthermore, this study relied on self-reported height and weight. US-based studies have shown that weight tends to be under-reported,¹⁰⁸⁻¹¹¹ and while it is unlikely that data are missing at random,^{109,112} it is difficult to discern what might underlie the BMI associations observed in this study.

The findings also shed light on different methods of assessing nutrition knowledge. FoodProK scores were positively associated with a measure of health literacy, the NVS, which provides a functional assessment of respondents' ability to understand and apply numeric and descriptive information contained in NFTs. Given the focus of the NVS on a nutrition label, this measure might be considered to assess nutrition literacy.²⁸ In contrast, a commonly used measure of self-rated nutrition knowledge, in which participants rate their perceived level of knowledge on a scale of 1 to 5, was very weakly associated with health literacy, as well as FoodProK scores. Respondents who rated themselves as 'extremely knowledgeable' scored lower on the literacy and FoodProK measures, which suggests that many respondents drastically overestimate their nutrition knowledge. This finding reinforces the need to move beyond single-item measures towards functional tests of nutrition knowledge, such as the FoodProK, in order to capture some of the nuance and complexity of nutrition knowledge. A key shortcoming of self-reported measures is that they rely on respondents' interpretation of the terms 'label understanding' or 'nutrition knowledge' – which may not align with researchers' definitions of these concepts. Functional tests provide an opportunity to objectively test consumers in pre-defined aspects included in a measure.

The strength of this study lies in the large sample size and multi-country design, which enabled comparisons of nutrition knowledge using a functional measure. Several limitations should also be considered. First, the sample was recruited using non-probability sampling, which does not enable the generation of nationally representative population estimates. For example, although data were weighted by age, sex at birth, region, ethnicity (except in Canada) and education (except in Mexico), the Mexico sample had higher levels of education than the Mexican population based on census estimates, while self-reported BMI was lower than national estimates in each of the five countries.^{43,113-119} Moreover, there is potential for social desirability bias given

the use of self-reported measures.^{108,120} There are also limitations of the FoodProK score, as content validity testing demonstrated poorer performance in the meat category compared to other categories.⁴¹ Sensitivity tests revealed the FoodProK score performed similarly irrespective of whether 6-, 7- or 8-point scales were used; however, further validity and reliability testing of this measure is required, including examining its ability to accurately capture nutrition knowledge in diverse populations and contexts. Modest differences in knowledge may be related to the FoodProK test's limited ability to detect differences in nutrition knowledge.

3.2.6 Conclusions

In sum, the current study suggests some differences in consumers' ability to distinguish levels of food processing for common foods, with somewhat lower levels of nutrition knowledge in countries with the highest intake of highly processed foods. Differences in nutrition knowledge based on consumer characteristics highlight the need for policies and interventions that are accessible to those with lower literacy and education. Consumers who tend to have higher nutrition knowledge, including females, higher education groups, and those with specific dietary goals, performed better on the FoodProK score. This pattern of findings suggests the need for novel methods to support uptake of nutrition education efforts across populations, with attention to ameliorating existing disparities. Tools such as the FoodProK can be used to evaluate the impact of policies and interventions targeting nutrition knowledge across contexts, advancing the evidence in this area.

3.3 Study 3 – Correlates of self-reported and functional understanding of nutrition labels across five countries: Findings from the 2018 International Food Policy Study

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Authors: Bhawra J,¹ Kirkpatrick SI,¹ Hall MG,² Vanderlee L,³ Thrasher JF,⁴ Hammond D.¹

¹School of Public Health and Health Systems, University of Waterloo, Canada

²Department of Health Behavior, Gillings School of Global Public Health, and Lineberger Comprehensive Cancer Center, University of North Carolina, Chapel Hill, United States

³École de Nutrition, Centre nutrition, santé et société (Centre NUTRISS) and Institut sur la nutrition et les aliments fonctionnels (INAF), Université Laval, Québec, Canada

⁴Arnold School of Public Health, University of South Carolina, USA

3.3.1 Abstract

Background: Nutrition labels on pre-packaged foods are an important source of nutrition information; however, differences in comprehension of varying label formats may limit their use and effectiveness. This study examined levels and correlates of consumers' self-reported understanding of numeric Nutrition Facts tables (NFt) and interpretive front-of-package (FOP) labels, as well as functional NFt understanding across five countries.

Methods: Adults (≥ 18 years) from the International Food Policy Study completed online surveys in November-December 2018. Participants were recruited using Nielsen Consumer Insights Global Panel in Australia ($n = 3901$), Canada ($n = 4107$), Mexico ($n = 4012$), United Kingdom (UK) ($n = 5121$), and the United States (US) ($n = 4445$). Three linear regression models examined the association between label understanding (self-reported NFt/FOP, functional NFt) and consumer dietary behaviours, functional nutrition knowledge, and sociodemographic characteristics. NFt understanding was measured across all five countries, with FOP labelling assessed only in countries with mandatory (Mexico) or voluntary labelling policies (Australia, UK).

Results: Self-reported and functional NFt understanding was highest in the US and Canada, followed by Australia, the UK, and Mexico ($p < 0.0001$). Functional and self-reported NFt understanding were weakly correlated ($r_s = 0.18$, $p < 0.0001$). In adjusted analyses, functional NFt understanding was higher among women ($p < 0.0001$); respondents from the 'majority' ethnic group in their respective countries ($p < 0.0001$), those with higher education levels ($p < 0.0001$) and higher functional nutrition knowledge ($p < 0.0001$), and those making efforts to consume less sodium, sugar or fat ($p < 0.0001$). Self-reported FOP label understanding was higher for interpretive labelling systems in Australia (Health Star Ratings) and the UK (Traffic Lights) compared with Mexico's Guideline Daily Amounts (GDA) ($p < 0.0001$). Mean self-reported FOP label understanding was higher than NFt understanding (though correlates were similar), with the exception of Mexico where self-reported NFt understanding was higher.

Conclusions: Cross-country differences in label understanding may reflect the effectiveness of mandatory vs. voluntary nutrition labelling policies and national healthy eating campaigns. Nutrition labels requiring greater numeracy skills (i.e., NFt, GDA) were more difficult for

consumers to understand than interpretive FOP labels (i.e., Traffic Lights). Differences in NFt and FOP label understanding by income adequacy, education, and health literacy suggest potential disparities in labelling policy uptake among subgroups.

Keywords: nutrition label, food label, nutrition facts table, nutrition facts panel, front-of-package label, nutrition labelling policy, consumer understanding, functional understanding, international

3.3.2 Introduction

Nutrition labels on food packages provide nutrient content information at the point-of-purchase to support consumers in making informed choices.¹⁻⁴ Nutrition Facts tables (NFts) – labels found at the back or side of packaged foods – are one of the most commonly used sources of nutrition information, particularly among consumers trying to modify their dietary intake.⁵⁻⁷ However, studies have found that consumers generally struggle with applying NFt information, including interpreting serving sizes and percent daily value information.⁸⁻¹⁴

Poor NFt understanding has been observed across countries, with studies using both self-reported measures and functional tests of label understanding identifying issues with numeracy, as consumers struggle to interpret and apply label information.^{12,14,15-18} Consumers with lower education, income, or literacy are less likely to understand and therefore use NFts.^{8,12,16,19} These disparities in NFt understanding are troubling given those with lower socioeconomic status are also more vulnerable to poor dietary patterns and nutrition-related chronic disease due to other barriers in accessing healthy foods.²⁰⁻²³

In response to concerns about NFts, front-of-package (FOP) labels have been proposed as a policy solution for providing simple and interpretive nutrition information in a noticeable location on food packages.^{2,24,25} Several FOP labelling systems are in use globally and range in presentation (i.e., nutrient-specific vs. summary-indicator labels), design (i.e., various symbols, colours, sizes), and nutrient focus.^{24,25} For example, nutrient-specific FOP labels (e.g., Traffic Lights, ‘high-in’ labels) display select nutrient information from the NFt, often highlighting nutrients of public health concern such as sodium, saturated fats, and sugars.^{24,25} Summary-indicator systems (e.g., Health Star Ratings [HSR], Nutri-Score) summarize nutrient content and product healthfulness using algorithms to provide an overall score for the product.^{24,25} To date, most FOP labelling systems, including HSR in Australia and New Zealand, and Traffic Light symbols in the United Kingdom (UK), have been implemented on a voluntary basis; however, countries such as Chile and Mexico have implemented mandatory FOP ‘high-in’ labels and Guideline Daily Amounts (GDA), respectively.²⁶

Overall, studies suggest FOP labels are easier for consumers to understand than NFts alone.^{2,8,27,28} ‘Pre-implementation’ experimental research demonstrates higher self-reported and functional understanding of FOP labels compared with NFts among adults.²⁹⁻³⁴ When shown

multiple FOP label formats, consumers indicate a preference for color-coded labels such as Traffic Lights³²⁻³⁷ compared with NFts or GDA labels.^{25,35-39} In other studies that included ‘high-in’ labels, when respondents were asked to rate the healthiness of various food products using FOP label information in nutrient search tasks, ‘high-in’ systems were reported as easiest to use, followed by multiple Traffic Lights and GDA.⁴⁰⁻⁴³ Qualitative studies similarly indicate consumers’ preference for simple, directive information on labels with minimal text.⁴⁴⁻⁴⁸ Among consumers with lower self-reported nutrition knowledge, income, and education, the preference for simpler FOP label designs is consistent with better understanding of these labelling systems.^{8,19,29,30-33,49,50}

In general, studies using self-reported measures demonstrate that consumers tend to overestimate their ability to use and apply label information.^{12,18,51-55} Functional measures of label understanding, which commonly ask participants to complete a rating task comparing foods based on nutritional profile, have found that interpretative FOP labels have higher comprehension, and therefore greater potential to promote healthy food choices compared to numerical label formats such as the NFt or GDA.^{36,40,41,43,56}

Label understanding is influenced by a variety of factors including individual-level characteristics such as consumer nutrition knowledge and dietary practices, to broader nutrition education policies and national health promotion efforts.^{5-7,57,58} To date, few studies have examined whether understanding of nutrition labels differs across countries, including potential disparities among subgroups. Using cross-sectional data from the International Food Policy Study (IFPS), this study aimed to determine levels and correlates of self-reported and functional nutrition label understanding across countries. In particular, four research questions were examined: 1) What are the levels of self-reported (NFt and FOP) label and functional NFt understanding across Australia, Canada, Mexico, the UK, and the United States (US)? 2) Does self-reported FOP label understanding vary by label type (i.e., HSR vs. GDA)? 3) Is self-reported label understanding associated with functional label understanding and consumers’ nutrition knowledge? and 4) Does label understanding vary by consumers’ dietary behaviours or sociodemographic characteristics?

3.3.3 Methods

Study design and participants

This study used cross-sectional data from the 2018 wave of the IFPS.⁵⁹ Respondents aged 18 years and over were recruited through Nielsen Consumer Insights Global Panel and their partners' panels, and completed web-based surveys in November-December 2018. The Nielsen panel are recruited using both probability and non-probability recruitment methods in each country. After applying age- and sex-based quotas to facilitate recruitment of a diverse sample approximating known proportions in each country, email invitations were sent to a random sample of panelists; panelists known to be ineligible were not invited. Surveys were conducted in English in Australia and the UK; Spanish in Mexico; English or French in Canada; and English or Spanish in the US. The median time to complete the survey across all countries was 40 minutes.

Of the 22,824 respondents who completed the 2018 IFPS survey, a subsample of 21,586 respondents from Australia (n = 3,901), Canada (n = 4,107), Mexico (n = 4,012), the UK (n = 5,121), and the US (n = 4,445) were included in the current study. Those with missing data for self-reported NFT understanding (n=160), self-reported FOP label understanding (n=153), functional NFT understanding (n=29), FoodProK score (n=17), dietary efforts (n=122), food shopping role (n=29), education (n=69), ethnicity (n=296), and income adequacy (n=182) were excluded from analyses. All respondents provided informed consent prior to completing the survey and received remuneration in accordance with the panel's usual incentive structure (e.g., points-based or monetary rewards, chances to win prizes). The study was reviewed by and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 21460). More details can be found in the 2018 IFPS Technical Report.⁵⁹

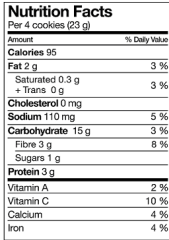

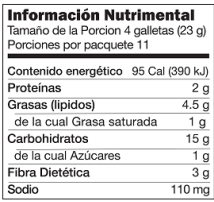
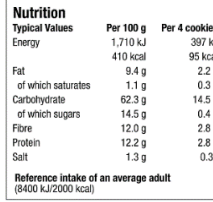
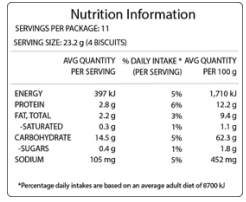

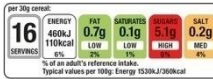

Measures

Self-reported understanding of food labels

Participants were shown an image of the NFt that appears on packages in their country and asked, "Do you find this information... 'very hard to understand,' 'hard to understand,' 'neither hard or easy to understand,' 'easy to understand,' or 'very easy to understand.'" In addition, participants in Australia, Mexico and the UK were then shown an image of a FOP label for their respective countries and asked to respond to the same measure of self-reported understanding

(Table 1). This measure was adapted from the 2014 Food and Drug Agency Health and Diet Survey.⁶⁰

Table 1: Food labels by country in the International Food Policy Study survey

	Canada	United States	Mexico	United Kingdom	Australia
NFt					
FOP label	None	None			

NFt – Nutrition Facts table, FOP – front-of-package.

Functional test of NFt understanding

Participants completed an online version of the Newest Vital Sign, which consists of six questions that test functional ability to use NFts (**Supplementary Table 1**). The Newest Vital Sign assesses respondents’ ability to make mathematical calculations (numeracy), read and apply label information (prose literacy), and understand the label information (document literacy).⁶¹ It thus serves not only as a proxy measure of health and nutrition literacy,^{62,63} but also a functional measure of consumer NFt understanding. The NFt image used in the Newest Vital Sign tool was adapted to include NFt design and layout in each country (**Supplementary Table 2**). A score between 0 and 6 was calculated based on the number of correct answers, with higher scores corresponding with a higher understanding of NFts.


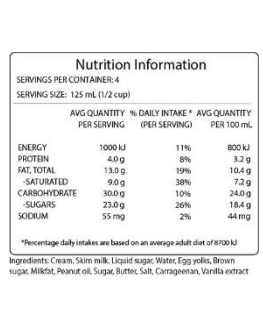
Supplementary Table 1: Newest Vital Sign questions

	Question																																				
	<p>This information is on the back of a container of ice cream.*</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2" style="text-align: left;">Nutrition Facts</th> </tr> <tr> <td colspan="2">Per 1/2 cup (125 mL)</td> </tr> <tr> <td colspan="2">Servings Per Container 4</td> </tr> <tr> <th style="text-align: left;">Amount</th> <th style="text-align: left;">% Daily Value</th> </tr> </thead> <tbody> <tr> <td colspan="2">Calories 250</td> </tr> <tr> <td>Fat 13 g</td> <td>20 %</td> </tr> <tr> <td> Saturated 9 g</td> <td>40 %</td> </tr> <tr> <td> + Trans 0 g</td> <td></td> </tr> <tr> <td>Cholesterol 28 mg</td> <td></td> </tr> <tr> <td>Sodium 55 mg</td> <td>2 %</td> </tr> <tr> <td>Carbohydrate 30 g</td> <td>12 %</td> </tr> <tr> <td> Fibre 3 g</td> <td></td> </tr> <tr> <td> Sugars 23 g</td> <td></td> </tr> <tr> <td>Protein 4 g</td> <td></td> </tr> <tr> <td>Vitamin A</td> <td>8 %</td> </tr> <tr> <td>Vitamin C</td> <td>0 %</td> </tr> <tr> <td>Calcium</td> <td>6 %</td> </tr> <tr> <td>Iron</td> <td>0 %</td> </tr> </tbody> </table> <p><small>*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.</small></p> <p><small>Ingredients: Cream, Skim milk, Liquid sugar, Water, Egg yolks, Brown sugar, Milkfat, Peanut oil, Sugar, Butter, Salt, Carrageenan, Vanilla extract</small></p>	Nutrition Facts		Per 1/2 cup (125 mL)		Servings Per Container 4		Amount	% Daily Value	Calories 250		Fat 13 g	20 %	Saturated 9 g	40 %	+ Trans 0 g		Cholesterol 28 mg		Sodium 55 mg	2 %	Carbohydrate 30 g	12 %	Fibre 3 g		Sugars 23 g		Protein 4 g		Vitamin A	8 %	Vitamin C	0 %	Calcium	6 %	Iron	0 %
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1	<p>If you eat the entire container, how many calories will you eat? Enter number of calories: <i>[open-ended]</i> Don't know Refuse to answer</p> <p><i>[Answer: 1000 is the only correct answer]</i></p>																																				
2	<p>If you are allowed to eat 60 grams of carbohydrates as a snack, how much ice cream could you have? Enter number of cup(s): <i>[open-ended]</i> Don't know Refuse to answer</p> <p><i>[Answer: Any of the following is correct: 1 cup, half the container, 2 servings]</i></p>																																				
3	<p>Your doctor advises you to reduce the amount of saturated fat in your diet. You usually have 42 g of saturated fat each day, which includes one serving of ice cream. If you stop eating ice cream, how many grams of saturated fat would you be consuming each day? Enter number of grams: <i>[open-ended]</i> Don't know Refuse to answer</p> <p><i>[Answer: 33 is the only correct answer]</i></p>																																				
4	<p>If you usually eat 2,500 calories in a day, what percentage of your daily value of calories will you be eating if you eat one serving? Enter percentage: <i>[numeric percentage]</i> Don't know Refuse to answer</p> <p><i>[Answer: 10% is the only correct answer]</i></p>																																				
5	<p>Pretend that you are allergic to the following substances: penicillin, peanuts, latex gloves, and bee stings. Is it safe for you to eat this ice cream?</p>																																				

	Yes No Don't know Refuse to answer <i>[Answer: No]</i>
6	[If "no", ask:] Why not? Enter reason: <i>[open-ended]</i> Don't know Refuse to answer <i>[Answer: Because it has peanut oil or because you might have an allergic reaction]</i>

Note: Country-specific Nutrition Facts table (NfT) displayed. Canadian NfT shown here.

Supplementary Table 2: Nutrition Facts Table images shown in Newest Vital Sign measure

	Canada	United States	Mexico	United Kingdom	Australia																																																														
NfT	 <p>Nutrition Facts Per 1/2 cup (125 mL) Servings Per Container 4</p> <p>Amount Per Serving</p> <p>Calories 250</p> <p>Fat 13 g 20% Saturated 9 g 40% + Trans 0 g Cholesterol 28 mg 2% Sodium 55 mg 2% Carbohydrate 30 g 12% Fiber 2 g Sugars 23 g</p> <p>Protein 4 g</p> <p>Vitamin A 8% Vitamin C 0% Calcium 6% Iron 0%</p> <p>*Percent Daily Values are based on a diet of 2,000 calories. †Your daily values may vary depending on your calorie needs.</p> <p>Ingredients: Cream, Skim milk, Liquid sugar, Water, Egg yolks, Brown sugar, Milkfat, Peanut oil, Sugar, Butter, Salt, Carrageenan, Vanilla extract</p>	 <p>Nutrition Facts Serving Size 1/2 cup Servings per container 4</p> <p>Amount Per Serving</p> <p>Calories 250</p> <p>Total Fat 13g 20% Saturated Fat 9g 40% Trans Fat 0g Cholesterol 28mg 12% Sodium 55mg 2% Total Carbohydrate 30g 12% Dietary Fiber 2g Sugars 23g</p> <p>Protein 4g</p> <p>Vitamin A 8% Vitamin C 0% Calcium 6% Iron 0%</p> <p>*Percent Daily Values are based on a diet of 2,000 calories. †Your daily values may vary depending on your calorie needs.</p> <p>Ingredients: Cream, Skim milk, Liquid sugar, Water, Egg yolks, Brown sugar, Milkfat, Peanut oil, Sugar, Butter, Salt, Carrageenan, Vanilla extract</p>	 <p>Información Nutricional Tamaño de la Porción 1/2 taza (125 ml) Porciones por envase 4</p> <p>Contenido energético 250 Cal (1046 kJ)</p> <p>Proteínas 4 g Grasas (lípidos) 13 g de la cual Grasa saturada 9 g Carbohidratos 30 g de la cual Azúcares 23 g Fibra Dietética 2 g Sodio 55 mg</p> <p>Ingredientes: Crema, Leche descremada, Azúcar líquida, Yemas de huevo, Azúcar morena, Grasa de leche, Azúcar, Aceite de cacahuete (Mani), Mantequilla, Sal, Carragenano, Extracto de vainilla</p>	 <p>Nutrition Servings per container: 4</p> <table border="1"> <thead> <tr> <th>Typical Values</th> <th>Per 100 mL</th> <th>1 serving (125 mL)</th> </tr> </thead> <tbody> <tr> <td>Energy</td> <td>837 kJ</td> <td>1046 kJ</td> </tr> <tr> <td></td> <td>200 kcal</td> <td>250 kcal</td> </tr> <tr> <td>Fat</td> <td>10.4 g</td> <td>13.0 g</td> </tr> <tr> <td>of which saturates</td> <td>7.2 g</td> <td>9.0 g</td> </tr> <tr> <td>Carbohydrate</td> <td>24.0 g</td> <td>30.0 g</td> </tr> <tr> <td>of which sugars</td> <td>18.4 g</td> <td>23.0 g</td> </tr> <tr> <td>Fibre</td> <td>1.6 g</td> <td>2.0 g</td> </tr> <tr> <td>Protein</td> <td>3.2 g</td> <td>4.0 g</td> </tr> <tr> <td>Salt</td> <td>0.1 g</td> <td>0.1 g</td> </tr> </tbody> </table> <p>Reference intake of an average adult (8400 kJ/2000 kcal)</p> <p>Ingredients: Cream, Skim milk, Liquid sugar, Water, Egg yolks, Brown sugar, Milkfat, Peanut oil, Sugar, Butter, Salt, Carrageenan, Vanilla extract</p>	Typical Values	Per 100 mL	1 serving (125 mL)	Energy	837 kJ	1046 kJ		200 kcal	250 kcal	Fat	10.4 g	13.0 g	of which saturates	7.2 g	9.0 g	Carbohydrate	24.0 g	30.0 g	of which sugars	18.4 g	23.0 g	Fibre	1.6 g	2.0 g	Protein	3.2 g	4.0 g	Salt	0.1 g	0.1 g	 <p>Nutrition Information SERVINGS PER CONTAINER: 4 SERVING SIZE: 125 mL (1/2 cup)</p> <table border="1"> <thead> <tr> <th></th> <th>AVG QUANTITY PER SERVING</th> <th>% DAILY INTAKE (PER SERVING)</th> <th>AVG QUANTITY PER 100 mL</th> </tr> </thead> <tbody> <tr> <td>ENERGY</td> <td>1000 kJ</td> <td>11%</td> <td>800 kJ</td> </tr> <tr> <td>PROTEIN</td> <td>4.0 g</td> <td>8%</td> <td>3.2 g</td> </tr> <tr> <td>FAT, TOTAL</td> <td>13.0 g</td> <td>19%</td> <td>10.4 g</td> </tr> <tr> <td>-SATURATED</td> <td>9.0 g</td> <td>38%</td> <td>7.2 g</td> </tr> <tr> <td>CARBOHYDRATE</td> <td>30.0 g</td> <td>10%</td> <td>24.0 g</td> </tr> <tr> <td>-SUGARS</td> <td>23.0 g</td> <td>20%</td> <td>18.4 g</td> </tr> <tr> <td>SODIUM</td> <td>55 mg</td> <td>2%</td> <td>44 mg</td> </tr> </tbody> </table> <p>*Percentage daily intakes are based on an average adult diet of 8700 kJ</p> <p>Ingredients: Cream, Skim milk, Liquid sugar, Water, Egg yolks, Brown sugar, Milkfat, Peanut oil, Sugar, Butter, Salt, Carrageenan, Vanilla extract</p>		AVG QUANTITY PER SERVING	% DAILY INTAKE (PER SERVING)	AVG QUANTITY PER 100 mL	ENERGY	1000 kJ	11%	800 kJ	PROTEIN	4.0 g	8%	3.2 g	FAT, TOTAL	13.0 g	19%	10.4 g	-SATURATED	9.0 g	38%	7.2 g	CARBOHYDRATE	30.0 g	10%	24.0 g	-SUGARS	23.0 g	20%	18.4 g	SODIUM	55 mg	2%	44 mg
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Note: NfT – Nutrition Facts table.

Correlates of label understanding were selected based on evidence regarding associations between nutrition knowledge, dietary behaviours, and sociodemographic characteristics.

Functional nutrition knowledge

Prior nutrition knowledge may influence consumers' understanding of nutrition labels;^{29,58,64-70} hence, this survey assessed consumer nutrition knowledge using the Food Processing Knowledge (FoodProK) score, a functional test of nutrition knowledge based on level of food processing.⁷¹ Respondents viewed and rated images of three food products within each of four categories: fruits (apple, apple juice, apple sauce), meat (chicken breast, deli chicken slices, chicken nuggets), dairy (1 percent milk, cheese block, processed cheese slices), and grains (oats, cereal, cereal bar). Products in each category were selected based on availability in multiple international contexts, and to represent varied levels of processing according to the NOVA

system.⁷² The 12 product images and corresponding NFts and ingredients lists were displayed one at a time, in random order. For each product, respondents were asked, “Overall, how healthy is this food product?” and answered using a scale of 0 to 10, with 0 representing ‘not healthy at all’ to 10 indicating ‘extremely healthy.’ Respondents’ FoodProK score (ranging from 0-8) was calculated based on whether they correctly ordered foods according to the NOVA classification for level of processing, with less processed foods representing higher healthiness.^{71,72}

Consumer dietary behaviours

Dietary modification efforts, another possible predictor of label understanding and usage, were measured by asking, “Have you made an effort to consume more or less of the following in the past year?” Respondents answered, ‘consume less,’ ‘consume more,’ or ‘no effort made,’ to a list of nutrients and food categories. This study focused on efforts in five categories that have received increasing attention in policies such as dietary guidelines within the five countries: ‘trans fats,’ ‘sugar/added sugars,’ ‘salt/sodium,’ ‘calories,’ and ‘processed foods.’^{23,73-78} A value of -1 was assigned for any responses to ‘consume less,’ +1 for responses to ‘consume more,’ and 0 for ‘no effort made’ in the five categories. Dietary modification efforts were recoded into a scale variable, with five points added to all responses to create a 0 to 10 scale where 0 represents ‘consume less’ responses to all categories, 10 represents ‘consume more’ responses to all categories, and the range between reflects all other response combinations.

Consumers with specific dietary practices, as well as those with a primary food shopping role in their households, are hypothesized to have greater interest in and exposure to labels.^{67,79-81} Respondents indicated whether they engaged in any of the following dietary practices: ‘vegetarian,’ ‘vegan,’ ‘pescatarian,’ ‘following a religious practice for eating (please specify),’ or ‘none of the above.’ This variable was recoded as binary (no specific dietary practices = 0; one or more dietary practices = 1).⁸² Food shopping role was captured using an adapted version of the United States Department of Agriculture Eating and Health survey measure: “Do you do most of the food shopping in your household?” with response options ‘yes,’ ‘no,’ or ‘share equally with other(s).’⁸³

Sociodemographic variables and body mass index

Nutrition label understanding has been shown to vary by sociodemographic and socioeconomic characteristics, which may contribute to greater disparities in nutrition outcomes.^{20-22,84-86} Age, sex at birth (female or male), country (Australia, Canada, Mexico, the UK, the US) and derived variables for education and ethnicity were included in analyses. Less than 1% (n=113) of IFPS respondents reported a gender different than their biological sex, which was insufficient for providing robust estimates in modelling. Hence, sex at birth was used as a binary covariate. Education level was categorized in accordance with country-specific criteria, with respondents classified as having ‘low’ (high school completion or lower), ‘medium’ (some post-secondary school qualifications, including some university), or ‘high’ (university degree or higher) levels of education.^{26,87-90} To enable cross-country comparisons, respondents were categorized as ‘majority’ in Mexico if they identified themselves as ‘Indigenous,’ and ‘majority’ in Australia, Canada, the UK and the US if they identified themselves as ‘white,’ predominantly English-speaking, or non-Indigenous based on country-specific ethnicity questions.^{89,90-92} Income adequacy was assessed by asking, “Thinking about your total monthly income, how difficult or easy is it for you to make ends meet?” with Likert scale response options ‘very difficult,’ ‘difficult,’ ‘neither easy nor difficult,’ ‘easy,’ and ‘very easy.’⁹³

Categorization of body mass index (BMI) followed World Health Organization criteria,⁹⁴ with self-reported height and weight used to classify respondents based on BMI <18.5 kg/m², 18.5 to 24.9 kg/m², 25.0 to 29.9 kg/m², and ≥30 kg/m². Response options ‘don’t know’ and ‘refuse to answer’ were provided for all survey questions and recoded as missing. Given the large number of cases with missing height and weight data – including those who selected ‘don’t know’ or ‘refuse to answer’ – a separate category for ‘missing’ was created and retained as a response category for analyses.

Statistical analysis

Descriptive statistics were used to summarize the sample profile and labelling outcomes by country. Analyses were conducted only on respondents who had complete data from all variables, with the exception of BMI, as described above. Respondents with missing data were not different with respect to self-reported or functional label understanding compared with the rest of the sample (data not shown).

Three multiple linear regression models were fitted to examine self-reported NfT understanding, FOP label understanding, and functional NfT understanding. All models were adjusted for sociodemographic characteristics (age, sex, country, income adequacy, education level, ethnicity), consumer dietary behaviours (food shopping role, dietary efforts and practices), BMI, and nutrition knowledge (FoodProK score). Multiple comparisons were conducted to assess all pairwise contrasts for categorical variables. The Benjamini-Hochberg procedure was applied to decrease the false detection rate following multiple exploratory tests.⁹⁵ All statistically significant pairwise contrasts are reported after applying the Benjamini-Hochberg procedure, assuming a false discovery rate of 10%. Spearman’s rank correlation tested bivariate associations between self-reported NfT understanding, self-reported FOP understanding, and functional NfT understanding (Newest Vital Sign score).

Statistical analyses were conducted using SAS Studio (SAS Institute, Cary, NC). Parameter estimates are reported with 95% confidence intervals (CIs). Data were weighted with post-stratification sample weights constructed using a raking algorithm with population estimates from respective country-based censuses based on age group, sex at birth, region, ethnicity (except in Canada), and education (except in Mexico).⁵⁹ All reported estimates are weighted.

3.3.4 Results

Sample characteristics are presented in **Table 2**.

Table 2: Sample Characteristics (n = 21, 586), International Food Policy Study, 2018

Characteristic	Australia (n=3901) % (n)	Canada (n=4107) % (n)	Mexico (n=4012) % (n)	United Kingdom (n=5121) % (n)	United States (n=4445) % (n)
Age Group					
18-29 years	21.3 (831)	18.9 (777)	29.8 (1194)	19.0 (974)	20.6 (914)
30-44 years	26.2 (1022)	24.7 (1014)	32.3 (1297)	24.8 (1270)	25.1 (1115)
45-59 years	24.7 (963)	25.8 (1059)	28.7 (1151)	25.9 (1327)	25.7 (1141)
60+ years	27.8 (1085)	30.6 (1257)	9.2 (370)	30.3 (1550)	28.6 (1275)
Sex					
Male	48.7 (1898)	49.4 (2028)	47.6 (1911)	47.8 (2448)	48.2 (2141)
Female	51.3 (2003)	50.6 (2079)	52.4 (2101)	52.2 (2673)	51.8 (2304)
Ethnicity					
Majority	76.1 (2969)	79.9 (3280)	78.7 (3156)	89.1 (4563)	76.1 (3382)
Minority	23.9 (932)	20.1 (827)	21.3 (856)	10.9 (558)	23.9 (1063)

Education Level					
Low	41.6 (1622)	41.0 (1683)	19.5 (782)	47.6 (2438)	58.2 (2585)
Medium	32.6 (1272)	34.1 (1400)	13.2 (531)	23.5 (1203)	10.0 (443)
High	25.8 (1007)	24.9 (1024)	67.3 (2699)	28.9 (1480)	31.8 (1417)
Income Adequacy					
Very difficult to make ends meet	8.5 (331)	8.4 (345)	12.0 (482)	6.8 (349)	9.4 (416)
Difficult to make ends meet	19.2 (750)	19.6 (804)	31.7 (1273)	18.5 (949)	20.3 (902)
Neither easy nor difficult to make ends meet	37.8 (1473)	36.8 (1511)	38.9 (1559)	36.0 (1844)	33.7 (1497)
Easy to make ends meet	23.6 (921)	22.5 (927)	13.9 (557)	24.7 (1265)	21.8 (970)
Very easy to make ends meet	10.9 (426)	12.7 (520)	3.5 (141)	14.0 (714)	14.8 (660)
Body Mass Index					
<18.5	3.1 (122)	3.2 (133)	2.1 (85)	2.9 (150)	3.4 (153)
18.5-24.9	36.3 (1416)	33.5 (1376)	39.6 (1588)	34.8 (1780)	31.2 (1385)
25.0-29.9	26.6 (1039)	28.8 (1183)	30.1 (1208)	27.0 (1384)	27.6 (1226)
≥30.0	20.9 (815)	24.7 (1015)	15.5 (620)	17.0 (870)	27.4 (1218)
Missing	13.1 (509)	9.8 (400)	12.7 (511)	18.3 (937)	10.4 (463)
Food Shopping Role					
Primary shopper	71.6 (2792)	72.0 (2959)	74.9 (3005)	74.6 (3820)	73.2 (3255)
Not primary shopper	6.9 (268)	5.9 (242)	5.0 (201)	4.5 (230)	6.6 (293)
Shared equally with others	21.5 (841)	22.1 (906)	20.1 (806)	20.9 (1071)	20.2 (897)
Dietary Practices					
No specific dietary practices	87.1 (3396)	90.4 (3714)	88.2 (3539)	86.8 (4446)	88.6 (3936)
One or more dietary practices (i.e., vegetarian, vegan, pescatarian, religious practices)	12.9 (505)	9.6 (393)	11.8 (473)	13.2 (675)	11.4 (509)
Dietary Efforts Score*					
	2.7 (2.2)	2.6 (2.1)	2.5 (2.3)	3.0 (2.1)	2.9 (2.3)
FoodProK Score*					
	5.0 (1.7)	5.1 (1.5)	4.8 (1.5)	4.9 (1.8)	4.6 (1.8)

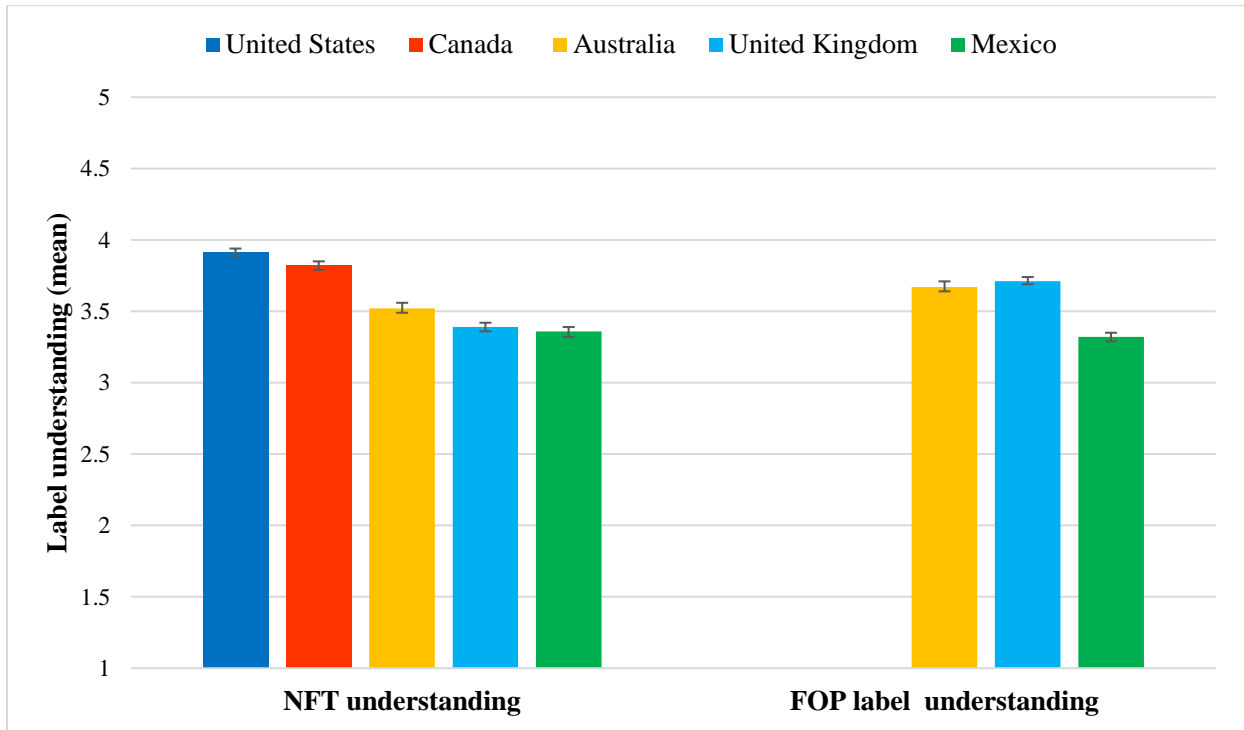
*Mean and standard deviation reported for dietary efforts and FoodProK score. Data presented have been weighted.

Self-reported and functional label understanding across countries

Respondents from the US self-reported higher NfT understanding than respondents from Canada, Australia, the UK, and Mexico (**Figure 1**). For FOP labels, the mean level of understanding for Traffic Lights and HSR labels was higher than GDA labels, respectively.

When comparing NfT and FOP labels in Australia, the UK, and Mexico, self-reported FOP label understanding was generally higher than NfT understanding, with the exception of Mexico.

Figure 1: Self-reported understanding of Nutrition Facts table and front-of-package label, by country



Notes: Mean levels of self-reported understanding are shown with 95% confidence intervals. A mean of 1 indicates ‘very hard to understand,’ and 5 indicates ‘very easy to understand.’ NFT – Nutrition Facts Table. FOP – front-of-package.

Table 3 shows Newest Vital Sign scores in each of the five countries. Respondents in all countries had the highest proportions of correct answers for questions pertaining to nut allergies, and the lowest proportion of correct answers for the question regarding levels of saturated fats. A greater number of respondents received full scores for questions requiring minimal or no mathematical calculations (i.e., Q5 and Q6).

Table 3: Functional understanding of Nutrition Facts tables, by country

Country	Newest Vital Sign Questions						Total Score (mean)
	Q1 – Calorie content % (n)	Q2 – Carbohydrates % (n)	Q3 – Saturated fats % (n)	Q4 – Percent daily value % (n)	Q5 – Allergy safety % (n)	Q6 – Allergy rationale % (n)	
Mexico (N=4012)	41.7% (1675)	41.5% (1667)	37.7% (1512)	44.9 % (1803)	62.0% (2489)	56.2% (2253)	2.84
United Kingdom (N=5121)	55.8% (2856)	53.2% (2726)	44.0% (2253)	48.3% (2473)	61.7% (3161)	55.8% (2860)	3.19
Australia (N=3901)	52.6% (2053)	46.3% (1805)	41.2% (1618)	49.6 % (1935)	66.3% (2585)	60.8% (2373)	3.23
United States (N=4445)	64.9% (2883)	55.0% (2444)	44.9% (1995)	53.0 % (2357)	68.8% (3057)	63.1% (2807)	3.50
Canada (N=4107)	62.7% (2576)	61.5% (2525)	45.0% (1848)	61.0 % (2505)	72.0% (2959)	67.2% (2762)	3.69

Notes: % refers to total percentage of respondents who answered the Newest Vital Sign question correctly in each country. Scores range from 0 to 6, with higher scores representing greater understanding of Nutrition Facts tables.

In general, self-reported NfT understanding was higher with higher Newest Vital Sign score (i.e., functional NfT understanding), with a few exceptions in Mexico and the US (Table 4). Self-reported FOP label understanding similarly was higher with higher Newest Vital Sign scores.

Table 4: Mean self-reported label understanding by Newest Vital Sign score across countries

NVS Score	Self-reported NfT understanding						Self-reported FOP label understanding			
	All country average	Canada	US	Australia	UK	Mexico	All country average	Australia	UK	Mexico
0	3.22	3.33	3.74	3.13	2.98	3.13	3.25	3.46	3.22	3.11
1	3.38	3.55	3.60	3.29	3.18	3.33	3.38	3.49	3.35	3.32
2	3.44	3.64	3.81	3.34	3.20	3.36	3.42	3.57	3.50	3.26
3	3.56	3.77	3.86	3.45	3.40	3.34	3.51	3.60	3.72	3.25
4	3.61	3.82	3.92	3.51	3.41	3.35	3.56	3.64	3.70	3.29
5	3.73	3.91	3.95	3.73	3.52	3.46	3.73	3.76	3.88	3.44
6	3.83	4.03	4.07	3.79	3.60	3.49	3.77	3.63	3.97	3.48

Notes: NVS – Newest Vital Sign. NfT – Nutrition Facts Table. FOP – front-of-package. UK – United Kingdom. US – United States. NfT means reflect 5-country average, and FOP label means reflect 3-country average for Australia, Mexico, and the United Kingdom only.

Functional NfT understanding was weakly correlated with self-reported understanding of NfT labels ($r_s=0.18$, $p<0.0001$) and self-reported understanding of FOP labels ($r_s=0.16$, $p<0.0001$). Self-reported NfT and FOP understanding were moderately correlated ($r_s=0.51$, $p<0.0001$).

Cross-country differences and correlates of NfT and FOP label understanding

As shown in **Table 5**, respondents from the US, Canada, and Australia self-reported significantly higher NfT understanding than respondents from Mexico ($p<0.0001$). Additional pairwise contrasts (data not shown) demonstrated that respondents from Australia reported significantly lower NfT understanding than respondents from Canada ($\beta=-0.27$; CI: -0.33, -0.22; $p<.0001$) and the US ($\beta=-0.41$; CI: -0.45, -0.35; $p<.0001$), and higher NfT understanding than UK respondents ($\beta=0.15$; CI: 0.10, 0.20; $p<.0001$). Respondents from Canada and the UK reported lower NfT understanding than those from the US ($\beta=-0.13$; CI: -0.18, -0.01; $p<.0001$; $\beta=-0.56$; CI: -0.61, -0.51; $p<.0001$, respectively), and respondents in Canada reported higher NfT understanding than UK respondents ($\beta=0.43$; CI: 0.38, 0.48; $p<.0001$). Respondents from Australia and the UK reported significantly higher FOP label understanding than respondents from Mexico ($\beta=0.41$; CI: 0.35, 0.47; $p<.0001$; $\beta=0.38$; CI: 0.32, 0.44; $p<.0001$).

Respondents from the US, Canada, Australia, and the UK scored significantly higher on the Newest Vital Sign measure than respondents in Mexico, indicative of higher functional NfT understanding (**Table 6**). Functional NfT understanding among respondents in Australia was significantly lower compared to Canadian and American respondents ($\beta=-0.31$; CI: -0.40, -0.21; $p<.0001$; $\beta=-0.38$; CI: -0.48, -0.29; $p<.0001$), adjusting for other covariates. Respondents from Canada ($\beta=0.25$; CI: 0.15, 0.34; $p<.0001$) received significantly higher scores for functional NfT understanding than those in the UK, and UK respondents received significantly lower scores than US respondents ($\beta=-0.32$; CI: -0.42, -0.23; $p<.0001$). The differences in functional NfT understanding scores between respondents in Australia and the UK, and Canada and the US were not statistically significant.

Self-reported NfT and FOP label understanding was higher among respondents with higher FoodProK scores ($\beta=0.06$; CI: 0.05, 0.07; $p<.0001$ for NfT; $\beta=0.08$; CI: 0.06, 0.09; $p<.0001$ for

FOP labels), primary food shoppers ($\beta=0.16$; CI: 0.08, 0.23; $p<.0001$; for NfT $\beta=0.14$; CI: 0.03, 0.25; $p=0.0078$ for FOP), those who engaged in specific dietary practices ($\beta=0.09$; CI: 0.04, 0.15; $p=0.0010$ for NfT; $\beta=0.08$; CI: 0.01, 0.14; $p=0.0161$ for FOP), as well as respondents reporting efforts to consume less sodium, sugars, trans fats, calories, or processed food ($\beta=0.06$; CI: 0.05, 0.07; $p<.0001$ for NfT; $\beta=0.08$; CI: 0.06, 0.09; $p<.0001$ for FOP). Similarly, respondents who scored higher on the FoodProK ($\beta=0.38$; CI: 0.36, 0.40; $p<.0001$), those who reported efforts to consume less sodium, sugars, trans fats, calories or processed food ($\beta=-0.10$; CI: -0.11, -0.09; $p<.0001$), and those with higher self-reported NfT understanding ($\beta=0.19$; CI: 0.16, 0.22; $p<.0001$) received significantly higher scores for functional NfT understanding. In contrast to self-reported label understanding, respondents who were primary food shoppers scored lower on the Newest Vital Sign than those who were not primary food shoppers ($\beta=-0.34$; CI: -0.48, -0.21; $p<.0001$) or who shared the responsibility equally with others in their households ($\beta=-0.24$; CI: -0.31, -0.17; $p<.0001$). Also, respondents engaging in vegetarian or other dietary practices had lower functional NfT understanding scores than those with no specific dietary practices ($\beta=-0.45$; CI: -0.54, -0.36; $p<.0001$).

With respect to sociodemographic characteristics, self-reported NfT and FOP label understanding was lower with higher age ($\beta=-0.005$; CI: -0.006, -0.004; $p<.0001$ for NfT; $\beta=-0.006$; CI: -0.008, 0.00; $p<.0001$ for FOP labels). Education was not significantly associated with self-reported NfT understanding; however, self-reported FOP label understanding was higher among respondents with 'high' education compared to 'low' education levels ($\beta=0.11$; CI: 0.06, 0.16; $p<.0001$). Both self-reported NfT and FOP label understanding were higher with higher income adequacy ($\beta=0.12$; CI: 0.11, 0.14; $p<.0001$ for NfT; $\beta=0.10$; CI: 0.08, 0.12; $p<.0001$ for FOP labels). Sex and ethnicity were not significantly associated with self-reported label understanding. For functional NfT understanding, females ($\beta=0.23$; CI: 0.17, 0.29; $p<.0001$), younger respondents ($\beta=-0.004$; CI: -0.006, -0.002; $p<.0001$), and those from 'majority' ethnic groups in their respective countries ($\beta=0.63$; CI: 0.55, 0.72; $p<.0001$) scored higher than their male, older, or 'minority' counterparts. Respondents with 'high' education scored higher for functional NfT understanding compared to those with 'medium' ($\beta=0.16$; CI: 0.80, 0.23; $p<.0001$) and 'low' education levels ($\beta=0.52$; CI: 0.44, 0.58; $p<.0001$).

Respondents with BMIs ≥ 30 , between 25-29.9, < 18.5 , or 'missing' self-reported lower NFt understanding compared to those with a BMI between 18.5-24.9. Moreover, respondents with missing BMI or BMI ≥ 30 self-reported lower NFt understanding compared to those with BMIs < 18.5 ($\beta = -0.17$; CI: -0.28, -0.05; $p = 0.0044$; $\beta = -0.14$; CI: -0.25, -0.03; $p = 0.0152$, respectively). Respondents with BMIs ≥ 30 also self-reported lower FOP label understanding compared to those with BMIs between 18.5-24.9 ($\beta = -0.09$; CI: -0.15, -0.03; $p = 0.0066$). Similarly, respondents with missing BMI data scored significantly lower for functional NFt understanding compared with all other BMI categories ($p < 0.0001$ for all), however those with BMIs ≥ 30 scored higher compared to respondents with BMIs between 18.5-24.9 ($\beta = 0.10$; CI: 0.02, 0.19; $p = 0.0148$) and 25-29.9 ($\beta = 0.09$; CI: 0.01, 0.18; $p = 0.0297$).

Table 5: Sociodemographic and behavioural correlates of self-reported NFt and FOP label understanding

	NFt Understanding Mean (SD)	NFt understanding			FOP label understanding Mean (SD)	FOP label understanding		
		β	95% CI	p-value		β	95% CI	p-value
Country								
Mexico	3.36 (1.07)	Ref			3.31 (1.09)	Ref		
United Kingdom	3.36 (1.12)	0.01	-0.04, 0.07	0.6609	3.65 (1.01)	0.38	0.32, 0.44	*<.0001
Australia	3.53 (1.11)	0.16	0.10, 0.21	*<.0001	3.68 (0.97)	0.41	0.35, 0.47	*<.0001
Canada	3.81 (0.95)	0.44	0.38, 0.49	*<.0001	-	-	-	-
United States	3.90 (0.95)	0.57	0.51, 0.62	*<.0001	-	-	-	-
Age								
	-	-0.005	-0.006, -0.004	*<.0001	-	-0.006	-0.008, -0.005	*<.0001
Sex at Birth								
Male	3.56 (1.08)	Ref			3.55 (1.03)	Ref		
Female	3.60 (1.06)	0.00	-0.04, 0.03	0.8489	3.56 (1.05)	-0.04	-0.08, 0.00	0.0589
Ethnicity								
Minority	3.67 (1.16)	Ref			3.55 (1.24)	Ref		
Majority	3.57 (1.05)	-0.03	-0.08, 0.01	0.1553	3.55 (1.01)	0.02	-0.05, 0.08	0.5305
Education Level								
Low	3.56 (1.37)	Ref			3.52 (1.27)	Ref		
Medium	3.58 (0.97)	0.02	-0.03, 0.06	0.4544	3.58 (0.99)	0.02	-0.04, 0.08	0.5115
High	3.61 (0.91)	0.04	0.00, 0.08	0.0588	3.57 (0.93)	0.11	0.06, 0.16	*<.0001
Income Adequacy								
	-	0.12	0.11, 0.14	*<.0001	-	0.10	0.08, 0.12	*<.0001
Body Mass Index								
18.5-24.99	3.65 (1.04)	Ref			3.62 (0.99)	Ref		
<18.5	3.70 (1.15)	0.06	-0.05, 0.17	0.2790	3.56 (1.17)	-0.06	-0.21, 0.09	0.4146
25.0-29.99	3.58 (1.05)	-0.06	-0.10, -0.01	*0.0076	3.53 (1.03)	-0.05	-0.11, 0.00	0.0490

≥30.0	3.57 (1.09)	-0.08	-0.13, -0.03	*0.0010	3.49 (1.07)	-0.09	-0.15, -0.03	*0.0066
Missing	3.42 (1.14)	-0.11	-0.16, -0.05	*0.0002	3.50 (1.10)	-0.05	-0.12, 0.02	0.1619
<i>Food Shopping Role</i>								
Not primary shopper	3.46 (1.14)	Ref			3.43 (1.13)	Ref		
Share equally with others	3.54 (1.05)	0.07	0.00, 0.16	0.0766	3.53 (1.13)	0.08	-0.03, 0.19	0.1574
Primary shopper	3.61 (1.07)	0.16	0.08, 0.23	*<.0001	3.57 (1.04)	0.14	0.03, 0.25	*0.0078
<i>Dietary Practices</i>								
No specific dietary practices	3.57 (1.07)	Ref			3.54 (1.04)	Ref		
One or more dietary practices (i.e., vegetarian, vegan, pescatarian, religious practices)	3.63 (1.10)	0.09	0.04, 0.15	*0.0010	3.62 (1.04)	0.08	0.01, 0.14	*0.0161
<i>Dietary Efforts Score</i>								
	-	-0.05	-0.06, -0.04	*<.0001	-	-0.04	-0.05, -0.03	*<.0001
<i>FoodProK Score</i>								
	-	0.06	0.05, 0.07	*<.0001	-	0.08	0.06, 0.09	*<.0001

Notes: β - parameter estimate, CI – Confidence Intervals, SD – Standard Deviation. Ref – Reference category, NFt – Nutrition Facts Table, FOP – front-of-package. Sample size for NFt understanding model is 21, 586, and 12,360 for the FOP label understanding model. *Variables are significant ($p < 0.05$) after post hoc adjustment using Benjamini-Hochberg procedure.

Table 6: Sociodemographic and behavioural correlates of functional NFt understanding (n=21,586)

	β	95% CI	p-value
Country			
Australia vs. Canada	-0.31	-0.40, -0.21	*<.0001
Australia vs. Mexico	0.46	0.36, 0.57	*<.0001
Australia vs. United Kingdom	-0.06	-0.15, 0.03	0.1957
Australia vs. United States	-0.38	-0.48, -0.29	*<.0001
Canada vs. Mexico	0.77	0.67, 0.87	*<.0001
Canada vs. United Kingdom	0.25	0.15, 0.34	*<.0001
Canada vs. United States	-0.08	-0.17, 0.02	0.1134
United Kingdom vs. Mexico	0.52	0.43, 0.62	*<.0001
United Kingdom vs. United States	-0.32	-0.42, -0.23	*<.0001
United States vs. Mexico	0.84	0.75, 0.95	*<.0001
Age			
	-0.004	-0.006, -0.002	*<.0001
Sex at Birth			
Female vs. Male	0.23	0.17, 0.29	*<.0001
Ethnicity			
Majority vs. Minority	0.63	0.55, 0.72	*<.0001
Education Level			
Medium vs. Low	0.36	0.28, 0.43	*<.0001
High vs. Low	0.52	0.44, 0.58	*<.0001
High vs. Medium	0.16	0.80, 0.23	*<.0001
Income Adequacy			
	0.00	-0.02, 0.03	0.8572
Body Mass Index			
Missing vs. <18.5	-0.72	-0.92, -0.53	*<.0001
Missing vs. 18.5-24.9	-0.69	-0.79, -0.59	*<.0001
Missing vs. 25-29.9	-0.70	-0.80, -0.60	*<.0001
Missing vs. \geq 30	-0.80	-0.90, -0.69	*<.0001
\geq 30 vs. <18.5	0.07	-0.11, 0.26	0.4494
\geq 30 vs. 18.5-24.9	0.10	0.02, 0.19	*0.0148
\geq 30 vs. 25-29.9	0.09	0.01, 0.18	*0.0297
25-29.9 vs. 18.5-24.9	0.01	-0.07, 0.08	0.8023
25-29.9 vs. <18.5	-0.02	-0.21, 0.16	0.8186
<18.5 vs. 18.5-24.9	0.03	-0.15, 0.21	0.7349
Food Shopping Role			
Primary shopper vs. Not primary shopper	-0.34	-0.48, -0.21	*<.0001
Primary shopper vs. Share equally with others	-0.24	-0.31, -0.17	*<.0001
Not primary shopper vs. Share equally with others	-0.10	-0.25, 0.04	0.1725
Dietary Practices			

One or more dietary practices (i.e., vegetarian, vegan, pescatarian, religious practices) vs. No specific dietary practices	-0.45	-0.54, -0.36	*<.0001
<i>Dietary Efforts Score</i>	-0.10	-0.11, -0.09	*<.0001
<i>FoodProK score</i>	0.38	0.36, 0.40	*<.0001
<i>Self-reported NFT understanding</i>	0.19	0.16, 0.22	*<.0001

Notes: β - parameter estimate, CI – Confidence Intervals. NFt – Nutrition Facts table. *Variables are significant ($p < 0.05$) after post hoc adjustment using Benjamini-Hochberg procedure. Reference category is noted after ‘vs.’

3.3.5 Discussion

Several studies have assessed consumer understanding of front- and back-of-package nutrition labelling systems across multiple countries;^{27,29,30,28,56,96} however, this is the only population-based, multi-country analysis, to our knowledge, to report on levels of understanding for different label types, and to use the Newest Vital Sign measure as a functional test of NFt understanding. The results therefore provide several unique insights.

Respondents in the US self-reported the highest level of NFt understanding, and also scored highest on the functional test of NFt understanding, followed by Canada, Australia, the UK and Mexico. Given that NFts are mandatory and similarly formatted in all countries, these differences may be explained by parallel healthy eating policies or food labelling campaigns in each country. For example, the US and Canada released fact sheets, websites, and updates to school curricula alongside changes to food labelling policy to increase exposure to and education about food labels.^{76,77,98,99} Other countries have developed similar campaigns; however, it is possible that more aggressive NFt label promotion in Canada and the US compared to other countries resulted in relatively higher self-reported NFt understanding. It is also possible that the findings reflect differences in levels of numeracy or health literacy across countries, as this study found an association between self-reported and functional NFt understanding, that while focused on interpreting a nutrition facts label, has been conceptualized as an indicator of health literacy.⁶¹ We are not aware of previous studies that have explicitly examined numeracy or health literacy levels among the countries in the current study.

Another potential explanation for cross-country differences lies in the prominence of processed, packaged foods, as countries with a greater reliance on packaged food consumption may have greater exposure to – and therefore understanding – of NfTs. Americans obtain as much as 60% of their total energy intake from ultra-processed foods – potentially the highest among all countries in this study.^{72,100-105}

As expected, mean self-reported NfT understanding was higher with higher Newest Vital Sign scores in all countries, but with a weak correlation between these measures. Moreover, many respondents in this study self-reported high NfT understanding while performing poorly on the functional measure. These findings are consistent with research indicating that consumers tend to overestimate their nutrition knowledge.^{12,18,51,52,54,55,106} In particular, studies have shown that consumers perform poorly on functional tasks, in part due to low awareness about what percent daily value means, and in some cases, confusion about terminology (i.e., calories versus kilojoules).^{9,12,18,107-111}

Self-reported FOP label understanding was highest in Australia, followed by the UK and Mexico. Although self-reported understanding of FOP labels was higher than for NfTs in Australia and the UK, the differences were more modest than some experimental studies might suggest. This may reflect that FOP labels are voluntary in both countries and appear on a minority of products.^{53,112} Mexico was the only country in which self-reported understanding of FOP labels was lower than NfTs. Although the FOP GDA in Mexico is mandatory, this finding likely reflects the design and type of information included on the Mexican FOP label. HSR and Traffic Lights labels in Australia and the UK use symbols and provide interpretive information, whereas Mexico's industry-based GDA system provides reductive nutrient information similar to the NfT – simply replicating this information from the back to FOP. Previous research has demonstrated that consumers have poor understanding of the numeric information on GDA labels, which is consistent with the current findings.^{25,38,41,113} The findings from this study highlight the importance of simple, interpretative information, particularly in countries which may have lower levels of numeracy. Accordingly, Mexico recently approved a new regulation to replace the GDA with FOP 'high-in' labels similar to those used in Chile.¹¹⁴

Food processing knowledge was associated with greater label understanding, particularly for functional NfT understanding. Packaged foods are predominantly highly processed; thus, it is expected that consumers with an increased interest or knowledge of nutrition would have a better understanding of both levels of food processing,¹⁰⁶ as well as how to interpret the information on NfTs. Given the repercussions for noncommunicable disease risk,^{102,105,115} consumers with a greater understanding of the relative healthiness of food products based on processing would be better equipped to navigate the increasingly processed food landscape.^{72,116-118}

Respondents with a primary food shopping role had higher self-reported NfT and FOP label understanding, but lower functional NfT understanding than those who were not primary shoppers. This finding is surprising given literature suggesting that consumers with specific dietary preferences and needs have increased interest and reliance on labels to support food choices,^{4,6,7,57,58} and primary shoppers likely have greater exposure to labels.⁷⁹ Those engaging in vegetarian or other dietary practices also reported higher NfT and FOP understanding, but scored lower on the functional test of NfT understanding. These findings point to discrepancies in self-report versus functional measures. While self-reported measures can still be informative in labelling policy research, they may not accurately reflect consumers' ability to read and interpret NfTs – particularly for labels involving numeracy skills.

With respect to sociodemographic characteristics, self-reported label understanding decreased with age, which may reflect lower awareness of labels or lower numeracy skills among older age groups.^{17,119-122} Consistent with existing literature,¹²³⁻¹²⁸ this study found higher functional NfT understanding among females, 'majority' ethnic groups, and respondents with higher income adequacy and education levels compared to their respective counterparts. These differences may be explained by disparities in label comprehension, as consumers with lower education, in particular, may have lower numeracy skills than those with higher educational attainment.¹⁷ FOP labels were designed to be accessible to consumers with lower education or literacy levels, however differences in understanding were observed in this study based on income adequacy and education. Research has shown that respondents with lower incomes demonstrate poorer understanding and responsiveness to FOP labels than those with higher incomes,^{25,49} although some evidence points to FOP 'high-in' labels, in particular, having similar benefits across sociodemographic subgroups compared to other labelling systems.^{42,129,130} More research is

needed to explore whether disparities persist for FOP label understanding across various label types, however this evidence is important to consider as lower label comprehension may be compounded by competing priorities in food selection. Consumers identifying as ethnic minorities in their respective countries and those with low incomes may prioritize cultural preferences or affordability in food purchasing and consumption, which could impact attention to NFt and resultant comprehension or use.^{49,126,131-133}

Respondents with BMIs between 18.5 to 24.9 self-reported higher NFt understanding than all other BMI categories. Similarly, self-reported FOP label understanding was higher for respondents in this BMI range compared to those with BMIs ≥ 30 . In contrast, those with BMIs ≥ 30 scored higher for functional NFt understanding compared to respondents with BMIs between 18.5-24.9 and 25-29.9. The literature demonstrates mixed findings regarding label understanding and BMI.^{128,134-135} The use of self-reported measures of label comprehension suggests a possible role of weight-based goals in shaping NFt use; however, more research is needed to unpack patterns and differences in functional NFt understanding based on weight status, either objectively measured or perceived.

There were several limitations of the current analysis. The sample was recruited using non-probability sampling, which does not enable nationally representative population estimates. For example, although data were weighted by age, sex, and region, the Mexico sample had higher levels of education than the Mexican population based on census estimates, while mean BMI was lower than national estimates in each of the five countries.⁵⁹ The primary outcomes, NFt and FOP label understanding, as well as BMI, are subject to social desirability bias given the use of self-reported measures. There are also limitations of the functional NFt understanding measure, as the Newest Vital has been tested across a variety of age and ethnic groups in different countries, but has not yet been validated as a self-administered measure.^{62,136-142} Moreover, despite being tested among Hispanic American populations,¹⁴³ the Newest Vital Sign has not been tested in Mexico. This study was also limited to understanding of labels and did not examine the implications of label use for food choices and dietary quality.

3.3.6 Conclusions

This study found between-country differences in self-reported and functional label understanding across countries, with the highest levels of NfT and FOP label understanding in the US and Australia, respectively, and the lowest levels of label understanding in Mexico. Cross-country differences may reflect the extent to which mandatory vs. voluntary nutrition labelling policies are implemented and effective, as well as the uptake of parallel healthy eating policies or food labelling campaigns in each country.

The findings also suggest that simple, interpretative FOP labels, such as the HSR and Traffic Lights are easier to understand than GDA, a numerical-based FOP label. This study provides empirical support for Mexico's decision to replace GDA labels with Chilean-style 'high in' labels which are more easily understood by consumers.^{40,41-43,114,144} Future research should examine the extent to which mandatory vs. voluntary FOP labelling policies affect consumers' functional label understanding, as well as implications for dietary patterns across different sociodemographic groups.

The differences found in label understanding by consumer characteristics such as sex, ethnicity, income adequacy, education, and health literacy suggest that current nutrition labelling policies may be contributing to existing disparities in nutrition-related health behaviors and outcomes, as nutrition labels are less accessible to certain groups.²⁰⁻²³

Finally, this study also provides insight into the measurement of label understanding. While self-reported measures may have a role in large population-level surveys, study findings using self-report should be interpreted with caution due to the weak correlation between these measures. The use of the Newest Vital Sign as a functional measure of NfT understanding demonstrates a new application for this tool which captures consumers' ability to understand and interpret various components of NfTs better than current self-reported measures.

3.4 Study 4 – A five-country study of front- and back-of-package nutrition label awareness and use: patterns and correlates from the 2018 International Food Policy Study

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Authors: Jasmin Bhawra,¹ Sharon I. Kirkpatrick,¹ Marissa G. Hall,² Lana Vanderlee,³ David Hammond¹

¹School of Public Health and Health Systems, University of Waterloo, Canada

²Department of Health Behavior, Gillings School of Global Public Health, Lineberger Comprehensive Cancer Center, and Carolina Population Center, University of North Carolina, Chapel Hill, United States

³École de Nutrition, Centre nutrition, santé et société (Centre NUTRISS) and Institut sur la nutrition et les aliments fonctionnels (INAF), Université Laval, Québec, Canada

3.4.1 Abstract

Background: Front-of-package (FOP) nutrition labels on packaged processed foods provide simplified information compared to traditional Nutrition Facts tables (NFts). Evidence comparing label use and awareness across countries is necessary to evaluate the uptake of different labelling policies across subgroups. The current study examined patterns and correlates of NFt use and awareness in five countries – Australia, Canada, Mexico, the United Kingdom (UK), and the United States (US) – and of FOP labels in the three countries (mandatory Guideline Daily Amounts in Mexico; voluntary Health Star Ratings in Australia and voluntary Traffic Lights in the UK).

Methods: Adults (≥ 18 years) recruited using Nielsen Consumer Insights Global Panel in each country ($n=21,586$) completed online surveys in November-December 2018. Linear regression and generalized linear mixed models examined differences in label use and awareness between countries and label types (NFt vs. FOP) based on sociodemographic and other correlates.

Results: Respondents from the US, Canada, and Australia reported significantly higher NFt use and awareness than those in Mexico and the UK. Mexican respondents reported the highest level of FOP label awareness, followed by those in the UK and Australia, whereas UK respondents reported the highest FOP label use followed by those in Mexico and Australia. NFt but not FOP label use was higher among females, ‘minority’ ethnic groups, and those with higher nutrition knowledge. NFt use was also higher among respondents with ‘adequate literacy’ compared to those with a ‘high likelihood of limited literacy.’ In contrast, FOP use was higher among those with a ‘high likelihood of limited literacy’ compared to ‘adequate literacy’ across countries. In countries with both NFt and FOP labelling systems, use and awareness was higher for NFts in Australia and Mexico, with UK respondents reporting higher FOP label than NFt use and awareness.

Conclusions: Lower use of mandatory Guideline Daily Amount labels compared to voluntary FOP labelling systems provides further support for Mexico’s decision to switch to mandatory ‘high-in’ symbols. The patterns of use and awareness by sociodemographic correlates, including health literacy, suggest simple, accessible FOP labelling policies may encourage broader use across countries.

Key words: nutrition labelling, food policy, nutrition knowledge, international

3.4.2 Introduction

Non-communicable diseases including cardiovascular disease, type 2 diabetes, and obesity are the world's leading causes of premature death and disability, with dietary intake an important risk factor.^{1,2} In recent decades, a global dietary shift towards highly processed foods – including ultra-processed foods – has contributed to poor overall dietary quality.^{1,4-8} Ultra-processed foods are “formulations of food substances often modified by chemical processes and then assembled into ready-to-consume, hyper-palatable food and drink products using flavours, colours, emulsifiers, and a myriad of other cosmetic additives.”³ These foods typically contain high amounts of sodium, sugar, saturated or trans fats, leading to energy-dense, nutrient-poor food environments.⁶⁻¹³

Given that ultra-processed foods constitute more than half of energy intake in high-income countries including Canada, the United States (US), and the United Kingdom (UK),^{3,5,9,14} and between one-fifth to one-third of energy intake in middle-income countries such as Mexico and Brazil,^{3,15-17} governments have adopted policy measures, such as nutrition labelling, to support healthy eating.^{18,19} Nutrition labels are found on packaged foods and provide consumers with nutrient information at the point-of-purchase to aid informed decision-making in an increasingly processed food landscape,^{5,18-20} while also incentivizing the food industry to reformulate towards healthier nutritional profiles.^{1,19,21,22} Nutrition labels implemented to date include back- or side-of-package nutrition facts tables (NFts) and front-of-package (FOP) labelling systems. NFts feature quantitative information on nutrient amounts, whereas FOP labels focus on simplified, interpretive information, often using symbols instead of numeric information to promote comprehension.²³⁻²⁵

In most cases, NFts implemented in different countries have a similar appearance and information content.^{26,27} In contrast, FOP labels differ across countries and may be nutrient-specific or summary indicator systems.^{23,28} Nutrient-specific FOP labelling systems highlight select nutrients in the product, such as Mexico's Guideline Daily Amount label, which reinforces information also in the NFt, including calories, total sugars, saturated fats, and sodium.²⁹ Summary indicator systems summarize nutrient content and product healthfulness using algorithms to provide a score or ordinal ranking of the overall product.^{23,30} For example, Australia's Health Star Rating assigns 0.5 to 5 stars to a food product, with higher star ratings corresponding with healthier options,³¹ whereas the UK has adopted an interpretative, nutrient-specific Traffic Lights system

indicating amounts of total fat, saturated fats, total sugars, and sodium in a product using color-coding (high=red, medium=yellow, low=green).^{32,33} FOP labelling policies may be voluntarily implemented or mandatory in a given jurisdiction. The Mexican Guideline Daily Amount system is mandatory and industry-based, unlike the Health Star Rating and Traffic Light systems, which are voluntary and government-led. Voluntary policies provide food manufacturers with an option to opt out of implementing FOP labels. For example, the Health Star Rating appears on less than one-third of packaged food products,³⁴ whereas in countries such as Chile and Mexico, FOP labels are mandatory and must be displayed on all packaged products.

Consumer awareness and use are key indicators of the visibility and effectiveness of labelling policies and related nutrition education initiatives. Awareness is indicative of consumers' attention and exposure to labelling policy, thus precedes label use.³⁵ Label understanding is critical to – but does not guarantee – label use.³⁵ Label awareness, understanding, and use are influenced by a range of factors, which have largely been explored via experimental or 'pre-implementation' studies.^{23,25,36-39} A growing number of pre-implementation studies suggest FOP labels are easier to understand than NFts, particularly among consumers with lower education and income.^{21,40-47} On the other hand, greater use of NFts has been observed among women and those with higher income and education.^{41,42,48-50} Moreover, consumers with specific motivation (i.e., diet-or weight-related goals), dietary behaviors (i.e., vegetarianism), and with prior nutrition knowledge have been associated with higher NFt label awareness and use.^{30,35,50-56} Given the relative dearth of post-implementation research and recency of FOP labelling policies, it is unclear whether use of FOP labels is associated with similar consumer characteristics as NFts.

There is also little post-implementation data that compares use and awareness of FOP labels across different countries, or NFt to FOP label use within countries with both label types. These evidence gaps limit our ability to evaluate the uptake and effectiveness of different labelling policies across subgroups (i.e., among consumers with high vs. lower health literacy levels) and countries, which may inform policy adoption or dissemination strategies in countries considering FOP labelling systems. This study thus aimed to examine differences in nutrition label awareness and use across five countries (Australia, Canada, Mexico, the UK, and the US), three of which have FOP labelling policies in place (Australia, Mexico and the UK). In particular, this study

explored between-country differences in NFt use and awareness; correlates of NFt and FOP label use and awareness; and NFt vs. FOP label use and awareness in countries with both.

3.4.3 Methods

Study design and participants

This study used cross-sectional data from the 2018 wave of the International Food Policy Study.⁵⁷ Respondents aged 18 years and over and were recruited in Australia, Canada, Mexico, the UK, and the US through Nielsen Consumer Insights Global Panel and their partners' panels, and completed web-based surveys in November-December 2018. The Nielsen panels use probability and non-probability recruitment methods in each country. Email invitations were sent to a random sample of panelists after targeting for age and sex in each country. Quotas were applied to facilitate recruitment of a diverse sample that approximated known proportions in each country for males and females in four age groups: 18-29, 30-44, 45-64, and 65 years and over. Respondents were queried about a range of topics related to nutrition and the food environment, including food purchasing, dietary behaviours, nutrition knowledge, and perceptions of national-level food policies. Surveys were conducted in English in Australia and the UK; Spanish in Mexico; English or French in Canada; and English or Spanish in the US. The median time to complete the survey across all countries was 40 minutes.

All respondents provided consent prior to completing the survey and received remuneration in accordance with their panel's usual incentive structure (e.g., points-based or monetary rewards or chances to win prizes). The study was reviewed by and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 30829). More details can be found elsewhere.⁵⁷

Of the 22,824 respondents who completed the 2018 IFPS survey, a subsample of 21,586 respondents from Australia (n = 3901), Canada (n = 4107), Mexico (n = 4012), the UK (n = 5121), and the US (n = 4445) were included in the current study. Those with missing data for ethnicity (n=296), income adequacy (n=182), education (n=69), food shopping role (n=29), dietary efforts (n=122), health literacy status (n=29); self-reported NFt awareness (n=157) and use (n=184); self-reported FOP label awareness (n=201) and use (n=201); and Food Processing Knowledge (FoodProK) (n=17) were excluded from analyses. Respondents with missing data were not



different with respect to label awareness and use compared with the rest of the sample (data not shown).

Measures

Self-reported awareness and use of food labels

Label awareness was measured by showing respondents country-specific NFts (Table 1) and asking, “Have you seen this type of food label on packages or in stores?” (response options were never/rarely/sometimes/often/all the time). Label use was measured by asking, “How often do you use this type of food label when deciding to buy a food product?” (never/rarely/sometimes/often/all the time). These measures were adapted from the 2014 Food and Drug Agency Health and Diet Survey.⁵⁸ After answering questions about the NFts, respondents from Australia, Mexico, and the UK were shown images of the FOP labels in place in their countries, including voluntary Health Star Ratings, mandatory Guideline Daily Amounts, and voluntary multiple Traffic Lights, respectively (**Table 1**), and asked to respond to the same measures of label awareness and use. All labelling variables were analyzed as continuous variables (1-5 scale). Potential correlates of label awareness and use were identified from the literature and included nutrition knowledge, consumer dietary behaviours, BMI, and sociodemographic characteristics.

Table 1: Food labels by country in the 2018 International Food Policy Study survey

	Australia	Canada	Mexico	United Kingdom	United States																																																																																																																					
NFt	<p>Nutrition Information</p> <p>SERVINGS PER PACKAGE: 11 SERVING SIZE: 23.2 g (4 BISCUITS)</p> <table border="1"> <thead> <tr> <th>AVG QUANTITY PER SERVING</th> <th>% DAILY INTAKE * (PER SERVING)</th> <th>AVG QUANTITY PER 100 g</th> </tr> </thead> <tbody> <tr> <td>ENERGY</td> <td>397 kJ</td> <td>5%</td> <td>1,710 kJ</td> </tr> <tr> <td>PROTEIN</td> <td>2.8 g</td> <td>6%</td> <td>12.2 g</td> </tr> <tr> <td>FAT, TOTAL</td> <td>2.2 g</td> <td>3%</td> <td>9.4 g</td> </tr> <tr> <td>-SATURATED</td> <td>0.3 g</td> <td>1%</td> <td>1.1 g</td> </tr> <tr> <td>CARBOHYDRATE</td> <td>14.5 g</td> <td>5%</td> <td>62.3 g</td> </tr> <tr> <td>-SUGARS</td> <td>0.4 g</td> <td>1%</td> <td>1.8 g</td> </tr> <tr> <td>SODIUM</td> <td>105 mg</td> <td>5%</td> <td>452 mg</td> </tr> </tbody> </table> <p>*Percentage daily intakes are based on an average adult diet of 8700 kJ</p>	AVG QUANTITY PER SERVING	% DAILY INTAKE * (PER SERVING)	AVG QUANTITY PER 100 g	ENERGY	397 kJ	5%	1,710 kJ	PROTEIN	2.8 g	6%	12.2 g	FAT, TOTAL	2.2 g	3%	9.4 g	-SATURATED	0.3 g	1%	1.1 g	CARBOHYDRATE	14.5 g	5%	62.3 g	-SUGARS	0.4 g	1%	1.8 g	SODIUM	105 mg	5%	452 mg	<p>Nutrition Facts Per 4 cookies (23 g)</p> <table border="1"> <thead> <tr> <th>Amount</th> <th>% Daily Value</th> </tr> </thead> <tbody> <tr> <td>Calories 95</td> <td></td> </tr> <tr> <td>Fat 2 g</td> <td>3 %</td> </tr> <tr> <td>Saturated 0.3 g + Trans 0 g</td> <td>3 %</td> </tr> <tr> <td>Cholesterol 0 mg</td> <td></td> </tr> <tr> <td>Sodium 110 mg</td> <td>5 %</td> </tr> <tr> <td>Carbohydrate 15 g</td> <td>3 %</td> </tr> <tr> <td>Fibre 3 g</td> <td>8 %</td> </tr> <tr> <td>Sugars 1 g</td> <td></td> </tr> <tr> <td>Protein 3 g</td> <td></td> </tr> <tr> <td>Vitamin A</td> <td>2 %</td> </tr> <tr> <td>Vitamin C</td> <td>10 %</td> </tr> <tr> <td>Calcium</td> <td>4 %</td> </tr> <tr> <td>Iron</td> <td>4 %</td> </tr> </tbody> </table>	Amount	% Daily Value	Calories 95		Fat 2 g	3 %	Saturated 0.3 g + Trans 0 g	3 %	Cholesterol 0 mg		Sodium 110 mg	5 %	Carbohydrate 15 g	3 %	Fibre 3 g	8 %	Sugars 1 g		Protein 3 g		Vitamin A	2 %	Vitamin C	10 %	Calcium	4 %	Iron	4 %	<p>Información Nutricional Tamaño de la Porción 4 galletas (23 g) Porciones por paquete 11</p> <p>Contenido energético 95 Cal (390 kJ)</p> <p>Proteínas 2 g</p> <p>Grasas (lípidos) 4.5 g de la cual Grasa saturada 1 g</p> <p>Carbohidratos 15 g de la cual Azúcares 1 g</p> <p>Fibra Dietética 3 g</p> <p>Sodio 110 mg</p>	<p>Nutrition</p> <table border="1"> <thead> <tr> <th>Typical Values</th> <th>Per 100 g</th> <th>Per 4 cookies</th> </tr> </thead> <tbody> <tr> <td>Energy</td> <td>1,710 kJ</td> <td>397 kJ</td> </tr> <tr> <td></td> <td>410 kcal</td> <td>95 kcal</td> </tr> <tr> <td>Fat</td> <td>9.4 g</td> <td>2.2 g</td> </tr> <tr> <td>of which saturates</td> <td>1.1 g</td> <td>0.3 g</td> </tr> <tr> <td>Carbohydrate</td> <td>62.3 g</td> <td>14.5 g</td> </tr> <tr> <td>of which sugars</td> <td>14.5 g</td> <td>0.4 g</td> </tr> <tr> <td>Fibre</td> <td>12.0 g</td> <td>2.8 g</td> </tr> <tr> <td>Protein</td> <td>12.2 g</td> <td>2.8 g</td> </tr> <tr> <td>Salt</td> <td>1.3 g</td> <td>0.3g</td> </tr> </tbody> </table> <p>Reference intake of an average adult (8400 kJ/2000 kcal)</p>	Typical Values	Per 100 g	Per 4 cookies	Energy	1,710 kJ	397 kJ		410 kcal	95 kcal	Fat	9.4 g	2.2 g	of which saturates	1.1 g	0.3 g	Carbohydrate	62.3 g	14.5 g	of which sugars	14.5 g	0.4 g	Fibre	12.0 g	2.8 g	Protein	12.2 g	2.8 g	Salt	1.3 g	0.3g	<p>Nutrition Facts Serving Size 4 cookies (23 g) Servings per container 11</p> <table border="1"> <thead> <tr> <th>Amount Per Serving</th> <th>% Daily Value*</th> </tr> </thead> <tbody> <tr> <td>Calories 95</td> <td>Calories from Fat 10</td> </tr> <tr> <td></td> <td>% Daily Value*</td> </tr> <tr> <td>Total Fat 2 g</td> <td>3 %</td> </tr> <tr> <td>Saturated 0.3</td> <td></td> </tr> <tr> <td>Trans 0 g</td> <td></td> </tr> <tr> <td>Cholesterol 0 mg</td> <td></td> </tr> <tr> <td>Sodium 110 mg</td> <td>5 %</td> </tr> <tr> <td>Total Carbohydrate 15 g</td> <td>3 %</td> </tr> <tr> <td>Dietary Fibre 3 g</td> <td>8 %</td> </tr> <tr> <td>Sugars 1 g</td> <td></td> </tr> <tr> <td>Protein 3 g</td> <td></td> </tr> <tr> <td>Vitamin A 2 %</td> <td>Vitamin C 10 %</td> </tr> <tr> <td>Calcium 4 %</td> <td>Iron 4 %</td> </tr> </tbody> </table> <p>* Percentage Daily Values are based on a 2,000 calorie diet.</p>	Amount Per Serving	% Daily Value*	Calories 95	Calories from Fat 10		% Daily Value*	Total Fat 2 g	3 %	Saturated 0.3		Trans 0 g		Cholesterol 0 mg		Sodium 110 mg	5 %	Total Carbohydrate 15 g	3 %	Dietary Fibre 3 g	8 %	Sugars 1 g		Protein 3 g		Vitamin A 2 %	Vitamin C 10 %	Calcium 4 %	Iron 4 %
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Dietary Fibre 3 g	8 %																																																																																																																									
Sugars 1 g																																																																																																																										
Protein 3 g																																																																																																																										
Vitamin A 2 %	Vitamin C 10 %																																																																																																																									
Calcium 4 %	Iron 4 %																																																																																																																									
FOP label	 <ul style="list-style-type: none"> Voluntary Health Star Ratings introduced in 2014 	None	<ul style="list-style-type: none"> Mandatory Guideline Daily Amounts introduced in 2016 	 <ul style="list-style-type: none"> Voluntary Traffic Lights introduced in 2013 	None																																																																																																																					

NFt – Nutrition Facts table, FOP – Front-of-package

Functional Nutrition Knowledge

Prior nutrition knowledge may influence consumers' ability and motivation to use nutrition labels.^{35,54,59} The survey assessed consumer nutrition knowledge using the FoodProK score, a functional test based on level of processing.⁶⁰ Respondents viewed and rated images of three food products within four categories: fruits (apple, apple juice, apple sauce), meat (chicken breast, deli chicken slices, chicken nuggets), dairy (1 per cent milk, cheese block, processed cheese slices), and grains (oats, cereal, cereal bar). Products in each category were selected based on availability in multiple international contexts, and to represent varied levels of processing according to the NOVA system.³ The 12 product images and corresponding NFts and ingredients lists were displayed one at a time, in random order. For each product, respondents were asked, "Overall, how healthy is this food product?" and answered using a scale of 0 to 10, with 0 representing 'not healthy at all' to 10 indicating 'extremely healthy.' Respondents' FoodProK score (ranging from 0-8) was calculated based on whether they correctly ordered foods according to the NOVA classification system for level of processing, with less processed foods representing higher healthiness.^{60,61}

Health Literacy Status

Respondents completed an adapted version of the Newest Vital Sign in which an ice cream container Nft was shown and respondents answered six questions that assessed their ability to make mathematical calculations (numeracy), read and apply label information (prose literacy), and understand the label information (document literacy).^{62,63} The Newest Vital Sign thus serves not only as a proxy measure of health and nutrition literacy,^{63,64} but also as a functional measure of consumer Nft understanding. The Nft images were adapted to include Nft design and layout specific to each country.⁵⁷ A score between 0 and 6 was calculated based on the number of correct answers, with higher scores corresponding with greater Nft understanding.

Consumer dietary behaviours

Diet modification efforts, another possible predictor of label awareness and use,^{54,55} were measured by asking, "Have you made an effort to consume more or less of the following in the past year?" Respondents answered, 'consume less,' 'consume more,' or 'no effort made,' to a list of nutrients and food categories. This study focused on efforts in five categories that have received

increasing attention in policies such as dietary guidelines within the five countries: ‘trans-fats,’ ‘sugar/added sugars,’ ‘salt/sodium,’ ‘calories,’ and ‘processed foods.’⁶⁵⁻⁶⁹ A value of -1 was assigned to ‘consume less,’ +1 to ‘consume more,’ and 0 for ‘no effort made’ for each of the five categories. Five points were added to the sum of the five categories to create a scale ranging from 0 to 10, with 0 representing ‘consume less’ responses to all categories, 10 representing ‘consume more’ responses to all categories, and the range between reflecting all other response combinations.

Consumers with specific dietary practices, as well as those with a primary food shopping role in their households, are hypothesized to have greater interest in and exposure to labels.^{54,55,70,71} Respondents indicated whether they followed any dietary practices (vegetarian/vegan/pescatarian/a religious practice for eating). Responses were recoded to indicate no dietary restrictions or one or more dietary restriction.⁷² Food shopping role was captured by asking, “Do you do most of the food shopping in your household?” (Yes/No/Share equally with others).⁷³

Sociodemographic variables and body mass index

To capture differences in nutrition label awareness and use based on sociodemographic characteristics, age group (18-29, 30-44, 45-59, and 60+ years), sex at birth (female or male), country (Australia, Canada, Mexico, the UK, the US), and derived variables for education and ethnicity were included in analyses. Less than 1% (n =113) of respondents reported a gender different than their biological sex; hence, sex at birth was used as a binary covariate. Education level was categorized in accordance with country-specific criteria, with respondents classified as having ‘low’ (high school completion or lower), ‘medium’ (some post-secondary school qualifications, including some university), or ‘high’ (university degree or higher) levels of education.⁷⁴⁻⁷⁸ Ethnicity was treated as a binary variable to enable between-country comparisons, with respondents categorized as ‘majority’ in Mexico if they identified themselves as ‘Indigenous,’ and ‘majority’ in Australia, Canada, the UK and the US if they identified themselves as ‘white,’ predominantly English-speaking, or non-Indigenous based on country-specific ethnicity questions.^{76,78-80} Income adequacy was assessed by asking, “Thinking about your total monthly income, how difficult or easy is it for you to make ends meet?” (Very difficult/Difficult/Neither easy nor difficult/Easy/Very easy).⁸¹

Weight status may play a role in consumers' use or interest in nutrition labels, particularly among those with weight-related goals.^{55,56,82} Categorization of BMI followed World Health Organization criteria,⁸³ with self-reported height and weight used to classify respondents based on BMI <18.5 kg/m², 18.5 to 24.9 kg/m², 25.0 to 29.9 kg/m², and ≥30 kg/m². Given the large number of cases with missing height and weight data – including those who selected 'don't know' or 'refuse to answer' – a separate category for 'missing' BMI was created and retained as a response category for analyses.

Statistical analysis

Descriptive statistics were used to summarize the sample profile and labelling outcomes by country. Three multiple linear regression models were fitted to examine NFt/FOP use and NFt awareness across the five countries. All models were adjusted for sociodemographic characteristics (age, sex, country, income adequacy, education level, ethnicity), consumer dietary behaviours (dietary practices, modification efforts, food shopping role), and BMI. Due to the moderate correlation between the FoodProK and Newest Vital Sign ($r_s = 0.37$, $p < .0001$), FoodProK was added to the main model in a subsequent step to assess the influence of nutrition knowledge on the labelling outcomes.

Multiple comparisons were conducted to assess all pairwise contrasts for categorical variables. The Benjamini-Hochberg procedure was applied to decrease the false detection rate following multiple exploratory tests.⁸⁴ All statistically significant pairwise contrasts were reported after applying the Benjamini-Hochberg procedure, assuming a false discovery rate of 10%. The models tested two-way interactions between country and the covariates age, sex, ethnicity, education, income adequacy, BMI, health literacy status, dietary practices, dietary efforts, and food shopping role, as research has shown differences in label awareness and use based on these characteristics.^{35,41,50,52}

Generalized linear mixed models were run separately for Australia, the UK, and Mexico to test awareness of NFt vs. FOP labels, and use of NFt vs. FOP labels. A repeated-measures analysis was used to account for the correlated data within individuals for these measures. Each model included two-way interactions for the individual-level variables above to assess whether awareness/use differed for NFt vs. FOP labels among these subgroups. Finally, Spearman's rank

correlations tested the correlation between the four self-reported labelling outcomes (NfT awareness and use, FOP label awareness and use).

Statistical analyses were conducted using SAS Studio (SAS Institute, Cary, NC). Parameter estimates are reported with 95% confidence intervals (CIs). Data were weighted with post-stratification sample weights constructed using population estimates from respective country-based censuses based on age group, gender, region, ethnicity (except in Canada), and education (except in Mexico).⁵⁷ All reported estimates are weighted.

3.4.4 Results

Sample characteristics are presented in **Table 2**.

Table 2: Sample Characteristics (n = 21, 586), International Food Policy Study, 2018

Characteristic	Australia (n=3901) % (n)	Canada (n=4107) % (n)	Mexico (n=4012) % (n)	United Kingdom (n=5121) % (n)	United States (n=4445) % (n)
Age Group					
18-29 years	21.3 (831)	18.9 (777)	29.8 (1194)	19.0 (974)	20.6 (914)
30-44 years	26.2 (1022)	24.7 (1014)	32.3 (1297)	24.8 (1270)	25.1 (1115)
45-59 years	24.7 (963)	25.8 (1059)	28.7 (1151)	25.9 (1327)	25.7 (1141)
60+ years	27.8 (1085)	30.6 (1257)	9.2 (370)	30.3 (1550)	28.6 (1275)
Sex					
Male	48.7 (1898)	49.4 (2028)	47.6 (1911)	47.8 (2448)	48.2 (2141)
Female	51.3 (2003)	50.6 (2079)	52.4 (2101)	52.2 (2673)	51.8 (2304)
Ethnicity					
Majority	76.1 (2969)	79.9 (3280)	78.7 (3156)	89.1 (4563)	76.1 (3382)
Minority	23.9 (932)	20.1 (827)	21.3 (856)	10.9 (558)	23.9 (1063)
Education Level					
Low	41.6 (1622)	41.0 (1683)	19.5 (782)	47.6 (2438)	58.2 (2585)
Medium	32.6 (1272)	34.1 (1400)	13.2 (531)	23.5 (1203)	10.0 (443)
High	25.8 (1007)	24.9 (1024)	67.3 (2699)	28.9 (1480)	31.8 (1417)
Income Adequacy					
Very difficult to make ends meet	8.5 (331)	8.4 (345)	12.0 (482)	6.8 (349)	9.4 (416)
Difficult to make ends meet	19.2 (750)	19.6 (804)	31.7 (1273)	18.5 (949)	20.3 (902)
Neither easy nor difficult to make ends meet	37.8 (1473)	36.8 (1511)	38.9 (1559)	36.0 (1844)	33.7 (1497)
Easy to make ends meet	23.6 (921)	22.5 (927)	13.9 (557)	24.7 (1265)	21.8 (970)

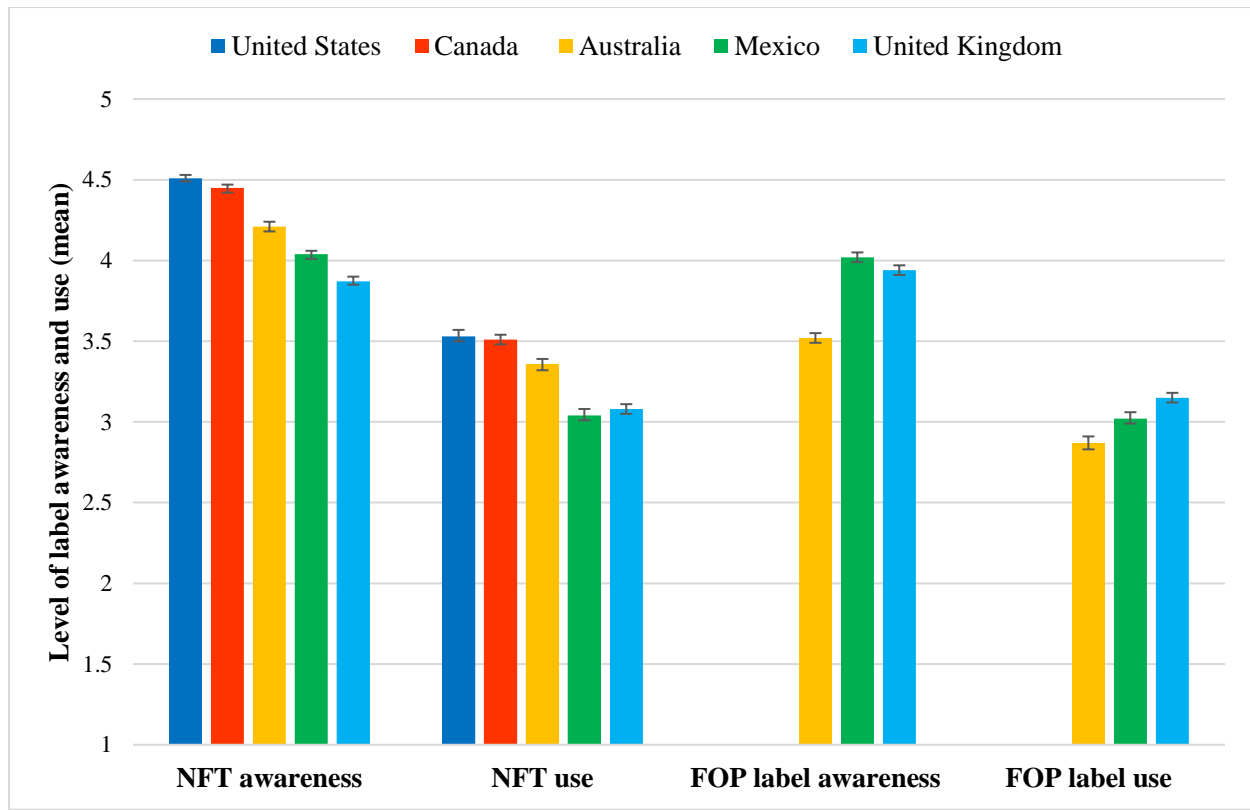
Very easy to make ends meet	10.9 (426)	12.7 (520)	3.5 (141)	14.0 (714)	14.8 (660)
Body Mass Index					
<18.5	3.1 (122)	3.2 (133)	2.1 (85)	2.9 (150)	3.4 (153)
18.5-24.9	36.3 (1416)	33.5 (1376)	39.6 (1588)	34.8 (1780)	31.2 (1385)
25.0-29.9	26.6 (1039)	28.8 (1183)	30.1 (1208)	27.0 (1384)	27.6 (1226)
≥30.0	20.9 (815)	24.7 (1015)	15.5 (620)	17.0 (870)	27.4 (1218)
Missing	13.1 (509)	9.8 (400)	12.7 (511)	18.3 (937)	10.4 (463)
Food Shopping Role					
Primary shopper	71.6 (2792)	72.0 (2959)	74.9 (3005)	74.6 (3820)	73.2 (3255)
Not primary shopper	6.9 (268)	5.9 (242)	5.0 (201)	4.5 (230)	6.6 (293)
Shared equally with others	21.5 (841)	22.1 (906)	20.1 (806)	20.9 (1071)	20.2 (897)
Dietary Practices					
No specific dietary practices	87.1 (3396)	90.4 (3714)	88.2 (3539)	86.8 (4446)	88.6 (3936)
One or more dietary practices (i.e., vegetarian, vegan, pescatarian, religious practices)	12.9 (505)	9.6 (393)	11.8 (473)	13.2 (675)	11.4 (509)
Dietary Efforts Score*					
	2.7 (2.2)	2.6 (2.1)	2.5 (2.3)	3.0 (2.1)	2.9 (2.3)
NVS score*					
	3.23 (2.12)	3.69 (1.97)	2.84 (1.99)	3.19 (2.22)	3.50 (2.12)
FoodProK Score*					
	5.0 (1.7)	5.1 (1.5)	4.8 (1.5)	4.9 (1.8)	4.6 (1.8)

Notes: NVS – Newest Vital Sign, FoodProK – Food Processing Knowledge. *Mean and standard deviation reported for dietary efforts, NVS, and FoodProK score.

Patterns and correlates of Nft use and awareness

Figure 1 shows patterns of mean Nft use and awareness across countries (categorical responses can be seen in **Supplementary Tables 1 and 2**). Respondents from the US, Canada, and Australia reported significantly higher Nft use than respondents from the UK, and respondents from Mexico reported the lowest use among all countries (see **Table 3**). Similarly, Nft awareness was highest among respondents from the US, followed by Canada, Australia, the UK, and Mexico. A Spearman rank correlation indicated a moderate correlation between self-reported Nft use and awareness across all countries ($r_s = 0.41$, $p < .0001$).

Figure 1: Nutrition Facts table and front-of-package label awareness and use by country



Notes: NFT – Nutrition Facts Table, FOP – front-of-package. Mean levels of awareness and use are shown with 95% confidence intervals. A mean of 1 indicates no awareness/use, and 5 indicates the highest level of self-reported awareness/use.

Supplementary Table 1: Nutrition label use across countries

Response	NFt use, % (n)						FOP label use, % (n)			
	All countries	Australia	Canada	Mexico	UK	US	All countries	Australia	Mexico	UK
1 – Never	8.7% (1877)	7.5% (293)	6.9% (285)	11.4% (457)	11.2% (575)	6.0% (267)	10.9% (1342)	12.0% (410)	11.2% (441)	9.9% (491)
2 – Rarely	16.3% (3522)	15.3% (597)	12.4% (511)	20.8% (833)	19.5% (1000)	13.1% (581)	19.9% (2466)	20.8% (713)	21.5% (848)	18.1% (904)
3 – Sometimes	31.6% (6817)	31.0% (1209)	29.2% (1201)	30.8% (1237)	35.9% (1836)	30.0% (1335)	35.7% (4412)	40.2% (1378)	31.8% (1256)	35.7% (1778)
4 – Often	27.1% (5852)	27.8% (1085)	31.1% (1277)	26.5% (1062)	22.6% (1158)	28.6% (1270)	23.6% (2912)	20.0% (687)	24.9% (981)	25.0% (1244)
5- All the time	16.3% (3517)	18.4% (717)	20.3% (834)	10.6% (423)	10.7% (552)	22.3% (992)	9.9% (1228)	7.1% (242)	10.7% (421)	11.3% (565)

Note: NFt – Nutrition Facts table. FOP – front-of-package. UK – United Kingdom. US – United States. Label use was measured by asking, “How often do you use this type of food label when deciding to buy a food product” Sample size for NFt use is 21,586 and 12,360 for FOP label use.

Supplementary Table 2: Nutrition label awareness across countries

Response	NFt awareness, % (n)						FOP label awareness, % (n)			
	All countries	Australia	Canada	Mexico	UK	US	All countries	Australia	Mexico	UK
1 – Never	0.0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0.0% (2)	0.0% (0)	0% (0)	0.0% (2)
2 – Rarely	5.0% (1085)	4.5% (176)	3.5% (143)	5.5% (222)	7.8% (399)	3.3% (146)	8.0% (985)	12% (412)	7.0% (277)	6.0% (297)
3 – Sometimes	17.2% (3716)	17.0% (665)	9.5% (389)	19.5% (783)	28.0% (1434)	10.0% (446)	27.8% (3441)	37.8% (1297)	21.7% (855)	25.9% (1288)
4 – Often	31.4% (6771)	32.5% (1268)	25.4% (1044)	42.5% (1707)	35.8% (1834)	20.7% (919)	36.6% (4528)	33.9% (1163)	38.1% (1506)	37.3% (1859)
5- All the time	46.4% (10014)	45.9% (1792)	61.7% (2533)	32.4% (1300)	28.4% (1455)	66.0% (2934)	27.5% (3403)	16.3% (558)	33.2% (1310)	30.8% (1536)

Note: NFt – Nutrition Facts table. FOP – front-of-package. UK – United Kingdom. US – United States. Label awareness was measured by asking, “How often have you seen this type of food label in packages or in stores?” Sample size for NFt awareness is 21,586 and 12,360 for FOP label awareness.

As shown in **Table 3**, respondents who were primary food shoppers or shared this responsibility equally with others reported higher NFt use than those who were not primary food shoppers in their households. Respondents engaging in vegetarian or other dietary practices, as well as those making efforts to reduce calories, sodium, sugars, trans fats, or processed food intake reported higher use of NFts. Respondents with ‘adequate health literacy’ reported higher NFt use compared to those with a ‘possibility of limited health literacy’ and a ‘high likelihood of limited health literacy.’ NFt use was also higher among respondents with higher nutrition knowledge ($\beta = 0.07$, CI: 0.05-0.07, $p < .0001$).

With respect to sociodemographic characteristics, older respondents reported lower NFt use compared to younger respondents. Females reported higher NFt use than males, and respondents from ‘majority’ ethnic groups in their respective countries reported lower NFt use than ‘minority’ ethnic groups. Respondents categorized as having ‘high’ education levels reported higher NFt use than those with ‘medium’ or ‘low’ education, and NFt use was higher with higher income adequacy. Finally, NFt use was lower among respondents with BMIs over 30 compared with those with BMIs between 18.5-24.9, 25-29.9, and the ‘missing’ category.

Table 3: Sociodemographic and behavioural correlates of Nutrition Facts table and front-of-package label use, International Food Policy Study, 2018

	NFt use (n=21,586)			FOP label use (n=12,360)		
	β	95% CI	p-value	β	95% CI	p-value
Country						
Australia vs. Canada	-0.10	-0.15, -0.04	*0.0080	-	-	-
Australia vs. Mexico	0.36	0.30, 0.42	*<.0001	-0.02	-0.08, -0.04	0.5339
Australia vs. United Kingdom	0.29	0.24, 0.34	*<.0001	-0.24	-0.29, -0.19	*<.0001
Australia vs. United States	-0.18	-0.24, -0.12	*<.0001	-	-	-
Canada vs. Mexico	0.46	0.40, 0.52	*<.0001	-	-	-
Canada vs. United Kingdom	0.39	0.33, 0.44	*<.0001	-	-	-
Canada vs. United States	-0.08	-0.14, -0.02	*0.0053	-	-	-
Mexico vs. United Kingdom	-0.07	-0.13, -0.01	*0.0178	-0.22	-0.28, -0.16	*<.0001
Mexico vs. United States	-0.54	-0.60, -0.48	*0.0001	-	-	-
United States vs. United Kingdom	0.47	0.41, 0.52	*<.0001	-	-	-
Age Group						
30-44 vs. 18-29 years	-0.02	-0.07, 0.03	0.3980	-0.01	-0.07, 0.05	0.7869
30-44 vs. 45-59 years	0.14	0.09, 0.19	*<.0001	0.13	0.06, 0.19	*0.0001
30-44 vs 60+ years	0.12	0.07, 0.17	*<.0001	0.20	0.14, 0.27	*<.0001
45-59 years vs. 18-29 years	-0.16	-0.22, -0.11	*<.0001	-0.13	-0.02, -0.06	*0.0002
45-59 years vs. 60+ years	-0.02	-0.07, 0.03	0.4086	0.08	0.01, 0.14	*0.0229

60+ years vs. 18-29 years	-0.14	-0.20, -0.08	*<.0001	-0.21	-0.28, -0.14	*<.0001
Sex at Birth						
Female vs. Male	0.07	0.03, 0.11	*0.0002	0.00	-0.04, 0.05	0.8391
Ethnicity						
Majority vs. Minority	-0.07	-0.12, -0.02	*0.0088	-0.05	-0.12, 0.02	0.1310
Education Level						
Medium vs. Low	0.09	0.04, 0.13	*0.0002	0.08	0.02, 0.14	*0.0095
High vs. Low	0.15	0.11, 0.20	*<.0001	0.21	0.15, 0.37	*<.0001
High vs. Medium	0.07	0.02, 0.11	*0.0021	0.13	0.07, 0.18	*<.0001
Income adequacy						
	0.08	0.06, 0.10	*<.0001	0.06	0.03, 0.08	*<.0001
Body Mass Index						
<18.5 vs. 18.5-24.9	-0.02	-0.13, 0.10	0.7483	-0.16	-0.31, -0.02	*0.0270
25-29.9 vs. <18.5	-0.03	-0.14, 0.09	0.6566	0.09	-0.05, 0.24	0.2124
25-29.9 vs. 18.5-24.9	-0.04	-0.09, 0.00	0.0421	-0.07	-0.12, -0.01	*0.0138
≥30.0 vs. <18.5	-0.08	-0.20, 0.03	0.1680	0.01	-0.14, 0.17	0.8490
≥30.0 vs. 18.5-24.9	-0.10	-0.15, -0.05	*<.0001	-0.15	-0.22, -0.08	*<.0001
≥30 vs 25-29.9	-0.06	-0.11, -0.01	*0.0243	-0.08	-0.15, -0.01	*0.0232
Missing vs. ≥30	0.08	0.01, 0.15	*0.0184	0.11	0.02, 0.20	*0.0119
Missing vs. 18.5-24.9	-0.02	-0.08, 0.04	0.5140	-0.04	-0.11, 0.04	0.3388
Missing vs. <18.5	0.00	-0.12, 0.12	0.9769	0.13	-0.03, 0.28	0.1082
Food Shopping Role						
Share equally with others vs. Not primary shopper	0.17	0.08, 0.27	*0.0003	0.13	0.01, 0.25	*0.0271
Primary shopper vs. Not primary shopper	0.32	0.23, 0.41	*<.0001	0.29	0.18, 0.40	*<.0001
Primary shopper vs. Share equally with others	0.15	0.10, 0.19	*<.0001	0.16	0.10, 0.22	*<.0001
Dietary Practices						
One or more dietary practices (i.e., vegetarian, vegan, pescatarian, religious practices) vs. No specific dietary practices	0.39	0.33, 0.45	*<.0001	0.30	0.23, 0.37	*<.0001
Dietary Efforts Score						
	-0.16	-0.17, -0.15	*<.0001	-0.13	-0.14, -0.12	*<.0001
Health Literacy Status						
Adequate literacy (score 4-6) vs. High likelihood of limited literacy (score 0-1)	0.07	0.03, 0.12	*0.0027	-0.11	-0.17, -0.06	*<.0001
Adequate literacy (score 4-6) vs. Possibility of limited literacy (score 2-3)	0.09	0.05, 0.14	*<.0001	-0.07	-0.14, -0.02	*0.0092

Possibility of limited literacy (score 2-3) vs. High likelihood of limited literacy (score 0-1)	-0.02	-0.07, 0.03	0.4714	-0.04	-0.10, 0.03	0.2675
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Notes: β - parameter estimate, CI – Confidence Interval, NFt – Nutrition Facts table, FOP – Front-of-package. *Variables are significant ($p < 0.05$) after post hoc adjustment using Benjamini-Hochberg procedure. All reported estimates are weighted.

For NFt use, age, sex, ethnicity, education level, income adequacy, health literacy, and dietary effort interactions with country were significant (**Supplementary Table 3**). Women in Mexico reported lower NFt use than UK women; however, Mexican respondents with ‘high’ education and income adequacy reported higher NFt use compared with respondents in the UK with similar education and income adequacy. Australian respondents with ‘adequate health literacy’ reported higher NFt use than ‘adequate health literacy’ respondents in the UK.

A similar pattern of correlates was observed for NFt awareness, with the exception of education for which respondents with ‘high’ education reported lower NFt awareness than those with ‘low’ education levels (**Supplementary Table 4**). When functional nutrition knowledge was added to this model, NFt awareness was higher among respondents with higher nutrition knowledge scores ($\beta = 0.06$, CI: 0.05-0.07, $p < .0001$). Two-way interaction terms for NFt awareness are reported in Supplementary Table 3. Canadian respondents with ‘high’ education reported lower NFt awareness than those with similar education in the UK. Mexican respondents with ‘adequate literacy’ and a ‘possibility of limited literacy’ reported lower NFt awareness than the corresponding health literacy groups in the UK.

Supplementary Table 3: Two-way interactions for five-country regression models on NFt awareness and use (n=21,586), International Food Policy Study, 2018

	NFt awareness β (CI), p-value	NFt use β (CI), p-value
Country x Age Group, p=<.0001 (awareness and use)		
Australia*30-44 years	-0.11 (-0.24, 0.02), p = 0.1068	-0.15 (-0.32, 0.01), p = 0.0705
Canada*30-44 years	-0.14 (-0.27, -0.01), p = 0.0260*	-0.16 (-0.33, 0.02), p = 0.0808
Mexico*30-44 years	-0.15 (-0.27, -0.03), p = 0.0107*	0.00 (-0.15, 0.15), p = 0.9747
UK*30-44 years	Ref	
Mexico*45-59 years	-0.06 (-0.18, 0.07), p = 0.4036	0.39 (0.23, 0.56), p <.0001*
UK*45-59 years	Ref	
Canada*60+ years	0.18 (0.05, 0.31), p = 0.0059*	0.31 (0.09, 0.53), p = 0.0050*
Australia*60+ years	0.22 (0.09, 0.35), p = 0.0010*	0.11 (-0.06, 0.29), p = 0.1893
Mexico*60+ years	0.10 (-0.07, 0.25), p = 0.2640	0.31 (0.09, 0.53), p=0.0050*
US*60+ years	0.26 (0.13, 0.37) p <.0001*	0.17 (0.00, 0.35), p = 0.0480
UK*60+ years	Ref	
Country x Sex, p=0.0298 (awareness) and 0.0330 (use)		
Mexico*Female	-0.13 (-0.21, -0.04), p = 0.0040*	-0.12 (-0.23, -0.01), p = 0.0329*
US*Female	-0.08 (-0.16, -0.00), p = 0.0611	0.07 (-0.04, 0.18), p = 0.2094
UK*Female	Ref	
Country x Education Level, p = 0.1135 (awareness) and 0.0151 (use)		
Canada*High education	-0.14 (-0.23, -0.04), p=0.0052*	0.02 (-0.11, 0.16), p = 0.7162
Mexico*High education	0.03 (-0.08, 0.13), p = 0.6231	0.24 (0.09, 0.28), p = 0.0011*
UK*High education	Ref	
Country x Income Adequacy, p= 0.0195 (awareness) and 0.0005 (use)		
Mexico*Income adequacy	0.00 (-0.04, 0.04), p = 0.9361	0.07 (0.02, 0.13), p=0.0095*
UK*Income adequacy	Ref	
Country x Ethnicity, p= 0.0205 (awareness) and 0.6785 (use)		
Canada*Majority	0.17 (0.03, 0.30), p = 0.0160*	0.00 (-0.18, 0.18), p = 0.9894
Mexico*Majority	0.15 (0.00, 0.30), p = 0.0513	-0.10 (-0.29, 0.08), p = 0.2879

US*Majority	0.13 (0.00, 0.28), p = 0.0515	0.00 (-0.17, 0.17), p = 0.9857
UK*Majority	Ref	
Country x Health Literacy Status, p=<.0001 (awareness) and 0.0027 (use)		
Australia*Adequate literacy	-0.02 (-0.13, 0.08), p = 0.6552	0.17 (0.04, 0.31), p = 0.0099*
US*Adequate literacy	0.07 (-0.04, 0.18), p = 0.2386	-0.11 (-0.25, 0.04), p = 0.1415
Mexico*Adequate literacy	-0.31 (-0.41, -0.19), p<.0001*	-0.07 (-0.21, 0.07), p = 0.3052
UK*Adequate literacy	Ref	
Mexico*Possibility of limited literacy	-0.21 (-0.33, -0.08), p = 0.0013*	-0.04 (-0.20, 0.11), p = 0.5832
UK*Possibility of limited literacy	Ref	
Country * Dietary Efforts Score, p <.0001 (awareness and use)		
Canada*Dietary efforts	0.00 (-0.02, 0.02), p = 0.8556	-0.03 (-0.06, 0.00) p = 0.0277*
Mexico*Dietary efforts	0.06 (0.04, 0.08), p<.0001*	0.06 (0.03, 0.09), p<.0001*
US*Dietary efforts	0.02 (0.00, 0.04), p=0.0221*	0.00 (-0.02, 0.03), p = 0.6408
UK*Dietary efforts	Ref	

Notes: NFt – Nutrition Facts table. β - parameter estimate. CI - Confidence Interval. US – United States. UK – United Kingdom. Ref – reference category. Regression model adjusted for sociodemographic (age, sex, country), socioeconomic (education, income adequacy), dietary behaviours (food shopping role, dietary practices, dietary efforts), body mass index, and health literacy. *Variables are significant (p<0.05). Country interactions with body mass index, food shopping role and dietary practices were not significant for NFt use or awareness. All reported estimates are weighted.

Supplementary Table 4: Sociodemographic and behavioural correlates of Nutrition Facts Table Awareness, (n=21,586), International Food Policy Study, 2018

	β	95% CI	p-value
Country			
Australia vs. Canada	-0.19	-0.24, -0.15	*<.0001
Australia vs. Mexico	0.14	0.10, 0.19	*<.0001
Australia vs. United Kingdom	0.34	0.29, 0.38	*<.0001
Australia vs. United States	-0.28	-0.32, -0.24	*<.0001
Canada vs. Mexico	0.34	0.29, 0.39	*<.0001
Canada vs. United Kingdom	0.53	0.49, 0.57	*<.0001
Canada vs. United States	-0.08	-0.12, -0.04	*<.0001
Mexico vs. United Kingdom	0.19	0.15, 0.24	*<.0001
Mexico vs. United States	-0.42	-0.47, -0.38	*<.0001
United States vs. United Kingdom	0.61	0.57, 0.66	*<.0001
Age Group			
30-44 years vs. 18-29 years	-0.08	-0.11, -0.04	*<.0001
30-44 vs. 45-59 years	0.03	-0.01, 0.07	0.0967
30-44 vs 60+ years	0.03	0.00, 0.07	0.0741

45-59 years vs. 18-29 years	-0.11	-0.15, -0.07	*<.0001
45-59 years vs. 60+ years	0.00	-0.03, 0.04	0.9434
60+ years vs. 18-29 years	-0.11	-0.15, -0.07	*<.0001
Sex at Birth			
Female vs. Male	0.12	0.09, 0.15	*<.0001
Ethnicity			
Majority vs. Minority	0.05	0.01, 0.09	*0.0086
Education Level			
Medium vs. Low	-0.03	-0.06, 0.01	0.1274
High vs. Low	-0.06	-0.09, -0.03	*0.0002
High vs. Medium	-0.03	-0.06, 0.00	0.0487
Income Adequacy			
	0.03	0.02, 0.05	*<.0001
Body Mass Index			
<18.5 vs. 18.5-24.9	0.10	0.02, 0.18	*0.0140
25-29.9 vs. <18.5	-0.15	-0.23, -0.07	*0.0003
25-29.9 vs. 18.5-24.9	-0.05	-0.08, -0.02	*0.0025
≥30.0 vs. <18.5	-0.13	-0.21, -0.04	*0.0023
≥30.0 vs. 18.5-24.9	-0.03	-0.07, 0.01	0.1220
≥30 vs 25-29.9	0.02	-0.01, 0.06	0.2439
Missing vs. ≥30	-0.07	-0.13, -0.02	*0.0068
Missing vs. 18.5-24.9	-0.10	-0.15, -0.05	*<.0001
Missing vs. <18.5	-0.20	-0.29, -0.11	*<.0001
Food Shopping Role			
Share equally with others vs. Not primary shopper	0.03	-0.03, 0.10	0.3113
Primary shopper vs. Not primary shopper	-0.01	-0.07, 0.05	0.6422
Primary shopper vs. Share equally with others	-0.05	-0.08, -0.01	*0.0045
Dietary Practices			
One or more dietary practices (i.e., vegetarian, vegan, pescatarian, religious practices) vs. No specific dietary practices	0.01	-0.03, 0.06	0.5426
Dietary Efforts Score			
	-0.06	-0.07, -0.05	*<.0001
Health Literacy Status			
Adequate literacy (score 4-6) vs. High likelihood of limited literacy (score 0-1)	0.49	0.46, 0.53	*<.0001
Adequate literacy (score 4-6) vs. Possibility of limited literacy (score 2-3)	0.21	0.18, 0.24	*<.0001
Possibility of limited literacy (score 2-3) vs. High likelihood of limited literacy (score 0-1)	0.28	0.24, 0.32	*<.0001

Notes: β - parameter estimate, CI – Confidence Intervals. NFT – Nutrition Facts Table. *Variables are significant ($p < 0.05$) after post hoc adjustment using Benjamini-Hochberg procedure. All reported estimates are weighted.

Patterns of FOP labelling behaviour and correlates of use

Respondents from Mexico reported the highest awareness of FOP labels (mean 4.0), followed by the UK (mean 3.9) and Australia (mean 3.5) (Figure 1). In addition, respondents in the UK reported the highest FOP label use (mean 3.2) and Australia the lowest (mean 2.9). FOP label use and awareness were moderately correlated ($r_s = 0.39$, $p < .0001$). Correlates of FOP label use were similar to NfT use, with a few exceptions (Table 3). Sex and ethnicity were not significantly associated with FOP label use, and respondents with ‘adequate literacy’ reported lower FOP label use compared to those with a ‘high likelihood of limited literacy.’ FoodProK score was not significantly associated with FOP label use ($\beta = 0.01$, CI: 0.00-0.02, $p = 0.1978$).

Use and awareness of NfTs versus FOP labels

In Australia, respondents reported higher use and awareness of NfTs compared to voluntary FOP Health Star Ratings. As shown in **Table 4**, respondents aged ≥ 60 years were more likely to be aware of and use NfTs than Health Star Ratings compared to 18-29-year-olds. Female respondents and those with higher income adequacy were also more likely to use NfTs than Health Star Ratings. Respondents with ‘adequate literacy’ were more likely to report higher NfT than FOP label use and awareness compared to those with a ‘high likelihood of limited literacy.’ Respondents with higher nutrition knowledge were more likely to use and be aware of NfTs than FOP labels. Specific dietary practices or efforts to consume less of specific nutrients (i.e., sugar, sodium, trans fat) were associated with higher NfT than FOP label use, and primary food shoppers were less likely to be aware of NfTs than FOP labels compared with respondents who were not primary food shoppers in their households.

In the UK, respondents reported lower NfT use and awareness compared with the voluntary FOP Traffic Light labels. Older age groups (60+, 45-59, and 30-44 years compared with 18-29 years) were more likely to be aware of or use NfTs compared to FOP Traffic Lights. Respondents who identified as belonging to the ‘majority’ ethnic group in the UK were more likely to report higher FOP label than NfT use and awareness compared with those from ‘minority’ ethnic groups. Respondents with ‘high’ education levels were significantly more likely to be aware of NfTs than FOP labels compared to respondents with ‘medium’ education levels. Similarly, respondents with ‘adequate literacy’ were more likely to report higher use and awareness of NfTs than FOP labels compared to respondents with a ‘high likelihood of limited literacy.’ Respondents engaging in

efforts to consume less sodium, sugar, trans fat, processed food or calories were more likely to use FOP labels than NFts.

In Mexico, respondents reported higher NFt use and awareness compared with Guideline Daily Amount labels. Older age groups and females were more likely to report higher NFt than FOP (Guideline Daily Amount) label awareness compared with 18-29-year-olds and males, respectively. Respondents who reported higher nutrition knowledge and those with 'adequate literacy' were more likely to report higher FOP label than NFt awareness compared to those with lower nutrition knowledge scores or a 'high likelihood of limited literacy,' respectively. Dietary efforts to consume less of specific nutrients were also associated with higher FOP label than NFt use. There were no significant differences between NFt and FOP label use among the subgroups tested in Mexico. Interactions between country and BMI were not significant for NFt awareness or use in Australia, the UK, or Mexico.

Table 4: Two-way interaction terms comparing Nft to FOP label awareness and use in Australia, the United Kingdom, and Mexico (n=12,360)

Variable	AUSTRALIA (n=3399)				UNITED KINGDOM (n=5050)				MEXICO (n=3911)			
	Label Awareness (Nft vs. FOP label)		Label Use (Nft vs. FOP label)		Label Awareness (Nft vs. FOP label)		Label Use (Nft vs. FOP label)		Label Awareness (Nft vs. FOP label)		Label Use (Nft vs. FOP label)	
	β (95% CI)	p-value	β (95% CI)	p-value	β (95% CI)	p-value	β (95% CI)	p-value	β (95% CI)	p-value	β (95% CI)	p-value
Age Group*Label Type												
30-44 years vs. 18-29 years	0.05 (-0.04, 0.15)	0.2869	0.01 (-0.11, 0.14)	0.8402	0.16 (0.09, 0.23)	*<.0001	0.13 (0.04, 0.20)	*0.0007	0.09 (0.04, 0.15)	*0.0009	0.01 (-0.04, 0.06)	0.7501
45-59 years vs. 18-29 years	0.27 (0.17, 0.38)	*<.0001	0.03 (-0.10, 0.16)	0.6289	0.12 (0.05, 0.20)	*0.0012	0.12 (0.04, 0.20)	*0.0023	0.21 (0.14, 0.28)	*<.0001	0.02 (-0.04, 0.09)	0.4376
60+ years vs. 18-29 years	0.49 (0.39, 0.59)	*<.0001	0.18 (0.06, 0.31)	*0.0037	0.14 (0.06, 0.21)	*0.0006	0.17 (0.09, 0.25)	*<.0001	0.28 (0.17, 0.39)	*<.0001	0.01 (-0.11, 0.12)	0.8963
Sex*Label Type												
Female vs. Males	0.08 (0.01, 0.15)	0.0944	0.11 (0.03, 0.19)	*0.0080	0.02 (-0.03, 0.06)	0.5146	0.04 (-0.01, 0.09)	0.1417	0.06 (0.01, 0.10)	*0.0155	0.01 (-0.03, 0.06)	0.5823
Ethnicity												
Majority vs. Minority	0.02 (-0.07, 0.12)	0.6534	0.06 (-0.06, 0.17)	0.3607	-0.10 (-0.18, -0.01)	*0.0252	-0.12 (-0.21, -0.03)	*0.0090	0.03 (-0.03, 0.10)	0.2856	-0.02 (-0.08, 0.05)	0.5901
Income Adequacy*Label Type												
	0.00 (-0.03, 0.03)	0.8251	0.05 (0.01, 0.09)	*0.0071	-0.01 (-0.03, 0.02)	0.5847	0.02 (0.00, 0.04)	0.1329	-0.02 (-0.05, 0.00)	0.0753	0.00 (-0.02, 0.02)	0.9493
Education Level												

High vs. Medium	0.01 (-0.07, 0.09)	0.7501	0.00 (-0.10, 0.10)	0.9882	0.08 (0.02, 0.13)	*0.0053	0.05 (-0.01, 0.11)	0.0827	-0.04 (-0.11, 0.03)	0.2969	0.02 (-0.05, 0.10)	0.5791
Health Literacy Status*Label Type												
Adequate literacy vs. High likelihood of limited literacy	0.23 (0.14, 0.32)	*<.0001	0.52 (0.41, 0.63)	*<.0001	0.08 (0.01, 0.14)	*0.0152	0.10 (0.04, 0.16)	*0.0023	-0.10 (-0.16, -0.04)	*0.0006	0.02 (-0.04, 0.08)	0.4644
Possibility of limited literacy vs. High likelihood of limited literacy	0.12 (0.02, 0.22)	*0.0156	0.09 (-0.03, 0.21)	0.1389	0.02 (-0.05, 0.09)	0.5776	0.04 (-0.04, 0.12)	0.2969	-0.05 (-0.11, 0.01)	0.1032	0.00 (-0.06, 0.06)	0.9478
FoodProK score*Label Type												
FoodProK score*Label Type	0.04 (0.02, 0.06)	*<.0001	0.04 (0.01, 0.07)	*0.0026	0.01 (0.00, 0.03)	0.1085	0.01 (-0.01, 0.02)	0.3324	-0.02 (-0.04, -0.01)	*0.0141	-0.01 (-0.03, 0.00)	0.2096
Dietary efforts*Label Type												
Dietary efforts*Label Type	-0.02 (-0.03, -0.01)	*0.0245	-0.06 (-0.08, -0.04)	*<.0001	0.01 (0.00, 0.02)	0.1820	0.02 (0.01, 0.04)	*0.0002	0.02 (0.01, 0.03)	*0.0008	0.00 (-0.01, 0.01)	0.6030
Dietary practices*Label Type												
Dietary practices*Label Type	0.02 (-0.08, 0.12)	0.6573	0.18 (0.06, 0.31)	*0.0040	0.04 (-0.03, 0.11)	0.2881	-0.01 (-0.08, 0.06)	0.7396	-0.02 (-0.09, 0.05)	0.6267	0.02 (-0.05, 0.09)	0.5999
Food Shopping Role*Label Type												
Primary food shopper vs. Not primary shopper	-0.25 (-0.40, -0.11)	*0.0006	0.06 (-0.11, 0.24)	0.4737	0.04 (-0.07, 0.16)	0.4700	0.12 (0.00, 0.24)	0.0472	-0.07 (-0.17, 0.04)	0.2185	0.04 (-0.07, 0.14)	0.5043

Notes: β – parameter estimate, CI – Confidence Interval, NFt – Nutrition Facts table, FOP – Front-of-package, FoodProK – Food Processing Knowledge. Model adjusted for sociodemographic (age, sex, ethnicity, education, income adequacy), consumer dietary behaviours (food shopping role, dietary practices, dietary efforts), health literacy and FoodProK score. *Variables are significant ($p < 0.05$). All reported estimates are weighted.

3.4.5 Discussion

This study examined patterns and correlates of the use and awareness of nutrition labels on the back-/side- and front-of-packages across five countries, and found differences based on sociodemographic, behavioural, and knowledge-related characteristics. These findings are relevant as an increasing number of countries adopt voluntary or mandatory FOP labelling policies.²⁴ Country-specific differences provide insights into which labels have the greatest reach and uptake among consumers. Evidence has shown greater uptake for mandatory labelling policies,²⁴ consistent with findings from this study demonstrating higher NFt use compared with voluntary FOP labelling systems (with the exception of Traffic Lights in the UK), and higher awareness of the mandatory FOP Guideline Daily Amount label in Mexico compared to voluntary FOP labelling systems. NFts have been a longstanding policy in all five countries;⁸⁵⁻⁸⁹ hence, high levels of use and awareness are not surprising. The highest levels of NFt awareness and use observed in this study were in the US, where a higher reliance on processed, packaged foods may have been a contributing factor.¹⁴

Among countries with FOP labelling systems, Guideline Daily Amount labels in Mexico had the lowest level of reported use, despite high levels of awareness. Mexico is the only country in this study with a mandatory FOP label, so greater awareness of Guideline Daily Amounts compared to NFts may have stemmed from relatively higher exposure to this label on the front-of-package.²⁴ The voluntary nature of FOP labels in Australia and the UK may account for lower levels of awareness and use compared to mandatory NFts, and may have resulted in lower FOP label exposure as Traffic Light labels and Health Star Ratings are estimated to appear on approximately 8% and 30% of food products, respectively.^{34,90} Lower awareness of voluntary labels supports consideration of mandatory FOP labelling policies, and also reiterates the importance of closely monitoring policy implementation.

Existing evidence also highlights that not all FOP labels are equal. The finding that self-reported use of the mandatory Guideline Daily Amount label was lower than voluntary FOP label use is consistent with literature documenting consumers' difficulty understanding these labels.^{25,91-96} Indeed, the Mexican government is replacing Guideline Daily Amounts with mandatory FOP 'high-in' labels similar to Chile,⁹⁷ as emerging evidence demonstrates ease of use and greater understanding of this simple, interpretative label format.^{39,93,98-101}

Label understanding is intrinsically connected to consumers' literacy and education levels. Consistent with the literature,^{41,42,48-50} respondents with higher education, literacy, and functional nutrition knowledge reported higher NfT use and awareness, likely reflecting numeracy skills and ability to understand label information.^{50,62,63,92} On the other hand, higher self-reported FOP label use among those with lower literacy may indicate a preference for simpler labels and potentially suggests greater accessibility of interpretative FOP label information compared with NfTs. As a result, consumers with lower literacy or nutrition knowledge may be at a disadvantage for applying nutrition information from labels, which could limit their ability to make healthier purchasing decisions.^{50,102-105}

Despite different rates of usage, there were many similarities in the correlates of NfT and FOP label use, with generally higher use among primary food shoppers, respondents with specific dietary practices or diet modification efforts, respondents with BMIs under 30, and females compared to males. Research has shown that consumers following specific dietary practices, or with diet- or weight-related goals, have increased motivation to seek out nutrition information, which likely drives higher label use.^{54,55,70,71} While primary food shoppers may not necessarily be making specific dietary efforts, they may be making food choices for others in their household (i.e., children), potentially motivating greater use of labels than those who are not primary food shoppers.⁷⁰ Moreover, studies have found women to be more health conscious than men, leading to greater use of nutrition information.^{30,51,106,107}

Label use was lower among older age groups and those with lower income adequacy. One potential explanation for lower label use among older individuals may be brand or product familiarity.³⁰ Studies on product health claims have shown that consumers who are familiar with a product are less likely to read labels or claims;^{30,108,109} hence, NfT and FOP labels may not be used by habitual consumers unless they are considering a new brand or product.¹¹⁰ Households with low incomes report prioritizing accessibility and affordability when making food purchasing and consumption decisions.^{40,104,111,112} As a result, these consumers may report using nutrition label information less often due to other priorities aside from nutrition quality. These findings reiterate the importance of creating a healthier food supply for all consumers to provide more equitable opportunities for healthy eating. Research has shown promising improvements in

healthier product reformulation as a result of mandatory nutrition labelling,^{22,34,113-115} which is necessary given the prominence of ultra-processed foods.^{1,4-8}

There are very few studies exploring label use differences by ethnicity,^{50,116,117} and this study found higher use of NFTs among ‘minority’ respondents. This finding may be explained by minority consumers’ greater dependence or interest in consulting NFTs for nutrient information, particularly among newcomers or immigrant groups if certain food products are unfamiliar. However, more research is required to better understand what other factors may be driving NFT use, and whether immigrant status or cultural food preferences may play a role in product familiarity and label use.

This study compared label awareness and use between five countries, with a large sample that enabled consideration of a range of covariates. A limitation is the non-probability-based sampling strategy, which does not enable the generation of nationally-representative population estimates. Although data were weighted by age, sex, and region, and ethnicity, the Mexico sample had higher levels of education than the Mexican population based on census estimates, while BMI was lower than national estimates in each of the five countries.^{57,118-124} Moreover, the primary outcomes (NFT/FOP label awareness/use) and several other correlates (FoodProK score, BMI) are subject to social desirability bias given the use of self-reported measures.¹²⁵⁻¹³⁰ In addition, the Newest Vital Sign has been tested across a variety of age and ethnic groups in different countries, but has not yet been validated as a self-administered measure.^{52,63,131-136} Lastly, the cross-sectional study design limits possible conclusions about the direction of variable relationships such as label use and nutrition knowledge.

3.4.6 Conclusions

Multi-country, population-level studies are important for ascertaining which labelling policies are most effective across subgroups. This study found that mandatory labelling policies (NFTs, Guideline Daily Amounts) had higher levels awareness than voluntary labels. Lower use of Guideline Daily Amount labels compared to voluntary FOP labelling systems provides further support for Mexico’s decision to switch to mandatory FOP ‘high-in’ symbols. Sociodemographic and other subgroup differences in label use are important as they indicate the reach of various labelling policies, which can potentially translate to dietary choices. Future research should

investigate the implications of labelling policies on consumers' eating patterns, and include countries with mandatory FOP labelling policies as well as other label types.

Chapter 4: General Discussion

4.1 Cross-country differences in nutrition knowledge and labelling behaviours

The current study provides new evidence on patterns and correlates of consumer use and understanding of nutrition labelling across five countries. The findings reinforce nutrition labels as a prominent source of nutrition information. Most respondents across all five countries reported using NFts, with the highest levels of self-reported use and functional understanding among respondents from the US and Canada. Differences across the five countries were relatively modest, with the exception of Mexico, where respondents reported the lowest levels of NFt and FOP label use compared to other countries. In contrast to patterns of label use and understanding, respondents from the US scored lowest on a functional test of one component of nutrition knowledge (the FoodProK score), followed closely by Mexico. There are several potential explanations for these cross-country patterns which may reflect differences in dietary intake, national dietary guidelines, and nutrition labelling policy promotion.

Country-specific dietary patterns or food culture may play a role in nutrition knowledge and label use among populations. Informal channels of nutrition education, such as family and cultural food practices, contribute to consumers' implicit understanding of a food's nutritive quality or properties.¹⁻³ This 'prior' knowledge may reinforce messaging from national nutrition education campaigns, or on the contrary, conflict with cultural beliefs around healthy eating.⁴⁻⁷ The association between dietary practices and healthfulness is further complicated by the fact that the global food supply is highly processed; hence, foods previously considered 'healthy' may be less nutritious after going through the industrial food process.⁸⁻¹³

While the food environment in each country differs, Canada, the US, the UK and Australia have similar "Western diets" compared to Mexico.⁸ Despite the fact that all IFPS countries have gone through a similar nutrition transition, Mexico's comparatively recent adoption of the Western diet – which includes a high intake of refined carbohydrates, fats, added sugars, and animal food sources – as well as rapid urbanization, resulted in one of the world's largest increases in diet-related NCDs between 1990-2010.^{8,14-16} Hence Mexican respondents' relatively lower nutrition knowledge, label understanding and use in this study may reflect a lag time in knowledge

dissemination and uptake among consumers regarding diet-related health risks. This is likely compounded by lower levels of literacy and numeracy among Mexican respondents which may limit their ability to use nutrition labels.¹⁷ Mexico is also the only middle-income country included in this study, and relatively less is known about label use and understanding in middle-income countries as most research in this area has been conducted in high-income countries.¹⁸⁻²³

In addition, populations in countries with a greater reliance on packaged food consumption may have had greater exposure to – and therefore have developed better understanding of – NFts. Americans obtain as much as 60% of their total energy intake from ultra-processed foods, the highest among all countries in this study.^{13,24-29} However, better label understanding does not necessarily translate to high nutrition knowledge. For instance, respondents in the US scored lowest on the FoodProK, which may reflect different social norms in populations where highly processed foods are ubiquitously available and consumed.

National dietary guidelines across all five countries are similar, which recommend lower consumption of sodium, saturated fat, and added sugars.³⁰⁻³⁵ Moreover, NFts are mandatory and similarly formatted in all countries; therefore, cross-country differences in label understanding, use, and nutrition knowledge may be explained by healthy eating policies or food labelling campaigns in each country. For example, the US and Canada released fact sheets, websites, and updates to school curricula alongside changes to food labelling policy^{30,35-37} to increase exposure to and education about food labels. Other countries have developed similar campaigns; however, it is possible that widespread NFt label promotion in Canada and the US compared to other countries resulted in relatively higher self-reported NFt understanding. Canada is the only country whose Food Guide – released shortly after the IFPS data was collected in 2018 – includes the recommendation to “limit highly processed foods,” including replacing sugary drinks in favour of fresh fruits.³⁸ Such messaging may contribute to increased NFt awareness and higher FoodProK scores in countries with specific direction regarding processed food consumption compared to other countries.

NFts remain a widely used and important source of information that provide nutrient details necessary for comparing similar products within a food category, whereas the FoodProK score is based on a broader understanding of level of processing across food categories. While they do not measure the same construct, NFt use and understanding were moderately correlated with the

FoodProK score. Hence NFts may be limited in educating consumers about broader dietary patterns and food categories, which has traditionally been the domain of dietary guidance.

Overall, national health promotion campaigns are important for supporting uptake of nutrition information on labels; however, systemic changes to the food environment are critical for consumers' ability to comply with national dietary guidelines.^{9,10,19} For example, improvements to the food supply, including healthier product reformulation, are necessary for providing equitable access to less highly processed food options.^{8-10,30-35} Mexico has implemented the most aggressive efforts to curb processed food consumption with soda taxes, mandatory nutrient-based standards for food sold in schools, banning junk food sales and marketing to children, and most recently, replacing the FOP GDA label to 'high-in' symbols.³⁹⁻⁴² These policies largely focus on consumer behaviours, but the ultra-processed food landscape must also be addressed from multiple levels in order to create a food environment conducive to healthy eating practices and high diet quality across countries.^{9,10,12,13}

4.2 The role of nutrition knowledge and functional measures

Higher functional nutrition knowledge was associated with higher NFt use, understanding, and awareness, as well as greater self-reported FOP label understanding. These findings are consistent with literature associating consumers' prior nutrition knowledge with higher label use across all age groups.^{20,43-50} Although the majority of research conducted in this area has been cross-sectional, it is likely the association between nutrition knowledge and labelling behaviours is bi-directional. Research suggests that prior knowledge may be a mediating factor in the relationship between motivation (i.e., specific diet modification goals) and decision accuracy in applying label information.^{20,51,52} Label exposure and use could also increase certain aspects of nutrition knowledge – such as food processing levels and related health risks. The FoodProK score was not significantly associated with FOP label use, which may reflect the fact that voluntary FOP labels are less likely to appear on products that are least healthy.^{53,54}

Most nutrition labelling studies have used self-reported measures;²⁰ however, research has shown that consumers tend to overestimate their nutrition knowledge and label understanding.^{49,55-62} This

study found that a commonly used measure of self-rated nutrition knowledge, in which participants rate their perceived level of knowledge on a scale of 1 to 5, was very weakly associated with functional NfT understanding, as well as FoodProK scores. Respondents who rated themselves as ‘extremely knowledgeable’ had low functional NfT understanding and FoodProK scores, suggesting that many respondents drastically overestimated their nutrition knowledge. This finding reinforces the need to move beyond single-item, self-reported measures towards functional tests of nutrition knowledge. A key shortcoming of self-reported measures is that they rely on respondents’ interpretation of the terms ‘label understanding’ or ‘nutrition knowledge’ – which may not align with researchers’ definitions of these concepts. Functional tests provide an opportunity to objectively test consumers in pre-defined aspects included in a measure.

While there are many functional measures of nutrition knowledge,⁶³⁻⁶⁶ the length and country-specific focus of many of these surveys makes them unsuitable for large, multi-country studies.^{66,67} To fill this gap, the FoodProK score was developed. The focus on processing levels is consistent with increasing inclusion of messages related to minimizing processed food consumption in dietary guidelines.^{30-34,68} Given that level of processing is not specific to a given population or context, this measure can serve as an indicator of consumer nutrition knowledge across studies, lending to the interpretation of cross-country research in this area. Preliminary face and content validity evidence suggests it is a reasonable general measure of nutrition knowledge. Future IFPS surveys will improve upon this measure to address issues, including replacing the processed meat product, after further testing.

Many respondents in this study also self-reported high NfT understanding while performing poorly on the functional measure (the Newest Vital Sign). Studies have shown that consumers perform poorly on these functional tasks, in part due to low awareness about what percent daily value means, and in some cases, confusion about terminology (i.e., calories versus kilojoules).^{58,59,69-74} While self-reported measures may have a role in large population-level surveys, the study findings using self-report should be interpreted with caution due to the weak correlation between these measures. Functional tests provide more reliable estimates than self-reported measures.

Overall, this study provides evidence of the importance of nutrition knowledge to labelling outcomes across countries. However, while nutrition knowledge is critical to label use and

understanding, other factors, such as health literacy and healthy food affordability and access, likely play an important role in determining *who* can “apply” their nutrition knowledge.^{20,52} The theme of subgroup disparities in label use and awareness is explored in greater detail below.

4.3 Disparities in nutrition knowledge and labelling behaviours

Consistent with other research, the current study suggests nutrition labelling policy may not be equally effective among all sociodemographic groups.^{50,52,75-85} Women, consumers engaging specific dietary practices (i.e., vegetarianism) or efforts (i.e., to consume less sodium or sugar), consumers with higher nutrition knowledge and health literacy, younger respondents, and those with higher income and education were among the subgroups who reported higher use and awareness of nutrition labels compared to their counterparts. Nutrition knowledge was generally higher among the same sociodemographic subgroups, which highlights existing disparities in nutrition information access and resource use that may eventually contribute to poorer nutrition-related health outcomes among consumers with lower label use.⁸⁶⁻⁹⁰

The literature offers several explanations for the patterns observed in this study. Research suggests that women are generally more health conscious than men, which leads to greater use and interest in nutrition information such as labels.⁸²⁻⁸⁴ With respect to dietary patterns and BMI, consumers with specific dietary practices or weight-related goals may have greater motivation or interest in nutrition information, and using labels to support their food choices.^{44,79,91,92} Similarly, consumers with higher nutrition knowledge and health literacy may be better equipped to interpret and apply label information, as the literature indicates positive associations between knowledge and label use.^{20,43-50}

Label use and awareness was generally higher with higher education and income adequacy, but these factors were not associated with nutrition knowledge. This finding may reflect the fact that a range of other relevant variables were adjusted for in the models that could have mediated associations between education/income and nutrition knowledge, such as health literacy. With respect to label use and awareness, this finding may suggest differences in decision-making ability as energy-dense, nutrient-poor packaged foods tend to be more affordable than more nutritious, whole food options.^{90,98-101} As a result, food purchasing decisions may be less influenced by the nutritive value, thereby decreasing reliance on labels. With respect to ethnicity, this study found

higher use of NFts among ‘minority’ respondents, but higher NFt understanding among ‘majority’ respondents. This finding may be explained by minority consumers’ greater need or interest in consulting NFts for nutrient information, particularly among newcomers or immigrant groups, if certain food products are unfamiliar. On the contrary, understanding may have been poorer among minority consumers with lower English proficiency.^{102,103} Research has shown that low health literacy is more common among certain sociodemographic groups, including minority ethnic groups, those with low income and education, and older consumers; hence, respondents may have experienced a cumulative effect of these factors on labelling behaviours.^{72,104} More research would be required to better understand what factors may be driving label use among different ethnic groups, and whether health literacy, English proficiency, immigrant status, and cultural food preferences play a role in product familiarity, label influence, and nutrition knowledge.

In addition to health literacy, lower label use among older age groups in this study may be attributed to brand or product familiarity.⁸² Studies on product health claims have shown that consumers who are familiar with a product are less likely to read labels or claims;^{82,93,94} therefore, NFt and FOP labels may similarly have lesser influence on previous consumers unless they are looking at a new brand or product.⁹⁵ Nutrition knowledge, on the other hand, was higher among older age groups, which may be explained by a greater need to acquire nutrition information to maintain health with age.^{96,97}

Sociodemographic characteristics (i.e., belonging to an ethnic minority or low SES group), in and of themselves, likely do not predict label use or nutrition knowledge. Other moderating factors such as motivation, self efficacy, and numeracy skills among these subgroups, as well as the broader food environment, influence consumers’ exposure and ability to use labels.^{76,103,105} Research indicates labels can influence food choices;¹⁰⁶⁻¹¹² however, they are among a myriad of factors that consumers consider in food purchasing and consumption.^{113,114} Hence, while labelling policies can exacerbate existing disparities in nutrition information access and understanding via their label design and presentation of information, it is unlikely that they are responsible for creating subgroup differences in policy uptake. Sociodemographic and other groups which experience an advantage in higher label use or comprehension (i.e., higher SES, literacy) likely benefit more from these policies than other groups.

As described in the following sections, evidence suggests that label design and consistent policy implementation can exert influence on nutrition label uptake to potentially supersede differences based on consumer characteristics.

4.4 Poor understanding of NFts and the need for FOP labelling systems

Research in the area of FOP labels has been rapidly increasing as more countries have adopted voluntary or mandatory FOP labelling policies. Among the three countries in this study with FOP labels, respondents from the UK reported the highest levels of use and understanding for Traffic Lights; respondents from Mexico reported the highest levels of awareness of the GDA, but the lowest mean understanding; and respondents from Australia reported the lowest awareness and use of HSR labels.

Mexico is the only IFPS country with a mandatory FOP label, so it is likely that greater awareness of GDAs compared to NFts stemmed from greater visibility of the GDA on all packaged foods. In contrast, the use of voluntary labelling systems may have impacted consumers' exposure to FOP labels in Australia and the UK, as HSR and Traffic Light labels only appear on approximately 30% and 8% of food products, respectively.^{115,116} Australia and New Zealand are among the few countries which have evaluated a voluntary FOP labelling policy (the HSR), thus comparable post-implementation policy data in other countries is not available to assess consumer awareness and use.¹¹⁴

In general, self-reported FOP label understanding was higher than NFt understanding, consistent with existing evidence, with the exception of Mexico where self-reported NFt understanding was higher.^{21,58,59,103,117,118} Nutrition labels requiring greater numeracy skills (i.e., NFt, GDA) were more difficult for consumers to understand than interpretive FOP labels (i.e., Traffic Lights). UK respondents' comparatively higher use of Traffic Light labels is consistent with evidence regarding its ease of use and understanding.^{80,119-122}

Consumers with lower health literacy tend to use labels less as they struggle with understanding quantitative label information.^{18,58,103,123,124} Numeracy skills, in particular, are required to interpret label information, as serving size calculations and an understanding of percent daily value are required to deduce nutritive content in a food product.^{58,59,69-74} While formal education is a factor in health literacy and numeracy skills,^{80,103} inadequate nutrition education and promotional

strategies may also contribute to consumers being ill-equipped to interpret NfT label information. For example, though most countries have created guides for nutrition label use,¹²⁵⁻¹²⁷ consumers must actively seek out these resources as they are seldom promoted in publicly accessible domains (i.e., television advertising) or outside of educational settings. The functional test of NfT understanding (Newest Vital Sign) showed that respondents performed poorly on questions requiring mathematical calculations or numeracy skills. These findings suggest that poor NfT understanding may reflect problems with numeracy and low health literacy.

Although the FOP GDA in Mexico is mandatory, poor understanding likely reflects the type of information included on the Mexican FOP label. HSR and Traffic Light labels in Australia and the UK, respectively, use symbols and provide interpretive information, whereas Mexico's industry-based GDA system provides reductive nutrient information similar to the NfT. Previous research has demonstrated consumers' poor understanding of the numeric information on GDA labels, which is consistent with the current findings.^{53,128-133} Hence, it is also not surprising that the Mexican government is replacing the GDA with mandatory FOP 'high-in' labels similar to Chile.⁴⁰ Other countries are also following suit, with Canada proposing implementation of mandatory 'high in' labels for saturated fat, sodium, and sugars.¹³⁴⁻¹³⁷

While none of the countries participating in the current study had implemented 'high in' FOP labels, evidence is increasingly pointing toward this labelling system as easiest to use and understand among consumers.^{82,131,138,139} The implementation of 'high in' FOP labels in Mexico and other countries offers an excellent opportunity to compare labelling behaviours over time, GDA vs. 'high-in' labels, as well as potential unintended negative consequences (i.e., promotion of weight stigma).^{140,141}

Poor understanding of NfT labels highlights the importance of FOP labelling systems – particularly interpretative systems which studies suggest are easier for consumers to understand than NfTs alone.^{18,23,48,53,109,119,142-150} Evidence indicates high self-reported and functional understanding of FOP labelling systems such as Traffic Lights^{80,119-122} and 'high-in' labels.^{129,135,141,152} Among consumers with low self-reported nutrition knowledge, income, and education, the preference for simpler FOP label designs is consistent with better understanding of these labelling systems.^{18,23,48,99,109,119,146,150,152,153}

Recent research has shown that FOP ‘high-in’ labels may have similar benefits across sociodemographic subgroups compared to other labelling systems.^{131,138,139} More research is needed to explore whether disparities persist for FOP label understanding across various label types; however, the evidence points to the need for mandatory nutrition labelling policies in order to maximize reach and effectiveness, as well as the importance of government commitment to implement nutrition labelling policies with promotional and educational initiatives.

4.5 The case for mandatory nutrition labelling policies

This study contributes to the growing evidence that mandatory labelling policies have higher awareness among consumers across countries than voluntary labelling systems. The labels requiring higher numeracy skills (NFTs in all countries, GDA in Mexico) were also the only mandatory labels in this study; therefore, use and understanding was relatively lower than voluntary FOP labelling systems. Moreover, Mexico’s GDA label had shortcomings which have led it to be replaced by ‘high-in’ labels.^{53,128-131} This study provides support for Mexico’s decision to replace GDA labels with Chilean-style ‘high in’ FOP labels which have been shown to be comparatively easier for consumers to understand.^{40,129,133,139,151,153} The new FOP labels will display a black octagon indicating excess sugar or saturated fat if 10% or more of a product’s calories come from these nutrient groups; excess trans fat if the product contains 1% or more; excess sodium if the product has 1mg or more of sodium per calorie, 300mg or more of sodium in beverages and packaged foods, or 45mg or more in non-caloric beverages; and excess calories for foods with 275 calories or more per 100g, or 70 calories or more of free sugars per 100ml of beverage.⁴⁰ Future IFPS research will assess uptake of ‘high-in’ labels in Mexico, including cross-country comparisons to identify changes in labelling behaviour.

Mandatory labels are ‘universal’ policies, and therefore are theoretically accessible to everyone. Unlike voluntary labelling policies, the food industry cannot opt into a mandatory labelling system or selectively display nutrients in a product. Evidence also suggests that mandatory policies encourage healthier product reformulation.^{52,77,113,155-161} For example, following mandatory FOP label policy implementation in Chile, many packaged products were reformulated to avoid receiving ‘high-in’ labels.^{161,162} A simulation study that analyzed food product data between 2013

and 2019 found that total sugar content in packaged products would be reduced by approximately 15%, with smaller changes in other nutrient categories.¹⁶² Reformulation is one of the primary mechanisms through which labelling improves the food environment, and these systemic changes have the potential to modify consumer dietary intake over time.^{77,163}

4.6 Strengths and Limitations

This five-country study provided a unique opportunity to investigate labelling policy contrasts and impacts. The major strength of this study lies in the large sample size and multi-country design, which enabled direct comparisons of nutrition labelling policies, behaviours, and knowledge between countries with a variety of relevant covariates. The use of several functional measures, the Newest Vital Sign and FoodProK score, distinguishes this nutrition labelling study from others which have largely focused on self-reported outcomes. In particular, the country-specific adaptations made to NfTs in the Newest Vital Sign, and language options offered for the IFPS surveys, minimized the likelihood that English proficiency could have resulted in lower label understanding or nutrition knowledge scores among some sociodemographic subgroups (i.e., Hispanic respondents in the US) in our assessment.^{102,164}

There were several limitations of the current study design. First, study 1 relied upon a convenience sample of Registered Dietitians, and may not be representative of the broader dietetic community in Canada and elsewhere. Potential measurement-related limitations include poorer performance in the meat category compared to other food categories in the FoodProK score. Sensitivity tests revealed that the FoodProK performed similarly irrespective of whether 6-, 7-, or 8-point scales were used, which corresponded with dropping the meat category, dropping the processed meat item, or retaining the full measure, respectively. However, further testing is still required in diverse populations. Open-ended questions were used to obtain qualitative feedback, although in-person methods may have facilitated more detailed responses. The study did not assess test-retest reliability, or other types of validity (e.g. convergent, criterion), thus further psychometric testing in diverse samples and contexts is necessary to build validity evidence for the FoodProK score.

In studies 2 to 4, countries could not be assigned to labelling conditions as policy implementation is not within the control of the researchers. ‘Secular’ differences between countries, such as

different trends in disease prevalence, also could not be controlled for in the study design. However, the selected countries have high rates of obesity (Canada = 26%, US = 38%, Australia = 28%, UK = 27%, Mexico = 32%) based on Organization for Economic Co-operation and Development (OECD) data,¹⁶⁴ and have experienced the ‘nutrition transition’ characterized by ‘Western-style’ diets.^{165,166}

The sampling strategy was limited by the use of non-probability-based sampling, which does not enable generation of nationally representative population estimates. For example, although data were weighted by age, sex, region, and ethnicity, the Mexico sample had higher levels of education than census estimates, while self-reported BMI was relatively lower than national estimates in each of the five countries.¹⁶⁷⁻¹⁷⁴

This study is subject to social desirability bias due to the use of several self-reported outcome measures. Social desirability bias may have inflated estimates of label awareness/understanding/use, as similar studies assessing diet quality have found respondents reporting higher fruit and vegetable intake due to perceived social norms.¹⁷⁵⁻¹⁷⁷ However, research has shown that online data collection may help mitigate social desirability bias compared to in-person and phone surveys, as it provides respondents with greater anonymity.¹⁷⁸⁻¹⁸⁰ Moreover, as this study focused on cross-country comparisons, the presence of social desirability bias is expected to be constant across countries, thus should not account for any between-country differences observed in the outcomes of interest.

In addition, the Newest Vital Sign has been tested across a variety of age and ethnic groups in all the IFPS countries except Mexico, and has not yet been validated as a self-administered measure.^{85,124,181-187} This study used the Newest Vital Sign as a measure of functional NfT understanding because of the similarities in NfTs across countries; however, functional FOP label understanding was not assessed due to challenges with capturing comprehension of distinct FOP label types in a single measure.

Lastly, the current study uses cross-sectional data, which is unable to examine temporal effects and trends over time, including potential differences before and after nutrition labels are implemented. Longitudinal changes can be addressed by subsequent analyses with IFPS data collected over multiple waves.

Ultimately, nutrition label uptake and understanding are important because we expect label use to be associated with healthier dietary choices. Research indicates that label use helps with healthier selection when comparing products, and can increase healthy food purchasing and consumption. One caveat should be noted, as the literature indicates that label use may increase healthier purchase intentions (termed the ‘health halo effect’) more than actual dietary choices.⁸² In addition, FOP labels, irrespective of label type, may have limited influence on consumers’ perceptions of a product’s healthfulness, particularly when labels are placed on ‘vice’ products that are known to be less healthy.^{82,130,188} While there is not consensus in the literature about which FOP labelling system performs best, mandatory policies can increase FOP label influence by establishing standards for nutrient amounts and formats. Mandatory policies enable greater transparency from the food industry, and may potentially reiterate dietary guidance to provide unified recommendations for nutrient intake, food categories, and levels of processing.⁸² Overall, “nutrition labels induce a food-systems response,”¹⁶³ and can empower consumers with essential nutritive information to overcome barriers to healthy eating which can result from inadequate information.

4.7 Future Directions

Areas for future research highlighted by this dissertation include further validity testing of the Newest Vital Sign and the FoodProK score in multiple contexts. Future labelling policy research should include countries which have mandatory FOP labelling policies such as Mexico, Chile, and Ecuador, as well as countries with other label types (i.e., voluntary Nutri-Score in France) to enable comparisons between labelling systems. Moreover, research should focus on how varied labelling systems influence differences in consumer awareness, understanding, and use. Many countries, including Canada, are proposing mandatory FOP labelling policies which can be assessed via prospective, longitudinal studies such as the IFPS. Such studies provide an opportunity to assess the unique impacts of policy implementation on product reformulation, as well as consumer behaviours, attitudes, purchasing, and dietary intake over time. The interaction of labelling with other policy efforts, such as sugar taxation or food marketing bans, should also be considered in future research.

Research on the impact of new national nutrition guidelines – including evaluations of awareness, comprehension, use, and reach – is also needed to assess the effectiveness of national guidelines

and associated campaigns. For example, a revised Canada Food Guide was released shortly after the IFPS data were collected in 2018, and now includes the specific recommendation to “limit highly processed foods.”³⁸ Compared to other countries with less specific guidance on processed food consumption, future studies can assess the extent to which consumers are aware of or applying such information to inform health promotional strategies and campaigns.

In general, post-implementation research and policy evaluations are lacking to assess the uptake and effectiveness of implemented labelling policies. Australia and New Zealand provide an example of a robust multi-year evaluation that could be replicated in other countries.⁵² Consistent monitoring and surveillance are critical for understanding the extent that labelling policies contribute to changes in nutrition knowledge, food purchasing, and dietary intake. Nutrition labelling policy research and evaluation require population-based consumer data, as well as food supply and sales data, to generate a wholesome picture of policy impact and reach.

4.8 Conclusions

This international study showed that simple, interpretative FOP labels were easier to understand than numerical-based FOP labels; however, the findings also highlight the importance of mandatory, rather than voluntary policies to maximize reach. Nutrition labelling is intended as a ‘universal’ approach that does not target specific groups, which is both a strength and a weakness of this population health policy. Although evidence does not indicate that nutrition labels further disadvantage particular groups, in order to minimize widening disparities in label understanding and use, governments have a responsibility to address such gaps among specific subgroups. This includes greater implementation of simple, interpretative labelling policies supplemented by targeted educational campaigns. Other factors, including food access and affordability, are not within the purview of labelling policy, but must also be addressed for equitable policy uptake. Nevertheless, mandatory labelling policies can influence the food industry to reformulate food products to improve their nutritive value, contributing to a healthier food supply. In conclusion, this study reiterates the importance of understanding cross-country differences in nutrition labelling outcomes as this reflects the extent to which mandatory versus voluntary labelling policies are effective.

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Chapter 1

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Chapter 3.3

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Chapter 3.4

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Chapter 4

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APPENDICES

Appendix A: FOP Labelling Systems

FOP Labelling System	Nutritional Criteria Covered	Jurisdictions	Status (mandatory, voluntary)	Advantages	Disadvantages
Health Star Ratings ¹⁵⁰	<ul style="list-style-type: none"> • Calories • Serving size • Saturated fat • Sodium • Total sugars • Maximum of 5 stars: scores ranging from 0.5 to 5, with 5 being the healthiest 	Australia	Voluntary	<ul style="list-style-type: none"> • Targets nutrients of public health concern¹⁴³ • Clearly indicates serving size • Scoring makes it easier to compare products¹⁴³ • Provides specific nutrient amounts alongside an indication of high/low • Assesses nutritional value based on algorithm which considers food groups/types as well as <i>Australian Dietary Guidelines</i>¹⁵⁰ • Complementary to nutrition facts table • Scoring system does well discerning 	<ul style="list-style-type: none"> • Not all nutrients have associated high/medium/low cut-offs, so it is difficult for consumers to ascertain if nutrients of concern (i.e., sodium) are low/medium/high for the product serving size • Some inconsistencies with the <i>Guidelines</i>, including the use of total rather than added sugar in calculating the product rating. However, this is a reflection of the fact that added sugars are not required on the nutrient facts panel in Australia²²⁹

				between core and discretionary foods ²²⁹	
Multiple Traffic Lights ¹⁴⁷	<ul style="list-style-type: none"> • Calories • Serving size • Total fat • Saturated fat • Total sugar • Sodium 	United Kingdom	Voluntary	<ul style="list-style-type: none"> • Targets nutrients of public health concern¹⁴³ • Complementary to nutrition facts table • Clearly indicates serving size • Assess nutrient value based on %RI, which puts the nutrient amounts into the context of overall diet for consumers¹⁴⁷ 	<ul style="list-style-type: none"> • Nutrient cut-offs for high/medium/low are unclear • Food manufacturers can choose which nutrients to display, as only energy declaration is required if opting to include the label¹⁴⁷
'High' symbol warnings ^{101,224}	<ul style="list-style-type: none"> • Sodium • Total sugar • Saturated fat 	Canada, Mexico	Mandatory (not yet in effect in Canada, implemented in Mexico in 2020)	<ul style="list-style-type: none"> • Targets nutrients of public health concern¹⁴³ • Complementary to nutrition facts table • Some adjustment planned for child-focused products in light of the fact that lower DVs are need for children 1-3 years and 4+ years¹⁰¹ • Distinction in threshold amounts for 	<ul style="list-style-type: none"> • The %DV will not be noted in the label itself • Serving size and energy declaration not included in symbol • Foods with small reference amounts or small packages would not be required to include high warning symbols (i.e., condiments, which are typically high in sodium)¹⁰¹ • Consumers need to consult the nutrition facts table to see actual nutrient amounts

				prepackaged foods versus meals ¹⁰¹ <ul style="list-style-type: none"> • Exception made for healthy oils to avoid further mixed messaging and encourage consumption of healthy fats⁶⁵ 	
Guideline Daily Amount ¹⁴⁵	<ul style="list-style-type: none"> • Calories • Total sugar • Saturated fat • Sodium 	Mexico	Mandatory (removed in 2020 and replaced by 'high-in' symbols)	<ul style="list-style-type: none"> • Targets nutrients of public health concern¹⁰⁸ • Clearly indicates serving size • Assess nutrient value based on %DV, which puts the nutrient amounts into the context of overall diet for consumers¹⁴⁷ 	<ul style="list-style-type: none"> • Repeats information from the Nutrition Facts table • Focus on nutrients quantities confusing for consumers^{108,124}

Note: %DV – percent daily value; %RI – percent reference intake. This table does not include an exhaustive list of labelling systems or countries in which they have been implemented. Only countries included in the International Food Policy Study are noted here.