Exploring the associations between sweet taste perception and habitual dietary intake in New Zealand European women

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Abstract

Background: Obesity is a global epidemic, leading to the development of chronic diseases. Sweet taste perception has been identified as a driver of habitual dietary intake, thus may contribute to excessive weight gain. Investigating these associations in New Zealand (NZ) European women may provide insight into the factors leading to obesity.

Aim: To investigate sweet taste perception and habitual dietary intake in a group of NZ women of two distinct body mass index (BMI) groups, obese (BMI ≥30 kg/m^2) and normal (BMI ≥18.5 - 24.9 kg/m^2), aged between 18-45 years, and to identify potential associations between these factors.

Methods: One hundred and forty eight NZ European women, aged 18-45 years, were recruited. Participants were presented with four different aqueous glucose concentrations to assess sweet taste perception. Sweet hedonic liking and perceived intensity of each concentration were rated on a general Labelled Magnitude Scale. Participants completed a 220-item validated food frequency questionnaire to assess dietary intake. Height and weight were measured to calculate BMI (kg/m^2).

Results: Negative correlations between sweet hedonic liking and perceived sweet taste intensity were observed at the two highest glucose concentrations for the obese group, and at all four concentrations for the normal BMI group. Carbohydrate and sugar intake was significantly correlated with liking for the obese BMI group ($r = 0.337$, $p = 0.004$, and $r = 0.313$, $p = 0.008$, respectively). Significant associations between intensity ratings were found for the normal BMI group and with intake of fats, with polyunsaturated fat displaying the strongest correlation ($r = 0.300$, $p = 0.008$). Positive correlations between intake of desserts and liking ratings ($r = 0.257$, $p = 0.032$), and intake of starchy vegetables and intensity ratings ($r = 0.298$, $p = 0.012$) were observed for the obese BMI group at the highest glucose concentration.

Conclusion: The present study highlights a clear BMI-specific association between hedonic liking and perceived intensity of sweet taste, with intake of macronutrients and sugars, and with intake of sweet food groups, contributing to our understanding of the underlying aetiology leading to the development of obesity and chronic disease.

Key words: *sweet taste perception, sweet hedonic liking, perceived sweet taste intensity, habitual dietary intake, obesity*

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Abbreviation List

AMDR	Acceptable Macronutrient Distribution Range
ATP	Adenosine Triphosphate
BF%	body fat percentage
BIA	bioelectrical impendence analysis
BMI	Body Mass Index
DFE	Daily Frequency Equivalent
DLW	doubly labelled water
EAR	Estimated Average Requirement
EER	Estimated Energy Requirement
FFQ	food frequency questionnaire
GLAST	glutamate aspartate transporter
gLMS	general Labelled Magnitude Scale
GLP-1	Glucagon-like peptide-1
GPCR	G-protein-coupled receptors
NRV	Nutrient Reference Values
NTPDase2	nucleoside triphosphate diphosphohydrolase-2
NZ	New Zealand
PROMISE	PRedictors linking Obesity and gut MIcrobiomE
PROP	6-n-propylthiouracil
ROMK	renal outer medullary potassium channel
SD	standard deviation
SNP	single nucleotide polymorphisms
TAS1R2	taste receptor type 1 member 2
TAS1R3	taste receptor type 1 member 3
TE	total energy
WHR	waist:hip ratio

Chapter 1 - Introduction

1.1 Background and study justification

Food can simply be described as one of life's greatest pleasures, however the decision-making process leading to food selection is not as simple. Taste perception is one of the factors influencing dietary intake, with individual variations in taste leading to differences in habitual patterns of intake. This has driven an increased awareness and interest in understanding the extent to which individual taste perception can impact energy and nutrient intake, and overall long-term health outcomes.

Global and national data highlight an increasing prevalence of obesity in the population, coupled with a subsequent rise in the rates of chronic disease development (Ministry of Health, 2016; World Health Organization, 2017). In New Zealand (NZ), nearly a third of adults are obese - a figure which has steadily increased from 27% in 2006 to 32% in 2016 (Ministry of Health, 2016). This can be credited to a consistent imbalance between energy consumed and energy expended, leading to weight gain and obesity. This is further assisted by the current obesogenic environment, which has increased the accessibility of nutrient-poor, energy-dense foods and decreased the opportunities for daily physical activity (Sharpe & Bradbury, 2015; World Health Organization, 2017).

Gustation is the process which occurs when substances in the mouth interact with taste receptors found on taste buds. This results in signals being sent to the brain and interpreted as one of the five tastes currently established; sweet, bitter, sour, salty, and umami (Drewnowski, 1997). These taste sensations allow individuals to assess if food is safe to consume, ensuring that toxins and poisonous compounds are rejected (Drewnowski, 1997; Liu, Archer, Duesing, Hannan, & Keast, 2016). Taste perception also leads to the development of food preferences or aversions, further emphasising taste's contribution to the development of dietary habits (Sobal, Bisogni, Devine, & Jastran, 2006).

Sweet taste in particular has been well-explored in the literature due to the innate preference for sweet-tasting foods observed in infants and children (Mennella, Finkbeiner, & Reed, 2012). Glucose, a sugar found in many sweet foods, is an essential fuel source for the human brain, thus an innate preference for sweet is a survival mechanism to ensure that adequate fuel is consumed (Breslin & Spector, 2008). However, individual differences in sweet detection and perception may lead to an amplified intake of sweet food items with varying health outcomes. Unfortunately, society currently exhibits a pattern of excessive sugar intake, with increased consumption of sugar-sweetened beverages and candy (University of Otago and Ministry of Health, 2011a). These foods are energy-dense and nutrient-poor, contributing to the imbalance of energy leading to obesity.

Taste perception exhibits plasticity and has the ability to adapt based on exposures throughout one's life, dictated by body weight profile, sex, ethnicity and age (Drewnowski, 1997; Mennella, 2014). Food exposures early in life shape taste perception, having long-lasting consequences for dietary intake and health status (Drewnowski, 1997; Mennella, 2014). Individual differences in taste perception can alter the strength and intensity of the taste experienced in the mouth, subsequently impacting preference levels for that particular taste. It has been documented as one of the key values driving food choices, therefore has an underlying key role in the development of dietary habits (Nasser, 2001).

Previous research has proposed that individuals with a lower sensitivity and a higher preference towards sweet taste are more likely to consume a diet higher in sugars, compared to those with a higher sensitivity (Dias et al., 2015; Jayasinghe et al., 2017; Noel, Sugrue, & Dando, 2017). Further, those individuals with a higher habitual sugar intake will more likely have an excessive energy intake, leading to weight gain and obesity. A better understanding of the differences in taste perception between individuals may provide an explanation of differences in dietary intake, offering an explanation about the dietary behaviours leading to weight gain, and poor health outcomes.

1.2 Purpose of the study

Obesity and related non-communicable diseases are becoming increasingly prevalent both in the NZ population and globally. Although there are many factors leading to the development of obesity, the associations between dietary intake of individuals and their relative disease risk are clear. The determinants of food selection and dietary intake are complex, and many conceptual models have been developed to explain the process. Eating behaviour is not only based on conscious decisions, but also those which are subconscious, automatic, or habitual (Furst, Connors, Bisogni, Sobal, & Falk, 1996).

Taste perception is consistently highlighted as one of the major factors leading to food selection. Differences in sweet taste perception will be explored based on current research highlighting that the intake of sugar-containing foods, such as soft-drinks and sweet baked goods, has increased in parallel with the rise in global obesity rates. A number of studies to date have investigated the relationship between taste perception and habitual dietary intake in the NZ European population (Jayasinghe et al., 2017; Kindleysides et al., 2017). The present study seeks to explore the associations between measures of sweet taste perception and habitual dietary intake in a population of NZ European women of two distinct body mass index (BMI) profiles. It may be that those with a high BMI have vastly different taste perception profiles compared to those with a normal BMI, thus will require different dietary interventions and advice to improve their health outcomes. Further understanding taste perception as a determinant of food selection and eating behaviour will lead to the development of interventions to target increasing obesity rates and improve the overall health outcomes of New Zealanders.

1.3 Aims

Firstly, to investigate sweet taste perception and habitual dietary intake in a group of NZ European women of two distinct BMI groups, obese (BMI ≥30 kg/m^2) and normal (BMI ≥18.5 - 24.9 kg/m^2), aged between 18-45 years. Secondly, to explore and identify potential associations between sweet taste perception and habitual dietary intake in these women, as a means of further understanding some of the potential taste- and diet-related contributors to obesity.

1.4 Objectives

1. To investigate sweet taste perception, described as sweet hedonic liking and perceived sweet taste intensity, in NZ European women in two distinct BMI groups, identified as obese or normal, using a general Labelled Magnitude Scale.
2. To explore the differences in habitual dietary intakes, described as macronutrient distribution profiles and sweet food consumption frequencies, between women in the two distinct BMI groups.
3. To establish associations between sweet taste perception and macronutrient distribution profiles, of these women in the two distinct BMI groups.
4. To establish associations between sweet taste perception and sweet food consumption frequencies, of these women in the two distinct BMI groups.

1.5 Hypothesis

It is hypothesized that NZ European women in the obese BMI group will display a higher preference and lower sensitivity to highly sweet glucose samples, and that this will be associated with habitual dietary intakes which promote an excessive energy intake and subsequent weight gain.

1.6 Thesis structure

This study has been structured into four chapters. Chapter 1 introduces the research and highlights its importance. Chapter 2 is a review of the existing literature, covering topics on obesity, taste perception, and food selection. Chapter 3 is a presentation of the research study, including methodology, results, a discussion of the findings, and concluding remarks. Finally, chapter 4 is an overview of the outcomes, highlighting the strengths and limitations of the study, and detailing recommendations for future research.

1.7 Researcher's contributions to the study

Table 1.1. Researchers who contributed to the PROMISE study.

Researchers	**Contributions to the study**
Shivon Singh	Main researcher; involved in participant testing and taste perception data collection; taste perception and dietary intake data entry for PROMISE study participants; analysis of results presented in this thesis; statistical analysis; interpretation and discussion of results; author of thesis
Prof. Bernhard Breier	Academic supervisor; lead investigator of the PROMISE study; research ideas, strategy, direction; funding; directing investigation of taste perception, food hedonics, dietary intake, biomarker research; interpretation and review of results and discussion
Dr Marilize Richter	Academic co-supervisor; supporting the dietary and body composition analyses; research direction; assistance with statistical analysis and interpretation of results; review of methods, results, discussion, and conclusions
A/Prof. Rozanne Kruger	Academic mentorship; primary investigator of the PROMISE study; directing investigation of dietary and body composition assessment; study design; research direction; assistance with statistical analysis and interpretation of results
Sophie Kindleysides	PhD student; coordinator for the taste perception component of the PROMISE study; validation of the taste perception methodology; recruitment and testing of PROMISE study participants; taste perception data collection; data entry and analysis; assistance with research direction; review of methods
Niamh Brennan	PROMISE study coordinator; participant screening and recruitment
Nikki Renall, Jo Slater, Moana Manukia	Recruitment and testing of PROMISE study participants including: body composition assessment (height, weight, hip and waist circumference, BIA, DEXA scan), blood pressure measurements, blood sample, dietary questionnaires, physical activity questionnaires, sleep questionnaires *(Note: participants were recruited as part of the wider PROMISE study and only part of the data is used within this thesis)*
Bronte Anscombe, Elizabeth Cullen, Ashleigh Jackson	Dietary data entry (food record)
Carolin Friedle, Sunna Jacobsen	Taste perception data entry

PROMISE = PRedictors linking Obesity and gut MIcrobiomE; BIA = bioelectrical impendence analysis; DEXA = dual-energy x-ray absorptiometry; FFQ = food frequency questionnaire.

Chapter 2- Literature review

2.1 Introduction

Obesity has become increasingly prevalent over the past decade, with over a third of New Zealand (NZ) adults classified as obese. This increase has been coupled with a rise in the rates of chronic diseases, such as cardiovascular diseases, diabetes and certain cancers (Ministry of Health, 2016; World Health Organization, 2017). An imbalance between energy consumed and energy expended leads to weight gain and subsequent obesity if weight gain continues. This could be credited to the obesogenic environment in which we currently reside, which has led to a greater intake of energy-dense foods and a decrease in physical activity levels (Sharpe & Bradbury, 2015; World Health Organization, 2017).

Food choices are influenced by a range of social, environmental, and economic factors, however in instances where one food must be selected over another, the sensory attributes of food play a defining role. Sensory characteristics include aroma, mechanical stimulation, and visual input, however, taste has long been proposed as a key driver for dietary choices (Breslin & Spector, 2008). The process of gustation, or taste, begins with chemical substances entering the mouth and interacting with taste receptors found on taste buds on the tongue, leading to nutrient detection (Drewnowski, 1997). From an evolutionary perspective, this has ensured human survival through the avoidance of potentially harmful or toxic foods and the acceptance of nutritious foods (Liu et al., 2016). Any changes or disturbances to one's taste function may lead to an excessive or inadequate intakes of certain nutrients, with potentially harmful health consequences (Liu et al., 2016). The excessive consumption of any nutrient will lead to disturbances in normal functioning, as is seen with excessive energy intakes leading to weight gain and obesity.

A greater understanding of the influence of taste perception on habitual dietary intake will add to the current research about the causative factors of obesity and the associated health consequences.

2.2 Obesity

2.2.1 Introduction to obesity

Overweight and obesity are states of an excessive or abnormal accumulation of fat (World Health Organization, 2017). Body mass index (BMI) is a common measure used to define obesity in adults, and is calculated using weight (kg) divided by the square of height (m): kg/m^2. Table 2.1 details the classification system used for BMI measures, with poorer health outcomes and disease states becoming more prevalent at the higher end. Globally in 2016, 39% of adults (aged 18 years and over) were overweight, and a further 13% were obese, which has tripled since 1975 (World Health Organization, 2017).

Table 2.1. Internationally-recognised classification of adult body mass index (BMI).

Classification	**BMI (kg/m²)**
Underweight	<18.5
Normal	18.5-22.9
Overweight	≥25.0
Obese	≥30.0
Obese class I	30.0-34.9
Obese class II	35.0-39.9
Obese class III	≥40.0

Table above was adapted from World Health Organization (2006).

2.2.2 Obesity in New Zealand

Recent NZ adult obesity statistics indicate that 32% of adults are obese; an increase over the past decade from 27% in 2006/2007 (Ministry of Health, 2016). Ethnic differences are apparent, with Pacific adults having the highest rates of obesity (67%), compared to Maori (47%), European/Other (30%), and Asian adults (15%) (Ministry of Health, 2016). A greater prevalence has consistently been seen in women, with 32.6% classified as obese in 2015/16, compared to 30.5% of men (Ministry of Health, 2016). Specifically in NZ European women, there has been a progressive increase in obesity, with 31% in 2015/2016 compared to 25% in 2006/2007 (Figure 2.1) (Ministry of Health, 2016). Although average obesity rates for NZ European women are less than NZ women, the ongoing rise is of high importance due to the levels of health loss associated with being overweight or obese.

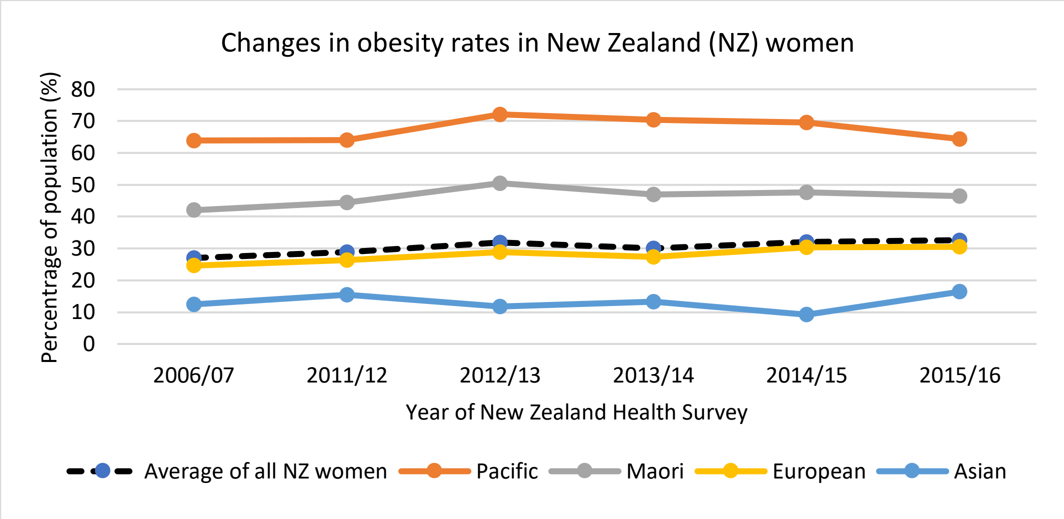

Figure 2.1. The prevalence of obesity in New Zealand women by ethnic group.

Figure above was created using data from Ministry of Health (2016).

2.2.3 Energy imbalance

Obesity is the end-product of a continuous imbalance between energy consumed and energy expended, leading to energy stored in body tissues as adipose tissue (Caballero, 2007). The increase in obesity rates is linked to the current obesogenic environment (Sharpe & Bradbury, 2015). The increased availability of highly processed, energy-dense foods and decreased levels of physical activity, due to sedentary workplaces and a reliance on cars for transportation, has allowed obesity to flourish (Sharpe & Bradbury, 2015; World Health Organization, 2017).

2.2.4 Food choices leading to obesity

Certain patterns of dietary intake, such as excessive intakes of sugar and fat-containing foods, which includes fast-food items, takeaways, desserts, and sweet baked goods, have been linked to an increased risk of weight gain and obesity (Cox, Hendrie, & Carty, 2016; Drewnowski, 1997; Hwang et al., 2016). Sugar-sweetened beverages have also been identified as key contributors to the increasing rates of obesity worldwide, both in children and adults (University of Otago and Ministry of Health, 2011a). Unfortunately, these items have become easily accessible and more favoured over traditional, highly nutritious diets consisting of meats, fruits, and vegetables. The NZ Ministry of Health (2015) emphasises the importance of making healthier food choices, which involves reducing intake of foods high in saturated fats, added sugars, and salt, as these tend to be higher in energy and lower in essential nutrients.

2.2.5 Key drivers determining food selection

Food is often described as one of life's greatest pleasures due to the pleasure response experienced upon consumption. Research indicates neurotransmitters are triggered in the brain when certain foods are eaten, with clear indications towards sugar and fat-containing foods as having the greatest pleasure response (Drewnowski, 1997). Many models attempt to conceptualise the food selection process, however they generally agree that the major categories involved in the food selection process are one's life course, influences, and personal system (Connors, Bisogni, Sobal, & Devine, 2001; Furst et al., 1996; Sobal & Bisogni, 2009).

The life course is dictated by the social, cultural, and physical environments one has been exposed to, which consciously and unconsciously influences food-related decisions (Furst et al., 1996). From a nutritional perspective, the life course also sets the scene for overall nutritional status and health outcomes. Ethnic traditions and cultural-specific cuisines are a key source of dietary diversity between population groups, regardless of if they share the same physical environment (Devine, Sobal, Bisogni, & Connors, 1999; Furst et al., 1996).

Individual influences are represented by the symbolic meanings and ideals associated with food, such as personal preferences or aversions, leading to an increased or decreased intake of certain items. Resources, including money and intangible factors such as skills and knowledge, are highly influential, as they can create or remove boundaries which impact dietary selection (Furst et al., 1996). Again, one's social environment is considered, due to the social facilitation of eating and the impact this may have on food choices (Furst et al., 1996; Herman, 2017; Sobal et al., 2006).

The personal system develops as a result of making habitual food selection decisions over time, and is dictated in part by sensory perceptions, such as taste and flavour. These are often cited as being the dominating and limiting factors in food selection, but also have the ability to adapt over time (Drewnowski, 1997; Furst et al., 1996; Sobal & Bisogni, 2009). Unlike in children, adults are more able to override their taste perception cues, allowing other aspects of one's personal system, such as monetary considerations and convenience, to be considered (Drewnowski, 1997).

2.3 Measuring dietary intake in individuals

There are five main techniques to assess dietary intake frequently utilised in research, categorised into two groups; daily consumption and usual consumption, with advantages and disadvantages summarised in Table 2.2 (Gibson, 2005; Lee & Nieman, 2007). All methods are riddled with strengths and weaknesses, thus method selection should consider the study's objectives and the participant characteristics (Gibson, 2005; Lee & Nieman, 2007). Gibson (2005) summarises the choice as a compromise between collecting accurate intake data and high response rates, therefore careful deliberation must be undertaken in order to maximise data reliability.

Daily consumption assessment methods include food recalls and records, which provides a 24-hour snapshot of an individual's actual dietary intake, thus cannot be used to assume usual intake. However, by carrying out multiple 24 hour recalls or food records which span multiple days, quantitative data about usual intakes can be collected. Estimates of usual intakes are crucial when assessing potential associations between diet and disease, or when determining levels of nutrient inadequacies (Gibson, 2005).

Food frequency questionnaires (FFQ) can also be used to determine the intake of food groups and items, allowing for the analysis of specific components of one's diet (Gibson, 2005). The FFQ provides retrospective data about an individual's usual intake of food or food groups, and can also be modified to highlight usual nutrient intakes (Gibson, 2005). Several studies from other countries have demonstrated the efficacy of FFQ-use for assessing intake of food groups (Esfahani, Asghari, Mirmiran, & Azizi, 2010; Watson, Collins, Sibbritt, Dibley, & Garg, 2009; Willett et al., 2017), whereas others have reported an overestimation of intake of certain food when compared to a other collection methods (Bjerregaard, Halldorsson, Kampmann, Olsen, & Tetens, 2018; Ryu, Kim, Kim, Kyung, & Park, 2017). Comparatively, when assessing energy and macronutrient intakes using a FFQ, total energy and carbohydrate intakes were found to be valid in one study (Bjerregaard et al., 2018), however not in another (Whitton et al., 2017). These retrospective methods allow for usual intakes over an extended time period to be uncovered, which can then be linked to outcomes, such as health status or body weight profile, allowing potential determinants and causative factors to be uncovered. However, varying levels of validity from studies in other countries highlight that a FFQ should be assessed for efficacy in the potential study population of interest prior to being used, as this will improve accuracy through the inclusion of culturally-specific portion sizes and food items (Whitton et al., 2017).

Table 2.2. Strengths and weaknesses of dietary assessment tools.

Dietary assessment tool & description	Strengths	Weaknesses
	Daily consumption	
24-hour recall Participants questioned by trained interviewers about food intake over the previous 24-hour period. Specific nutrient intakes can be calculated based of food composition data.	• Assesses actual intake • Multiple recalls from many individuals are valid to assess intakes of a group/population • Inexpensive and relatively fast to administer • Low burden leads to high compliance	• Not sufficient to describe usual intake of food • Relies on memory of participants, thus unsuitable for elderly and very young population • Participants may withhold information
Estimated food records Participants record foods and beverages eaten using household measures (cups, spoons), for a specified time period. Extra detail (brand names, cooking methods, recipes) is required.	• Assesses actual or usual intakes, depending on the time frame of the record • Does not rely on memory	• Participants may not estimate portion sizes correctly, leading to errors • High participant burden may lead to low compliance rates
	Usual consumption	
Weighed food records Participants required to weigh foods and beverages consumed over a specified time period. As with estimated food records, detailed descriptions should be recorded.	• "Gold standard" for dietary assessment • Highly precise method for estimating usual intakes of individuals • Provides highly detailed dietary data • More accurate than estimated food record	• Participants may alter their diet to simplify the weighing process • High participant burden, as the process is more time-consuming than estimated food records • Significant underreporting may occur

Dietary assessment tool & description	Strengths	Weaknesses
	Usual consumption	
Diet history Participants questioned by trained interviewers to estimate their usual food intake and eating patterns over a relatively long time period.	• No limit in the variability of responses, thus overcome the limitations of a food frequency questionnaire • Can assess usual intake over a long time period • Takes seasonal dietary variations into account	• Tends to overestimate nutrient intakes • Potential interviewer bias and requires trained interviewers • Labour-intensive and time consuming
Food frequency questionnaire Uses frequency-of-use responses to assess which food items are eaten during a specified time period. Responses can be daily, weekly, monthly, or yearly.	• Relatively quick data collection process • Low participant burden • Represent participant's usual intake over an extended time period • Used to identify food patterns in a group • Relatively inexpensive to administer	• Lower data accuracy compared to other methods • May not be representative of foods or portion sizes normally selected by participants • Data can be invalid if multiple food items are contained in the same food listing

Table above adapted from Gibson (2005); (Lee & Nieman, 2007).

2.4 Measurement errors in dietary assessments

Misreporting of dietary intake is an issue, regardless of the assessment method chosen (Bedard, Shatenstein, & Nadon, 2007; University of Otago and Ministry of Health, 2011b). Respondent bias can arise from different situations, including participants misunderstanding the requests of the research team, being influenced by the interviewer's non-verbal cues, or feeling inclined to report socially desirable responses, all of which will lead to data that under or over estimates energy and nutrient intakes, (Gibson, 2005; University of Otago and Ministry of Health, 2011b).

2.4.1 Underreporting

Total energy intakes are commonly underreported in dietary assessments, with examples documented in several national nutrition surveys (Gemming, Jiang, Mhurchu, Swinburn, & Utter, 2014). Findings indicated a decrease in self-reported energy intake compared to the previous survey conducted almost a decade prior, however a significant increase in mean body weight was observed, highlighting a clear measurement error (Gemming et al., 2014). Participants may have failed to accurately record all foods consumed, underestimated their portion sizes, or changed their usual dietary habits leading to undereating (Gibson, 2005; University of Otago and Ministry of Health, 2011b). Unfortunately, this leads to an overestimation of the prevalence of nutrient deficiencies or a falsification of the relationship between diet and disease, having implications for public health interventions (Livingstone & Black, 2003; University of Otago and Ministry of Health, 2011b).

Body weight is commonly associated with under reporting, with the probability of misreporting increasing as BMI increases (Bedard et al., 2007; Gibson, 2005; Livingstone & Black, 2003). Obese respondents have been found to severely under report in specific food categories, including high-energy and high-fat foods, such as sweets and desserts, potentially as a way to avoid judgement or criticism (Gibson, 2005; Lee & Nieman, 2007). Furthermore, food groups which are perceived to be healthy or 'good', such as fruit and vegetables, are more likely to be over reported, in an effort to appear to adhere to social expectations (Bedard et al., 2007; Lee & Nieman, 2007). Women are at a higher under reporting risk compared to men, which may be credited to women possessing a greater knowledge about healthy eating patterns or having a greater social awareness, thus providing answers which reflect their impression of what they should be consuming (Price, Paul, Cole, & Wadsworth, 1997). However, other studies have displayed no associations between gender and underreporting (Gibson, 2005; Livingstone & Black, 2003).

2.4.2 Over reporting

Although not as prevalent as under reporting, over reporting does occur, leading to inaccurate energy intake values (Gibson, 2005; Livingstone & Black, 2003). Clark et al. (1994) found that women who habitually consumed large portions were more likely to over report their total energy intake, compared to those who consumed smaller portions. Conversely, respondents who consume small portions of food may feel embarrassed and wish to conceal this information, thus report larger portion sizes which they deem to be socially acceptable (Lee & Nieman, 2007).

2.4.3 Reference portion sizes

A source of error within the FFQ itself is the specification of reference portion sizes for each food item listed. Although the portion sizes are determined from naturally occurring portions or represent average portion sizes, not all respondents adhere to the reference amount (Gibson, 2005). Researchers have argued that this point is invalid, as the frequency data obtained does provide accurate information about dietary variation and can highlight deficiencies regardless of the reference portion sizes (Gibson, 2005). However, this can lead to misreporting of total energy and nutrient intakes, skewing the predictors linking diet to disease.

2.4.4 Overcoming misreporting

A need exists for strategies to reduce reporting errors in dietary assessments. Gemming et al. (2014) highlighted the potential for new technology, such as wearable cameras, to minimise the risk of under reporting in food records and recalls, however this is not an adequate solution for diet histories or food frequency questionnaires. It has become a common practice for researchers to exclude participants who misreport from the overall data set, however this could potentially eliminate those who are at high risk of poor health outcomes (Bedard et al., 2007; Gibson, 2005). By scrutinising the validity of reported energy intakes, researchers can determine the overall quality of dietary data, reducing the likelihood of bias in the results. Two of the main methods to validate dietary intake data have been detailed below.

2.4.4.1 Doubly-labelled water technique

The doubly-labelled water (DLW) technique is considered the ‘gold standard’ for the measuring energy expenditure (Livingstone & Black, 2003). Subjects are required to orally ingest a dose of water containing stable isotopes of hydrogen and oxygen, and provide urine samples over the course of the measurement period. The principles and protocols of the method has been fully detailed elsewhere (Gibson, 2005; Livingstone & Black, 2003). Measuring the isotope turnover allows for total energy expenditure to be calculated and compared to estimated energy intake (Livingstone & Black, 2003). Although the DLW technique is a highly accurate method, it is expensive and requires sophisticated laboratory techniques, thus cannot be routinely used to validate intake data for large population-based studies (Gibson, 2005; Livingstone & Black, 2003).

2.4.4.2 Goldberg equation

A more cost-effective alternative is to validate energy intake using statistical methods, such as the Goldberg equation, thoroughly detailed in Goldberg et al. (1991). This equation predicts the appropriate energy intake cut-off limits that can be used when assessing dietary intake data, taking age, gender, and body weight into consideration. Values below the calculated limit are statistically unable to maintain energy balance and survival, therefore can be deemed as incorrectly reported data sets (Bedard et al., 2007; Livingstone & Black, 2003). The Goldberg equation has demonstrated effectiveness when assessing bias in a large group, however loses its specificity when assessing intake at an individual level (Livingstone & Black, 2003).

2.5 Taste perception

Early humankind's survival was determined by the ability to forage for food that was safe to consume, whilst providing adequate energy and nutrition. Although smell and sight are key contributors to the foraging process, taste is the ultimate decision-maker (Drewnowski, 1997; Liu et al., 2016). Taste perception is the culmination of chemical makeup, odours, mechanical stimulation, temperature in the oral cavity and visual inputs, which is evaluated by the gustatory system (Breslin & Spector, 2008). Activation of the gustatory system occurs when different chemicals come into contact with the specialised taste receptors found in the oral cavity (Breslin & Spector, 2008; Low, Lacy, McBride, & Keast, 2017). This allows for food to be evaluated, ensuring that potentially toxic or noxious compounds are not consumed, increasing the chance of survival (Loper, La Sala, Dotson, & Steinle, 2015). Alongside this, taste also acts to monitor the energy content of food, signs of spoilage, and ripeness, determining if food is nutritious, while also initiating the processes involved with food digestion (Behrens & Meyerhof, 2011; Breslin & Spector, 2008; Liu et al., 2016).

2.5.1 Gustation

The process of taste perception begins with recognition and cellular-level processing, occurring in the taste buds found in the oral cavity. In humans, the oral cavity houses approximately

5,000 to 10,000 taste buds, which can be found around the surface of the tongue, the palate, and on the epiglottis (Chaudhari & Roper, 2010). The surface of the tongue, also known as the lingual epithelium, is lined with three specialised types of gustatory papillae: fungiform, foliate, and circumvallate (Besnard, Passilly-Degrace, & Khan, 2016; Liu et al., 2016). The types of papillae are defined by their spacial organisation on the tongue, with fungiform located on the tip, foliate on the sides, and circumvallate closest to the oesophagus, where the majority of the taste buds are found (Besnard et al., 2016). These three regions are innervated by different branches of the cranial nerves allowing for taste perception to be evaluated in the brain (Breslin & Spector, 2008).

Taste buds are made up of 50 to 100 neuroepithelial cells, which take up a compact, column-like form (Besnard et al., 2016; Chaudhari & Roper, 2010; Laffitte, Neiers, & Briand, 2014; Loper et al., 2015). Taste buds are directly embedded within the lingual epithelium, with their tips exposed to the environment in the oral cavity (Besnard et al., 2016; Loper et al., 2015). The fluctuating environment has resulted in taste buds having an estimated lifespan of 10 days, hence they possess a unique ability to continuously regenerate (Breslin & Spector, 2008; Chaudhari & Roper, 2010; Loper et al., 2015). Taste buds can be found at varying stages of maturation, classed into four types (Type I, II, III and Type IV or basal) (Table 2.3) (Besnard et al., 2016).

Table 2.3. Classification of taste bud cell types.

Cell type	Description	Role
Type I	• Most abundant cell type • Expresses GLAST (glutamate transporter), NTPDase2 (for ATP hydrolysis) and ROMK (controls levels of potassium)	• Terminates nerve transmission • Neurotransmitter clearance • Ion transport and redistribution
Type II	• Contains GPCRs required to stimulate action potentials • Located near nerve fibres	• Taste receptor cells to detect sweet, bitter or umami only • Are excitable
Type III	• Expresses the proteins required for signal transmission • Expresses enzymes, and voltage-gated channels	• Presynaptic cells interpret signals from Type II cells, and transmit these to the nervous system • Detect sour compounds
Type IV or basal	• No clear structure, other than having a spherical shape	• Immature taste cells, which differentiate into mature types

GLAST = glutamate aspartate transporter, NTPDase2 = nucleoside triphosphate diphosphohydrolase-2, ATP = Adenosine Triphosphate, ROMK = renal outer medullary potassium channel, GPCR = G-protein-coupled receptors;
Table above adapted from Besnard et al. (2016); Chaudhari and Roper (2010); Loper et al. (2015).

2.5.2 Physiology of taste

Nutrient detection is dependent on the processes which occur after different chemical compounds stimulate the taste buds (Chaudhari & Roper, 2010). The G protein-coupled receptors (GPCRs), located in Type II cells, are specific to one chemical compound, hence not all GPCRs can detect all taste stimuli. Simply, when chemical compounds bind to GPCRs, an increase in cellular calcium levels is observed, causing the membrane to depolarize, generating an action potential (Chaudhari, 2014; Laffitte et al., 2014; Loper et al., 2015). Adenosine triphosphate (ATP) is then released into the cellular space, ultimately communicating with type II cells to excite type III cells. The neurotransmitters released are then secreted onto afferent nerve fibres, transmitting information from the taste buds into the brain (Chaudhari & Roper, 2010; Joseph, Reed, & Mennella, 2016).

The five basic taste modalities well-explored in the literature include sweet, umami, bitter, salty and sour (Breslin & Spector, 2008; Chaudhari & Roper, 2010). More recent evidence suggests that additional taste modalities exist for the detection of fat (Besnard et al., 2016) and of carbohydrates, separate to sweet taste, in food (Chambers, Bridge, & Jones, 2009). Varying food components are involved with activating each of the taste modalities, each with their own nutritional implications, as detailed in Table 2.4.

Table 2.4. Taste modalities and their nutritionally relevant food components.

Taste modality	Nutrient/s detected	Nutritional relevance
Sweet	Carbohydrates, as mono- and di-saccharides	Key source of energy and fuel for the brain and central nervous system
Umami	Protein, as amino acids (mainly L-glutamate)	Required for muscle growth and maintenance, and overall skeletal strength
Bitter	Plant metabolites or alkaloids, poisons	Protection from poisonous substances and toxic metabolites
Salty	Sodium ions, electrolytes, other minerals	Maintains body's fluid balance and blood circulation
Sour	Stimulated by acids, but not associated with specific nutrients	Protection from ingestion of excess acids and spoiled food, maintaining the acid-base balance in the body
Fat	Lipids, oleic acid	Potentially indicating energy-density, role not yet fully established

Table above compiled from Besnard et al. (2016); Breslin and Spector (2008); Chaudhari and Roper (2010); Laffitte et al. (2014); Low et al. (2017).

2.5.3 Sweet taste

Of the basic taste qualities, sweet taste is innately preferred by humans, with new born children displaying a greater preference towards sweet solutions compared to water (Drewnowski, 1997; Eny, Wolever, Corey, & El-Sohemy, 2010; Hwang et al., 2016; Keskitalo et al., 2007). Children have also displayed an ability to select flavours and tastes associated with a higher-energy content, typical of sweet tasting foods which contain glucose (Breslin & Spector, 2008; Drewnowski, 1989). Sweet tasting compounds are detected by a GPCR, known as a heteromer, comprised of two subunits, taste receptor type 1 member 2 (TAS1R2) and taste receptor type 1 member 3 (TAS1R3) (Breslin & Spector, 2008; Dias et al., 2015; Laffitte et al., 2014). Both subunits are expressed on the fungiform papillae, but slight structural differences result in TAS1R2 being specific to sweet taste, whereas TAS1R3 also possesses the ability to detect umami taste (Dias et al., 2015).

2.5.3.1 Functions of the sweet taste receptor

Interestingly, the heteromer has been detected in organs unrelated to taste perception, such as the intestine, pancreas, brain, colon, and bladder. The cells found in the intestine are known to secrete ghrelin, an appetite-inducing hormone, which is generally suppressed following the digestion and absorption of glucose and other carbohydrates (Laffitte et al., 2014). Thus, it is suggested the heteromer's role is to influence ghrelin release after the consumption of glucose-containing foods and to control energy intake (Laffitte et al., 2014). Similarly, the heteromer has been found to activate glucagon-like peptide-1 (GLP-1) secretion following the intake of glucose or sucrose, influencing rates of stomach emptying and satiety (Laffitte et al., 2014). Interestingly, when the heteromer's function was blocked, GLP-1 was no longer secreted causing a decrease in satiety, with implications for the control of energy intake (Sigoillot, Brockhoff, Meyerhof, & Briand, 2012). The heteromer is also located on the surface of the β-cells on the pancreas (Laffitte et al., 2014). The β-cells secrete the hormone insulin in response to rising levels of glucose in the blood, which act to transport glucose out of the blood and into different tissues in the body. However, research indicates the heteromer can also replicate the functions of the β-cells, specifically following the digestion of fructose-containing foods and artificial sweeteners (Henquin, 2012).

2.5.3.2 Measuring sweet taste perception

Detection and recognition threshold testing assesses an individual's responsiveness to a sweet taste stimuli, in an attempt to determine at which specific taste concentration recognition occurs by an individual (Jayasinghe et al., 2017; Webb, Bolhuis, Cicerale, Hayes, & Keast, 2015). In contrast, suprathreshold testing determines an individual's perceived intensity rating to a particular taste concentration, which is expected to have a positive relationship with increasing concentration (Breslin & Spector, 2008; Jayasinghe et al., 2017; Webb et al., 2015). Hedonic preference is a measure of how much an individual likes or dislikes the taste component, thus is tied closely to levels of acceptance across a range of taste concentrations (Drewnowski, Henderson, Levine, & Hann, 1999). Another measure of taste perception involves assessing bitter taste, in the form of a bitter compound, propylthiouracil (PROP), allowing individuals to be classed based on their perception of intensity, which can be applied to other tastes (Webb et al., 2015). Much like with selecting dietary data collection methods, selection of taste perception method is guided by the objectives and desired outcomes of the study.

2.5.4 How taste perception leads to food selection

Briefly, individual taste perception shapes food preferences and aversions, altering one's habitual consumption patterns, ultimately dictating one's overall nutritional and health status (Drewnowski, 1997; Huh, Hong, & Youn, 2017). However, the processes leading to the development of dietary habits are complex and cannot be solely credited to individual taste perception. At a younger age when the family home is a key factor, dietary habits are determined by familial practices and cultural influences, rather than personal taste preferences (Hwang et al., 2016). Further, one's sensitivity to chemical stimuli is dependent on exposure to different foods, thus is shaped by household dietary habits (Loper et al., 2015). Evidence suggests that dietary exposure can influence the expression of taste receptor genes, altering individual taste perception (Lipchock, Mennella, Spielman, & Reed, 2013). This highlights the importance of exploring the associations between changes in dietary habits and subsequent alterations in taste receptor gene expression in future research.

2.5.5 Link between sweet taste perception and intake of sweet foods

The influence of sweet taste perception on dietary intake has been well-researched in a variety of populations, with individual differences in taste receptors found to influence the intake of specific-sweet food items (Heba et al., 2017; Jayasinghe et al., 2017; Kourouniotis et al., 2016; Low, Lacy, McBride, & Keast, 2016; Tepper, Hartfiel, & Schneider, 1996). An increased preference for sweet taste has been linked to a higher intake of sweet compounds, found in simple and complex carbohydrates; a vital source of energy in the human diet (Cicerale, Riddell, & Keast, 2012; Mattes & Mela, 1986). Although it has been suggested that those with a lower taste sensitivity may require a higher intake in order to reach an adequate intensity perception, current research is conflicting in regards to whether this leads to an increased intake of specific nutrients. Low et al. (2017) reported a higher intake of complex carbohydrates in those who were more sensitive or had a high intensity perception to complex carbohydrates, whereas Noel et al. (2017) and Dias et al. (2015) reported that those with a low sensitivity and low intensity perception to sweet taste were more likely to have a higher intake of sugar-containing foods. An adaptive mechanism was also suggested, in that participants with a low sensitivity may develop a preference towards the taste of complex carbohydrates, thus have a greater intake of these foods (Low et al., 2017). Possessing a low sensitivity to complex carbohydrates is advantageous, due to their importance in providing energy for the human body, therefore being able to detect low quantities in food sources will better ensure survival (Low et al., 2017). However, currently these high-sugar carbohydrate foods are consumed in excess, leading to energy imbalances and subsequent weight gain.

2.5.6 Differences in taste perception

Genetics

Potential differences in sweet taste perception is driven by variations in the two receptor subunits, with previous research placing a focus on the TAS1R2 subunit. Fushan, Simons, Slack, Manichaikul, and Drayna (2009) found that some of the variation in sweet taste perception could be credited to two single nucleotide polymorphisms (SNPs) within the TAS1R2 gene, leading to an alteration in gene transcription and functional changes in the subunit. Further to this, Eny et al. (2010) explored whether two genetic variations, homozygous and heterozygous, found within the TAS1R2 subunit were associated with sugar consumption, taking body mass index into account. In individuals with a BMI greater than 25kg/m^2, a significant association was found between those who carried the homozygous version of the allele and a higher sugar intake, compared to individuals with a BMI less than 25kg/m^2 (Eny et al., 2010). Comparatively, Mennella et al. (2012) found that children aged between 7 and 14 years displayed differences in their ability to detect low concentrations of sweet taste, irrespective of genetic differences in their sweet taste receptors. This indicates that genetic variation in sweet taste receptors has not been linked with sweet taste detection thresholds in children, unlike in the adult population.

Sex

Cohen and Gitman (1959) and Fikentscher, Roseburg, Spinar, and Bruchmüller (1977) found men were less sensitive to taste and more likely to incorrectly identify basic tastes compared to women. However, a limitation of this finding is that both population groups were made up of elderly participants, introducing the potentially confounding variable of age. More recent evidence indicates that these differences could be credited to lifestyle-related differences between sex groups, however further research is needed (Yoshinaka et al., 2016). Comparatively, both Hyde and Feller (1982) and Murphy (1979) found no significant differences in taste perception between males and females.

Ethnicity and country

Ethnic differences in sweet taste perception are apparent, with differences in intensity ratings for the same samples observed between an Australian group and a Malaysian group (Holt, Cobiac, Beaumont-Smith, Easton, & Best, 2000), and a Chinese group and a Caucasian American group (Bertino, Beauchamp, & Jen, 1983). Continuous exposure to certain foods is an important factor to consider when exploring taste preferences, as these can differ greatly between families, cultures, ethnic groups, and countries, depending on food availability (Tuorila, 1996). Genetic differences between ethnic groups are also apparent, therefore differences in taste receptors genes should be considered. The unfamiliarity of the flavours and taste factors associated with new foods may be of concern to some individuals, as research indicates those who have had prior exposure to a food item generally express a greater liking compared to those with no prior exposure (Tuorila, 1996).

Age

Taste function, and therefore sensitivity perception, has been found to decrease with increasing age in adults, with younger adults and children reporting a higher intensity to sweet stimuli compared to older adults (Mennella, 2014; Yoshinaka et al., 2016). Age-related decreases in taste perception has been linked with malnutrition in the elderly, due to a decreased enjoyment and subsequent decreased intake of food (Drewnowski, 1997). A study by Stevens, Cruz, Hoffman, and Patterson (1995) found that after six repeated-measures of sweet taste perception, those under 27 years displayed a higher sensitivity compared to those over 64 years. Further, younger adults were also more likely to correctly identify different taste concentrations compared to older adults, however both sex groups were included in this population group, potentially influencing results (Hyde & Feller, 1982).

Habitual dietary intake patterns

Wise, Nattress, Flammer, and Beauchamp (2016) assessed if sweet taste perception could be altered by a reduction in intake of simple sugars, as is observed with a reduced salt diet leading to a lower salt preference over time. After two months of following a low sugar diet, the experimental group rated sweet puddings as being sweeter compared to the control group, however, no significant associations were observed with hedonic preference of sweet foods, leaving the question open about whether a lower sugar intake would lead to a change in taste preference as well as habitual dietary choices.

2.6 The link between sweet taste and BMI

Previous studies exploring the associations between BMI and sweet taste have been largely inconsistent. Bartoshuk, Duffy, Hayes, Moskowitz, and Snyder (2006) highlighted that obese individuals have an increased liking for sweetness compared to underweight individuals, which increased with BMI. Similarly, obese participants perceived a sweet solution as being less intense compared to non-obese participants (Bartoshuk et al., 2006; Hwang et al., 2016; Overberg, Krude, Wiegand, & Hummel, 2012; Pepino, Finkbeiner, Beauchamp, & Mennella, 2010). Similarly, participants who were overweight or obese reported lower sensitivities to sweet taste, compared to those in the normal BMI category (Dias et al., 2015). This suggests that those with a lower sensitivity may have a higher sugar intake or chose foods higher in sugars in order to reach a sufficient level of sweetness.

Table 2.5 provides a summary of previous studies exploring associations between taste perception, dietary intake and body composition in women, however, many of these studies faced methodological limitations, which may have reduced the accuracy and reliability of the results. Drewnowski et al. (1999) indicated that a larger sample size would have provided a greater statistical power, allowing for key findings to be further explored, which may also have presented as an issue for Jayasinghe et al. (2017) and Low et al. (2016). Cicerale et al. (2012) found no relation between sweet taste intensity and dietary intake, which may be credited to the use of only one sucrose concentration to test sweet taste perception, therefore not providing an accurate representation of the varying sweetness of sweet-tasting foods. Although important findings were uncovered from these studies, small methodological changes may increase the reliability and usability of the dataset, thus should be taken into consideration for future studies.

Table 2.5. Summary of studies investigating sweet taste perception and dietary intake in females.

Author (Date), Country	Topic	Participants	Method	Findings
Drewnowski et al. (1999), USA	Relationship between taste responses, food preferences and dietary outcomes	159 females, aged 20-60 years, living in Michigan, USA	• PROP and sucrose taste thresholds and suprathreshold scaling rated on scales. • 3-day food records to assess dietary intake	• Higher preferences for aqueous sucrose samples was associated with increased preference and intake of sweet desserts
Cicerale et al. (2012), Australia	Perceived intensity of sweet taste, food behaviours and dietary intake related to sugar consumption	85 university students, aged >18 years, living in Australia	• Sucrose solution rated on a general Labelled Magnitude Scale (gLMS) for sweet intensity • 24 hour recalls for dietary intake • Self-reported height and weight to calculate body mass index (BMI)	• No significant associations between intensity ratings and food variety, or with energy intake, or macronutrient intake.
Ettinger, Duizer, and Caldwell (2012), Canada	BMI and body fat measures, sweet taste perception and preference	72 females, aged 18-49 years, living in Canada	• Detection thresholds measured using sucrose solutions and perceived liking using custard samples. • BMI and body fat percentage (BF%) from skin fold sites	• Those in the overweight BMI category and with higher BF% had higher sweet threshold values and higher liking of sweetness compared to women of a normal weight

Author (Date), Country	Topic	Participants	Method	Findings
Jayasinghe et al. (2017), New Zealand	Sweet taste perception, and sweet food liking and intake	44 NZ European females, aged 20-40 years, living in Auckland, New Zealand	• Taste perception measures (detection threshold recognition threshold, intensity, and hedonic liking) using glucose samples • 4-day weighed food record, 69-item sweet-food food frequency questionnaire (FFQ), and sweet beverage liking questionnaire for dietary intake	• A significant relationship between liking and intensity of sweet taste, and dietary intake of sweet foods was observed, summarised as a high sweet food intake leading to a lower sweet taste perception
Low et al. (2016), Australia	Sweet taste function, anthropometry, and dietary intake	60 participants, aged 18-52 years, living in Melbourne, Australia	• Three measures of sweet taste perception (detection threshold, recognition threshold, suprathreshold intensity) using artificial sweeteners • BMI calculations and waist circumference measures • 80-item FFQ for dietary intake	• No significant associations between sweet taste and BMI or waist circumference, or with energy and macronutrient intakes • No significant associations between sweet taste and intake of sugar-sweetened foods

Author (Date), Country	Topic	Participants	Method	Findings
Pepino and Mennella (2012), USA	Hedonic response to sweet taste, habitual dietary intake and food consumption, in obese and normal BMI groups	54 females, aged 21-40 years, living in Pennsylvania, USA	• Sucrose and monosodium glutamate (MSG) detection thresholds rated on a gLMS	• Intensity and preference ratings did not differ between the BMI groups • however obese women had a higher preference upon repeated exposure to same tastant
Pepino et al. (2014), USA	Relationship between weight loss, taste perception, and eating behaviour	27 obese females, living in Missouri, USA	• Threshold sensitivities to sweet, salty, and savoury, rated on a gLMS • Eating behaviour rated on questionnaires assessing cravings and preferences	• Weight loss was associated with a decreased preference to sweet concentrations, decreased perceived sweetness, and decreasing cravings for sweet and fast- foods

PROP = 6-n-propylthiouracil, FFQ = food frequency questionnaire, BMI = body mass index, BF% = body fat percentage, gLMS = general Labelled Magnitude Scale.

2.7 Summary

The interest in taste perception and its role in the pathways which drive the relationship between food selection, dietary intake, and health outcomes provides a key opportunity to combat the global issue of obesity. The current obesogenic environment promotes the intake of highly processed, energy-dense foods, thus investigating taste as one of the factors influencing food intake will provide a better understanding of potential interventions and strategies to modify the current food environment.

Emerging data highlights that taste perception, particularly sweet taste, may be involved with a number of key pathways driving dietary intake and thus contributing to obesity. Genetic differences have been found to influence variation in taste perception, in particular with the genes coding for sweet taste receptors. Humans display an innate preference to sweet tasting foods, however this has led to the overconsumption of these high-energy, nutrient-poor food items, resulting in an imbalance of energy. Therefore, understanding individual differences in sweet taste sensitivity may provide evidence for public health campaigns to address the global epidemic of obesity.

The World Health Organisation has documented a global strategy for promoting healthy body weights, through the improvement of diet and physical activity levels (2004). The strategy highlights the important role the government can play in creating a health-promoting environment. Alongside other stakeholders, such as the food industry, changes must be made globally, regionally, and locally to enable the population to live healthier lives. Previous interventions and education strategies have been aimed at improving the nutritional quality of diets by increasing intakes of nutrient-rich foods and decreasing intakes of energy-dense, nutrient-poor foods. However, more current research suggests that taste perception, alongside other social and environmental factors, should be considered in future interventions, as this may increase the level of success and improve global health outcomes.

Chapter 3 - Research study manuscript

Note: This chapter has been prepared in manuscript format, and was edited in-line with article submission guidelines for the journal 'Nutrients'. The style of referencing in this manuscript differs from journal guidelines to ensure consistency between the chapters of this thesis and to adhere to university guidelines. Additional methodological details are included in Appendix A, supplementary results are included in Appendix B, and questionnaires and materials used are included in Appendix C.

Exploring the associations between sweet taste perception and habitual dietary intake in New Zealand European women

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3.1 Abstract

Background: Obesity is a global epidemic, leading to the development of chronic diseases. Sweet taste perception is a potential driver of dietary intake, thus exploring associations between sweet taste perception and dietary intake may contribute to the understanding of obesity development. **Aim:** To investigate associations between sweet taste perception and habitual dietary intake in women of two distinct body mass index (BMI) groups, obese (BMI ≥30 kg/m^2) and normal (BMI ≥18.5 - 24.9 kg/m^2). **Methods:** One hundred and forty eight NZ European women, aged 18-45 years, were presented with four glucose concentrations and rated sweet hedonic liking and perceived sweet taste intensity of each. A 220-item food frequency questionnaire was used to assess dietary intake, and height and weight were measured to calculate BMI. **Results:** Negative correlations between sweet hedonic liking and perceived sweet taste intensity were observed at the two highest concentrations for the obese group, and at all four concentrations for the normal group. Correlations were observed between carbohydrate and sugar intake and hedonic liking, and between intake of sweet beverages and preference ratings for the obese group, at the highest glucose concentration. **Conclusions:** The findings highlight a clear BMI-specific association between hedonic

preference and perceived intensity of sweet taste, with intake of macronutrients and sugars, and with intake of sweet food groups.

Key words: *sweet hedonic liking, perceived sweet taste intensity, dietary intake, macronutrients, obesity*

3.2 Introduction

National data from the New Zealand Ministry of Health highlight an increasing prevalence of obesity in the population, coupled with a subsequent rise in the rates of chronic disease development (Ministry of Health, 2016; World Health Organization, 2017). In New Zealand (NZ), nearly a third of adults are obese - a figure which has steadily increased over the past decade from 27% to 32% (Ministry of Health, 2016). This can be credited to a consistent imbalance between energy consumed and energy expended, leading to weight gain and obesity. This is further assisted by the current obesogenic environment, which increases the accessibility of nutrient-poor, energy-dense foods and decreases opportunities for daily physical activity (Sharpe & Bradbury, 2015; World Health Organization, 2017).

Gustation is the process which occurs when substances in the mouth interact with taste receptors found on taste buds. This results in signals being sent to the brain and interpreted as one of the five tastes currently established; sweet, bitter, sour, salty, and umami (Drewnowski, 1997). These taste sensations allow individuals to assess if food is safe to consume, ensuring that toxins and poisonous compounds are rejected (Drewnowski, 1997; Liu et al., 2016). Taste perception also leads to the development of food preferences or aversions, further emphasising taste's contribution to influencing dietary habits (Sobal et al., 2006).

Previous research has proposed that individuals with a lower sensitivity and a higher preference for sweet taste are more likely to consume a diet higher in sugars, compared to those with a higher sensitivity (Dias et al., 2015; Noel et al., 2017). Further, those individuals with a higher habitual sugar intake will more likely have an excessive energy intake, leading to weight gain and obesity (Dias et al., 2015; Noel et al., 2017). A better understanding of the differences in taste perception between individuals may offer an explanation about the dietary behaviours leading to weight gain, and poor health outcomes.

The present study aimed to (i) explore the differences in habitual dietary intakes of NZ European women, using data from a food frequency questionnaire (FFQ), (ii) investigate their sweet taste perception, specifically assessing sweet hedonic liking and perceived sweet taste intensity ratings to varying glucose concentrations and (iii) explore associations between sweet taste perception, dietary intake, and body mass index (BMI).

3.3 Methods

3.3.1 Study design

This was a sub-study of the PROMISE ("**PR**edictors linking **O**besity and gut **MI**crobiom**E**") study, using preliminary data from the NZ European cohort. The PROMISE study is a cross-sectional study, aiming to examine key pathways that modify the gut microbiome and influence body weight and long-term health of women living in NZ, of NZ European and Pacific ethnicity. Participants were categorised into two distinct BMI groups; obese (BMI ≥30 kg/m^2) and normal (BMI ≥18.5 - 24.9 kg/m^2). The protocol utilised in the PROMISE study was designed and carried out by members of the PROMISE research team.

3.3.2 Participants

One hundred and forty eight post-menarche, pre-menopausal NZ European women, aged between 18-45 years, living in Auckland, NZ, were eligible for inclusion in this study (Figure 3.1.).

Participants were recruited using social media, primary healthcare service providers, previous research databases and a recruitment agency. Participants were screened using an online screening questionnaire to determine their eligibility. Exclusion criteria included those who were currently pregnant, breastfeeding, or presented with a chronic illness. The ethics application for this study was prepared and submitted by the PROMISE research team. The study was approved by the Southern Health and Disability Ethics Committee (16/STH/32). All participants were informed in detail about the procedures involved and gave written consent.

Participants visited the Human Nutrition Research Unit at Massey University, Albany campus for two visits over a 14-day period. They were required to be in a fasted state for Visit 1, prior to completing sweet taste perception measurements and anthropometric measurements. Visit 2 involved the completion of a food frequency questionnaire (FFQ), alongside additional anthropometric measurements, taken using a standardised protocol (Appendix A.1).

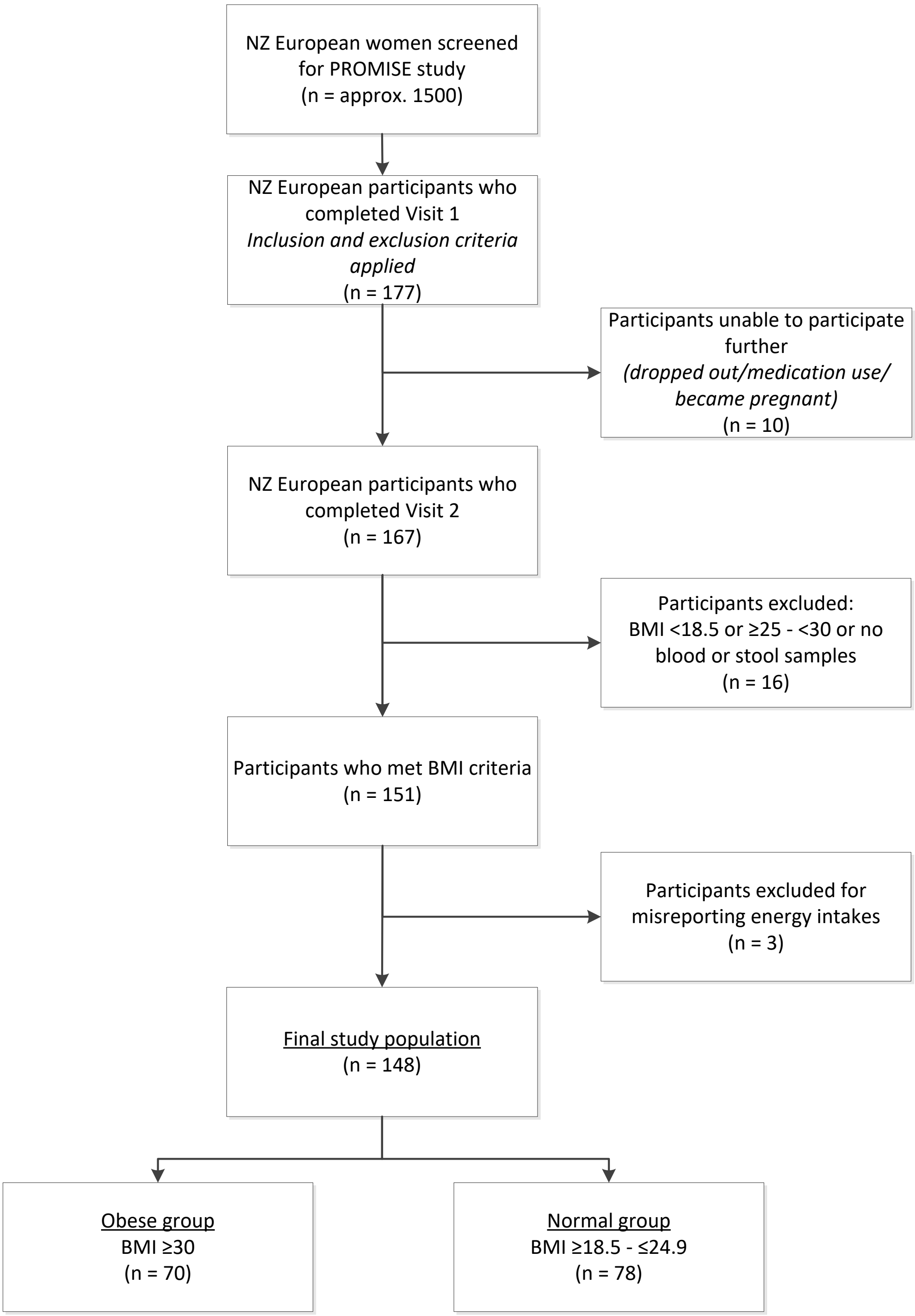


Figure 3.1. Outline of the recruitment process.

3.3.3 Sweet taste perception procedure

Taste perception measurements were undertaken in a controlled environment in the sensory research facility at Massey University, Albany campus. Participants were placed in individual testing booths and presented with four aqueous 10 mL samples of varying glucose concentrations in a computer-generated random order (163mM, 325mM, 650mM, 1300mM). They were instructed to take the whole sample into their mouth and use a sip-and-spit procedure (Lim, Urban, & Green, 2008). Distilled drinking water was offered in-between all samples as a mouth rinse. Hedonic liking and perceived intensity for each sample was rated on a 100 mm general Labelled Magnitude Scale (gLMS) (Appendix A.2) (Bartoshuk et al., 2004). The liking scale ranged from "strongest imaginable dislike of any kind" (-50 mm) to "strongest imaginable like of any kind" (50 mm) and the intensity scale ranged from "no sensation" (0 mm) to "strongest imaginable sensation of any kind" (100 mm).

3.3.4. Aqueous sweet sample preparation

Samples were prepared fresh on each day of testing, following a set protocol to make a 240mL stock solution with a molarity of 1300mM, consisting of 57.7g of glucose powder (Food Grade, Sherratt Ingredients, New Zealand), and 200mL of filtered bottled water. Serial dilutions using filtered bottled water were created from the stock solution (Table 3.1). A second protocol was created for when five or more participants were being tested to allow for a greater volume of stock solution to be created (Appendix A.3).

Table 3.1. Aqueous sample preparation for sweet taste perception testing.

Molarity	Glucose solution required	Water required
1300mM	57.7g glucose powder	200ml (final volume of 240mL)
650mM	100 ml from 1,300mM	100ml
325mM	100ml from 650mM	100ml
163mM	100ml from 325mM	100ml

3.3.5 Food frequency questionnaire

Each participant completed a 220-item, semi-quantitative FFQ, to assess their dietary intake over the previous month (Appendix C) (Houston, 2014). Participants indicated their frequency of intake using the following frequencies: never, less than once a month, 1 to 3 times a month, once a week, 2 to 3 times a week, 4 to 6 times a week, once a day, 2 to 3 times a day, and 4 or more times per day.

3.3.6 Dietary data measurements

FFQ data was converted into daily frequency equivalents (DFE) by allocating the nine frequency categories with a value proportional to 1.0, representing once a day (Appendix A.4). DFEs were entered into FoodWorks 8 (Professional edition, Xyris Software Pty Ltd, Australia, 2015) using a template specific for the FFQ (assumptions detailed in Appendix A.5) (Kruger et al., 2015). Data was analysed to determine energy and nutrient profiles for each participant, utilising the NZ FOODfiles 2014 data set (Sivakumaran, Huffman, & Sivakumaran, 2017). A total of 69 sweet foods were extracted from the FFQ and classified into 8 sweet food categories, replicating previous NZ-specific studies (Table 3.2) (Jayasinghe et al., 2017; Rivers, 2015). Sweet categories were ranked by total intake (as DFEs) with mean intake (as DFEs) and a single score for total sweet food intake also calculated. The top 30 most frequently consumed items were identified, ranked by total intake (as DFEs). Total intake, as grams per day (g/d), and mean daily intake, as grams per person per day (g/p/d), was also reported.

Table 3.2 Sweet food groupings used for dietary analysis.

Sweet food groups	Sweet food items included
Dairy	Flavoured milk, yoghurt, milk pudding
Cereals	Muesli, bran, bran-based, light and fruity, chocolate-based, sweetened cereals, breakfast drinks, muesli bars
Starchy vegetables	Pumpkin, kumara, sweet corn, beetroot
Fruit	Apple, pear, banana, orange, peach, mango, pineapple, grapes, strawberry, melon, kiwifruit, feijoas, tamarillo, sultanas, raisins, other dried fruit
Beverages	Fruit juice, fruit drink, iced tea, cordial, low-calorie cordial, energy drinks, energy drinks sugar-free, diet soft drink, regular soft drink, sport's drinks, flavoured water, hot chocolate, Milo, wine cooler, sparkling grape juice, ready-to-drink alcoholic drinks (RTD's), cider
Baking/sweets	Waffles, pancakes or pikelets, iced buns, cakes, sweet pies/pastries, other puddings/desserts, plain biscuits, fancy biscuits, lollies/sweets, chocolate
Desserts	Jelly, ice block, ice cream, custard
Spreads/ sweeteners	Sugar added to food/drinks, jam, honey

3.3.7 Misreporting criteria

Participants who misreported their dietary intake were excluded from the total sample, using individual estimations of daily energy expenditure compared to their estimated energy intake, from the FFQ (Appendix A.6) (Rhee et al., 2015; Westerterp, 2004). A combination of estimated daily energy expenditure and international cut-off margins was used to assess the plausibility of reported daily energy intake. For any participant identified outside of these parameters, their dietary intake data was individually scrutinised before being excluded.

3.3.6 Statistical analysis

IBM SPSS software for Windows (Statistical Package for the Social Sciences, Version 23, IBM Corporation, Chicago, IL, USA) was used. All data was treated as normally distributed according to the Central Limit Theorem (Field, 2013), since the sample size was greater than 30. Descriptive statistics for baseline participant characteristics, hedonic preference and perceived intensity ratings, energy and macronutrient profiles, and intake frequency of sweet food groups were reported as the mean ± standard deviation (SD). Categorical data, such as body fat percentage categories, were described as counts, frequencies, and percentages. When comparing the two BMI groups for significant differences, independent samples t-tests were used for continuous variables and chi-square test was used for categorical variables. Associations between continuous variables were investigated using Pearson's correlation coefficients. A $p < 0.05$ was considered to be statistically significant.

3.4 Results

3.4.1 Participant characteristics

The final participant number used for data analysis was 148. Participant characteristics for the obese group and normal BMI group are reported in Table 3.3.

Table 3.3. Participant characteristics for total group, and compared between obese and normal body mass index (BMI) groups.

Characteristics	Total (N = 148)	Obese BMI[a] (N = 70)	Normal BMI[a] (N = 78)
Age (years)	32 ± 7	34 ± 7	30 ± 6
Weight (kg)	78.1 ± 19.3	96.2 ± 11.5	61.9 ± 5.5
Height (m)	1.67 ± .06	1.68 ± .07	1.67 ± .06
BMI (kg/m^2)	27.9 ± 6.5	34.2 ± 3.0	22.1 ± 1.5
Waist circumference (cm)	85.2 ± 14.9	99.0 ± 8.8	72.8 ± 4.9
Hip circumference (cm)	108.8 ± 13.4	121.3 ± 7.4	97.7 ± 4.9
WHR (cm)	0.78 ± .06	0.82 ± 0.06	0.75 ± 0.05
BF% (%)	34.2 ± 10.6	44.1 ± 4.6	25.3 ± 5.4
BF% categories N (%)[b]			
Low[b]	22 (14.9)	0 (0)	22 (28.2)
Normal[b]	39 (26.4)	0 (0)	39 (50)
High[b]	87 (58.8)	70 (100)	17 (21.8)

BMI = body mass index, BF% = body fat percentage, WHR = waist:hip ratio;

Body fat percentage categories are reported as count (percentage), all others reported as mean ± standard deviation;

[a] BMI groups: Obese: ≥30 kg/m^2, Normal: ≥18.5 - 24.9 kg/m^2 (World Health Organization, 2006);

[b] Body fat percentages defined as: Low: <22%, Normal: 22-29.9%, High: ≥30% (Kruger et al., 2015).

3.4.2 Sweet hedonic liking and perceived sweet taste intensity

In both the obese and normal BMI groups, the highest glucose concentration (1300mM) had the lowest hedonic liking rating of the four concentrations (Table 3.4). Overall, there were no significant differences in liking rating between the BMI groups across all four concentrations. The normal BMI group perceived all four concentrations as more intense than the obese BMI group, with a significant difference observed at the highest sweet taste concentration (1300mM) ($p = 0.035$).

Table 3.4. Sweet hedonic liking and perceived sweet taste intensity ratings for four sweet taste concentrations compared between obese and normal body mass index (BMI) groups.

Sweet hedonic liking rating			
Glucose concentration (mM)	**Obese (mm)[a] (N = 70)**	**Normal (mm)[a] (N = 78)**	**P-value**
163	-1 ± 15	2 ± 19	0.232
325	1 ± 15	2 ± 24	0.758
650	5 ± 21	-3 ± 29	0.075
1300	-9 ± 31	-17 ± 37	0.156
Perceived sweet taste intensity rating			
163	17 ± 13	19 ± 18	0.405
325	29 ± 21	38 ± 33	0.057
650	59 ± 37	72 ± 42	0.054
1300	102 ± 46	118 ± 43	**0.035**

Values reported as mean ± standard deviation;

Differences between BMI groups at each concentration analysed using independent samples t-test, statistically significant values are highlighted in bold;

[a]BMI groups: Obese: ≥30 kg/m^2, Normal: ≥18.5 - 24.9 kg/m^2 (World Health Organization, 2006).

3.4.2 Relationship between sweet hedonic liking ratings and perceived sweet intensity ratings

Significant negative correlations were observed at the two highest glucose concentrations (650mM and 1300mM) between sweet hedonic liking and perceived sweet intensity for the obese group, and at all four concentrations for the normal BMI group (Figure 3.2).

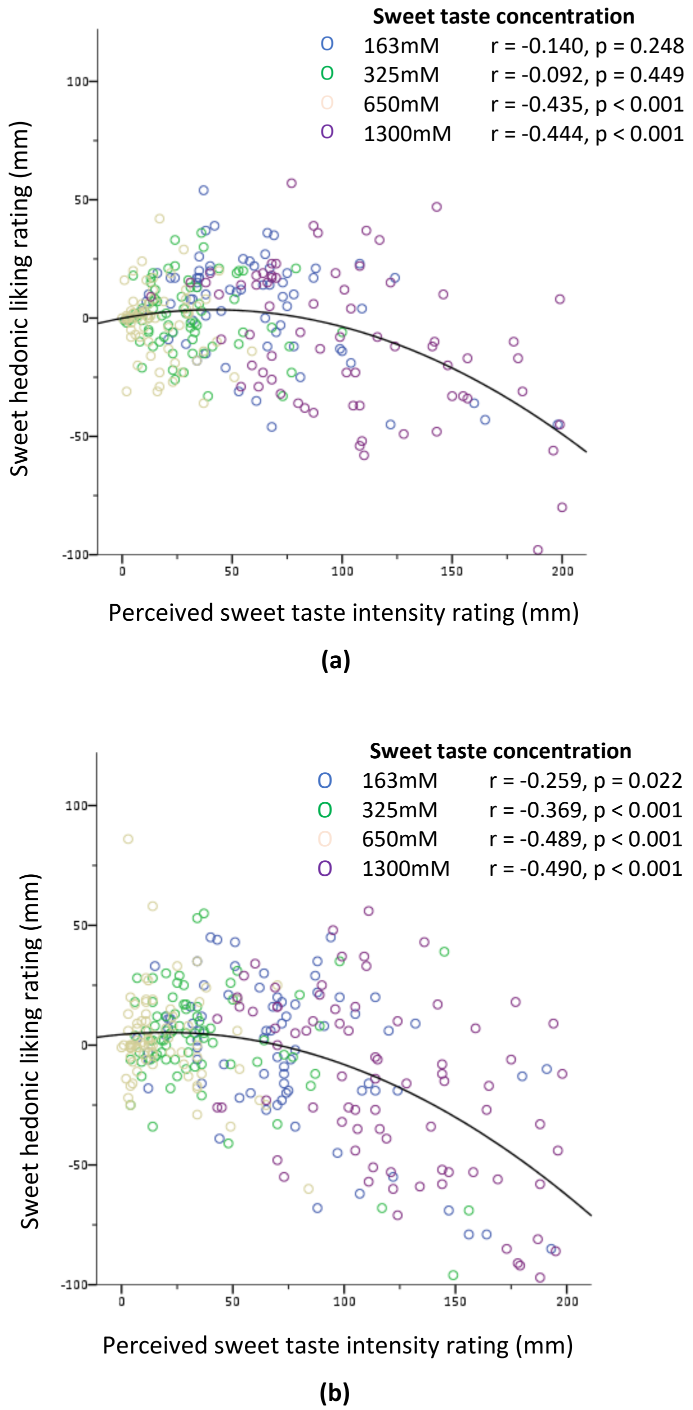


Figure 3.2. Scatterplot of the relationship between sweet hedonic liking and perceived sweet taste intensity for four sweet taste concentrations: (**a**) obese BMI group (N = 70); (**b**) normal BMI group (N = 78).

3.4.3 Energy and macronutrient distribution profiles

The energy and nutrient intake profiles for both BMI groups were explored, with no significant differences observed between the obese and normal BMI groups (Table 3.5). When compared to the Nutrient Reference Values (NRVs), only intakes of protein and monounsaturated fat for both BMI groups and polyunsaturated fat for the normal group (as percentages of total energy) were deemed to be within an adequate range. Carbohydrate intake for both BMI groups and polyunsaturated fat intake for the obese group were below the respective NRVs, with all other nutrients were above the NRVs for both groups.

Table 3.5 Energy and macronutrient distribution profiles compared between obese and normal body mass index (BMI) groups.

Energy/Nutrients	NRV	Obese[a] (N = 70)	Normal[a] (N = 78)	P-value
Total Energy (kJ)	8200-8700[c]	9057.9 ± 2680.1	8922.5 ± 2626.4	0.757
Protein (g)	37g[d]	96.2 ± 30.9	95.4 ± 35.3	0.889
% of TE	15-25%[e]	18.1 ± 2.9	18.2 ± 3.7	0.931
Carbohydrate (g)	-	209.9 ± 76.7	200.6 ± 62.5	0.419
% of TE	45-65%[e]	38.2 ± 8.2	37.4 ± 6.6	0.477
Total sugars (g)[b]	-	102.6 ± 35.5	98.0 ± 32.4	0.407
Dietary fibre (g)	25g[g]	28.4 ± 10.4	29.5 ± 12.1	0.535
Total fat (g)	-	95.0 ± 32.5	93.7 ± 33.6	0.818
% of TE	20-35%[e]	39.7 ± 7.3	39.6 ± 5.7	0.909
Saturated fat (g)	-	35.6 ± 19.3	34.2 ± 18.1	0.650
% of TE	<10%[e]	16.2 ± 4.3	15.7 ± 3.7	0.434
Monounsaturated fat (g)	-	29.1 ± 13.6	30.2 ± 15.5	0.666
% of TE	10-20%[f]	13.5 ± 2.7	13.8 ± 2.5	0.456
Polyunsaturated fat (g)	-	12.5 ± 5.7	13.5 ± 7.0	0.340
% of TE	6-10%[f]	5.9 ± 1.4	6.2 ± 1.6	0.177

NRV = Nutrient Reference Values for New Zealand, kJ = kilojoules, TE = total energy;
NRVs based on women aged 19-30 and 31-50 years old (National Health and Medical Research Council, 2006);
Values for obese and normal reported as mean ± standard deviation; Differences between BMI groups analysed using independent samples t-test;
[a] BMI groups: Obese: ≥30 kg/m^2, Normal: ≥18.5 - 24.9 kg/m^2 (World Health Organization, 2006);
[b] Total sugars includes glucose, fructose, sucrose, lactose and maltose;
[c] NRV-EER (Estimated Energy Requirement);
[d] NRV-EAR (Estimated Average Requirement);
[e] NRV-AMDR (Acceptable Macronutrient Distribution Range);
[f] NRV-SDT (Suggested Dietary Target);
[g] NRV-AI (Adequate Intake).

3.4.4 Sweet food categories

The three most frequently consumed sweet food categories for the obese BMI group were fruit, baking/sweets, and beverages, whilst the normal group had the same top two, with starchy vegetables ranked third (Table 3.6). The dessert category was the least frequently consumed category for both BMI groups. A significant difference in mean intake was observed for the beverages category, with the obese group consuming almost twice that of the normal group (0.86 DFEs vs 0.43 DFEs, respectively, p = 0.002).

Table 3.6. Frequency of intake of sweet food categories compared between obese and normal body mass index (BMI) groups.

	Obese[a] (N = 70)			Normal[a] (N = 78)		
Sweet food category	**Rank**	**Total intake (DFE)[b]**	**Mean intake (DFE)[b]**	**Rank**	**Total intake (DFE)[b]**	**Mean intake (DFE)[b]**
Fruit	1	121.3	1.73 ± 1.16	1	149.5	1.92 ± 1.21
Baking/sweets	2	97.8	1.39 ± 1.22	2	82.1	1.05 ± 1.09
Beverages	3	59.9	0.86 ± 0.97	5	33.7	**0.43 ± 0.54****
Spreads/sweeteners	4	47.9	0.68 ± 1.28	4	38.7	0.50 ± 0.72
Starchy vegetables	5	37.2	0.53 ± 0.42	3	41.3	0.53 ± 0.40
Cereals	6	30.3	0.43 ± 0.76	6	30.8	0.39 ± 0.57
Dairy	7	22.5	0.32 ± 0.41	7	21.6	0.28 ± 0.31
Dessert	8	10.5	0.15 ± 0.19	8	8.1	0.10 ± 0.14
Total sweet food	-	*427.4*	-	-	*405.8*	-

DFE = daily frequency equivalent;

Values for total intake reported as a count and mean intake as mean ± standard deviation;

Differences in mean intake between BMI groups analysed using independent samples t-test, statistically significant differences are highlighted in bold, **P < 0.01;

[a] BMI groups: Obese: ≥30 kg/m^2, Normal: ≥18.5 - 24.9 kg/m^2 (World Health Organization, 2006);

[b] DFE scores: Never: 0; <1x/month: 0.01; 1-3x/month: 0.07; 1x/week: 0.14; 2-3x/week: 0.36; 4-6x/week: 0.71; Once/day: 1.0; 2-3x/day: 2.5; 4+x/day: 4.0.

3.4.5 Top 30 sweet food items

When exploring the frequency of intake of sweet food items, the normal BMI group consumed bananas in the greatest frequency, followed by chocolate (Table 3.7). Comparatively, the obese group reported sugar added to food/drinks as their most frequently consumed item, also followed by chocolate similar to the normal group. Apples were the third most frequently consumed item for both BMI groups.

The obese BMI group consumed diet soft drinks and lollies/sweets twice as much as the normal group (64.79 grams, per person, per day (g/p/d) vs 24.74 g/p/d, p = 0.015, and 2.82 g/p/d vs 1.13 g/p/d, p = 0.009, respectively). Significant differences were found for intake of sweet pies/pastries, with the obese group consuming 4.32 g/p/d compared to the 2.38 g/p/d consumed by the normal group (p = 0.046). This was further reflected by each item's rank, with diet soft drinks ranked 7^{th} vs 20^{th}, lollies/sweets ranked 10^{th} vs 23^{rd}, and sweet pies/pastries ranked 23^{rd} vs 30^{th} for the obese and normal group, respectively.

The eight sweet food categories were all represented in the top 30 for both BMI groups. The fruit category appeared the most frequently for both BMI groups, with 11 items reported for the normal group and eight for the obese group. Six items each from the baking/sweets, spreads/sweeteners, and vegetables categories featured for both BMI groups. The categories with the lowest representation were dairy and dessert, each reflected by only one item, yoghurt and ice cream, respectively, for both BMI groups.

Table 3.7. Top 30 sweet food items ranked by total intake (DFE) compared between obese and normal body mass index (BMI) groups.

	Obese[a] (N = 70)				Normal[a] (N = 78)			
Sweet food items (weight)	**Rank**	**Total intake (DFE)[b]**	**Total intake (g/d)**	**Mean intake (g/p/d)**	**Rank**	**Total intake (DFE)[b]**	**Total intake (g/d)**	**Mean intake (g/p/d)**
Sugar in food and drinks (4.9g)	1	33.04	161.90	2.31	6	18.26	89.47	1.15
Chocolate (40g)	2	28.90	1156.00	16.51	2	25.95	1038.00	13.31
Apple (130g)	3	23.20	3016.00	43.09	3	24.32	3161.60	40.53
Banana (128g)	4	22.69	2904.32	41.49	1	34.22	4380.16	56.16
Orange (128g)	5	21.00	2688.00	38.40	7	16.57	2120.96	27.19
Yoghurt (123.5g)	6	20.99	2592.27	37.03	5	20.34	2511.99	32.21
Diet soft drink (250g)	7	18.14	4535.00	64.79	20	7.72	1930.00	**24.74***
Plain biscuits, cookies (18g)	8	16.75	301.50	4.31	13	11.84	213.12	2.73
Jam, honey, marmalade (6.9g)	9	14.82	102.26	1.46	4	20.47	141.24	1.81
Lollies/sweets (14g)	10	14.12	197.68	2.82	23	6.28	87.92	**1.13****
Kumara (173.3g)	11	13.56	2349.95	33.57	8	15.39	2667.09	34.19
Fancy biscuits (22g)	12	13.27	291.94	4.17	11	13.90	305.80	3.92
Muesli bars (32g)	13	12.99	415.68	5.94	15	9.74	311.68	4.00
Dried fruit (prunes) (33.6g)	-	-	-	-	14	10.27	345.07	4.42
Cakes, sweet muffins (60g)	14	12.68	760.80	10.87	12	13.81	828.60	10.62
Strawberries (78.8g)	15	11.35	894.38	12.78	10	14.37	1132.36	14.52
Pumpkin (110g)	16	9.40	1034.00	14.77	18	8.59	944.90	12.11
Hot chocolate drinks (7.4g)	17	9.27	68.60	0.98	28	4.81	35.59	0.46
Kiwifruit (100g)	18	8.55	855.00	12.21	21	6.70	670.00	8.59

Sweet food items (weight)	Rank	Total intake (DFE)[b]	Total intake (g/d)	Mean intake (g/p/d)	Rank	Total intake (DFE)[b]	Total intake (g/d)	Mean intake (g/p/d)
	Obese[a] (N = 70)				Normal[a] (N = 78)			
Beetroot (90g)	20	7.53	677.70	9.68	16	9.14	822.60	10.55
Muesli (cereal) (53g)	21	7.50	401.25	5.73	9	14.98	801.43	10.27
Pear (122g)	22	7.34	895.48	12.79	17	8.92	1088.24	13.95
Feijoas (30g)	-	-	-	-	22	6.29	188.70	2.42
Sweet pies/pastries (42g)	23	7.20	302.40	4.32	30	4.42	185.64	**2.38***
Sweet corn (132.5g)	24	6.71	889.08	12.70	19	8.18	1083.85	13.90
Sultanas (14g)	-	-	-	-	24	6.18	86.52	1.11
Soft drinks (260g)	25	6.67	1734.20	24.77	-	-	-	-
Ice cream (142.5g)	26	6.30	897.75	12.83	29	4.75	676.88	8.68
Grapes (45g)	27	5.93	266.85	3.81	25	6.05	272.25	3.49
Milo (2.6g)	-	-	-	-	27	5.14	13.36	0.17
Fruit juice (260g)	28	4.51	1172.60	16.75	-	-	-	-
Peach (143g)	29	4.33	619.19	8.85	26	5.63	805.09	10.32
Bran-based cereals (50g)	30	4.21	210.50	3.01	-	-	-	-

=Fruit **=Baking/ sweets** **=Beverages** **=Spreads/ sweeteners** **=Vegetables** **=Cereals** **=Dairy** **=Dessert**

DFE = daily frequency equivalent; g/d = grams per day; g/p/d = grams per person per day;

Differences in mean intake between BMI groups analysed using independent samples t-test; *Statistically significant differences highlighted in bold *P < 0.05, **P < 0.01;

[a]BMI groups: Obese: ≥30 kg/m^2, Normal: ≥18.5 - 24.9 kg/m^2 (World Health Organization, 2006);

[b]DFE scores: Never: 0; <1x/month: 0.01; 1-3x/month: 0.07; 1x/week: 0.14; 2-3x/week: 0.36; 4-6x/week: 0.71; Once/day: 1.0; 2-3x/day: 2.5; 4+x/day: 4.0.

3.4.6 Associations between sweet hedonic liking ratings and energy and macronutrient profiles

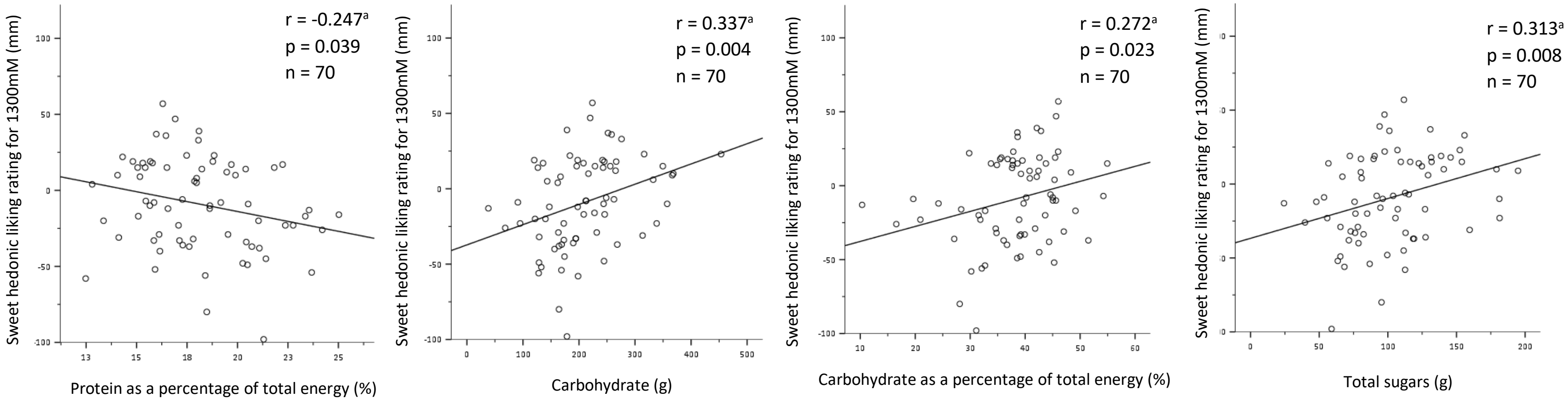
A negative correlation was observed between intake of protein (in grams) and liking for the highest glucose concentration (1300mM), indicating that as hedonic liking rating increased, intake of protein decreased (r = -0.247, p = 0.039) (Figure 3.3a). The strongest positive correlation was observed between liking for the highest glucose concentration and intake of carbohydrates (in grams) for the obese group (r = 0.337, p = 0.004) (Figure 3.3b). Carbohydrate (as a percentage of total energy) was positively correlated with the highest glucose concentration for both BMI groups (Figures 3.3c and 3.4a). Total sugar intake was also associated with liking for the highest concentration for the obese group (Figure 3.3d). Negative correlations were also observed between intake of total, mono, and poly-unsaturated fats for the normal group (Figures 3.4b-d).

Significant positive correlations were observed between liking for the second highest glucose concentration (650mM) and intake of carbohydrate (as a percentage of total energy) (r = 0.281, p = 0.018) and intake of total sugars (r = 0.257, p = 0.032) for the obese BMI group (Appendix B.1). A negative correlation was also observed at the same concentration with intake of total fat (as a percentage of total energy) for the same BMI group (r = -0.250, p = 0.037). No significant correlations were observed at the two lowest concentrations, 163mM and 350mM, for either BMI group (Appendix B.1).

3.4.7 Association between perceived sweet taste intensity ratings and energy and macronutrient profiles

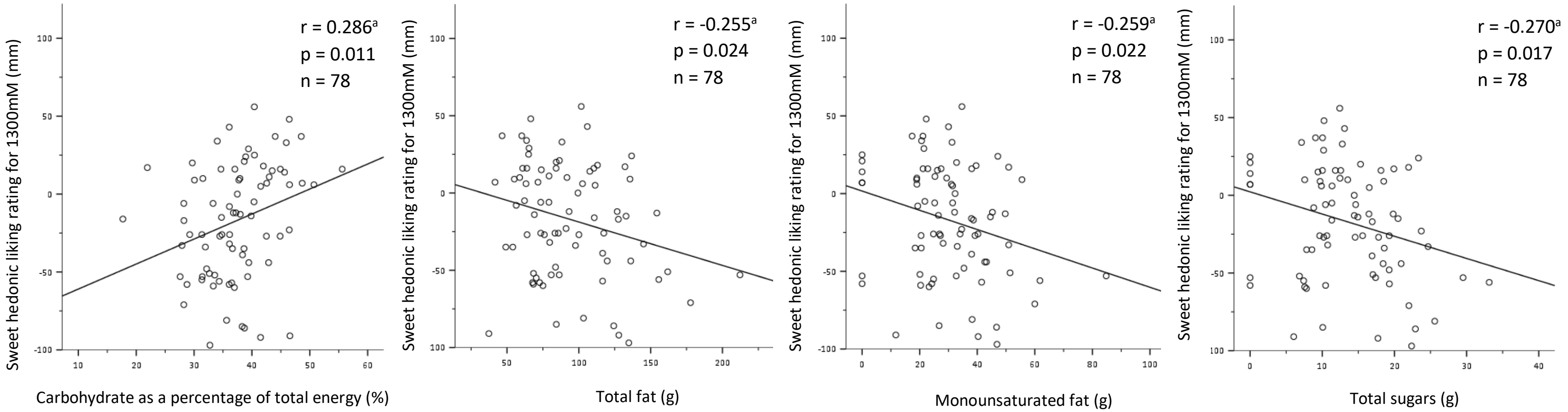
No significant correlations were observed between intakes of any nutrients and the perceived sweet taste intensity ratings for the obese BMI group (Appendix B.2). In the normal BMI group, positive associations were found between intake of total, mono, and poly-unsaturated fats and intensity ratings (Figures 3.5a-c), with the strongest correlation observed for intake of polyunsaturated fats (r = 0.300, p = 0.008).

No significant correlations were observed at the two lowest concentrations, 163mM and 350mM, for either BMI group (Appendix B.2).



(a) (b) (c) (d)

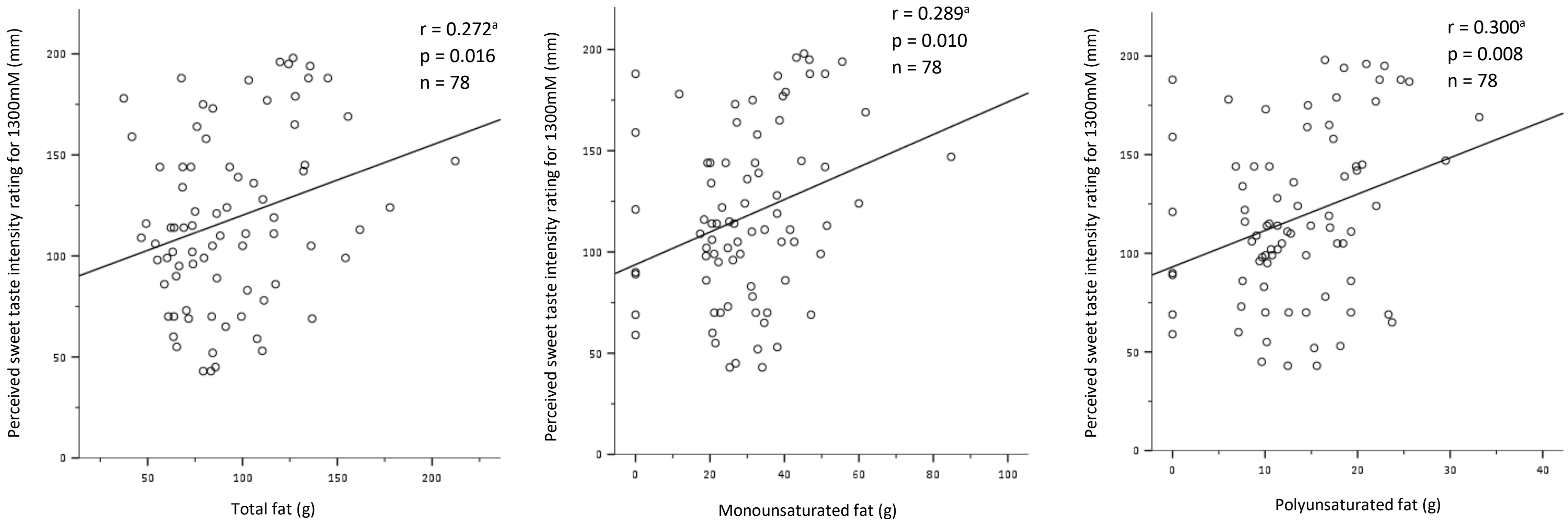
Figure 3.3. Correlation between hedonic liking rating for 1300mM and **(a)** intake of protein (as a % of total energy); **(b)** intake of carbohydrate; **(c)** intake of carbohydrate (as a % of total energy); **(d)** intake of total sugars for the obese BMI group.



(a) (b) (c) (d)

Figure 3.4. Correlation between hedonic liking rating for 1300mM and **(a)** intake of intake of carbohydrate (as a % of total energy); **(b)** intake of total fat; **(c)** intake of monounsaturated fat; **(d)** intake of polyunsaturated fat for the normal BMI group.

[a]*Data analysed using Pearson's correlation.*



(a) **(b)** **(c)**

Figure 3.5. Correlation between perceived sweet taste intensity rating for 1300mM and **(a)** intake of total fat; **(b)** intake of monounsaturated fat; **(c)** intake of polyunsaturated fat for the normal BMI group.

[a]Data analysed using Pearson's correlation.

3.4.8 Association between sweet hedonic liking ratings and intake of sweet food categories

The strongest correlation observed for the normal BMI group was between intake of beverages and hedonic liking for the highest glucose concentration (1300mM) ($r = 0.329$, $p = 0.003$) (Table 3.8). At the highest concentration, cereal intake was positively associated with liking for the normal BMI group and dessert was positively associated for the obese group. Intake of starchy vegetables and liking for the lowest glucose concentration (163mM) was the strongest correlation found for the obese BMI group ($r = 0.283$, $p = 0.018$). Starchy vegetables were also correlated with liking at the lowest concentration for the normal group, as was their intake of desserts. At the second highest concentration, significant positive associations were observed between fruit intake for the obese group, and beverages intake for the normal group.

3.4.9 Association between perceived sweet taste intensity ratings and intake of sweet food categories

No significant associations were found between perceived sweet taste intensity ratings and intake of sweet food categories for the normal BMI group. In the obese group however, intake of vegetables was positively associated with intensity ratings at the two highest concentrations only (Table 3.9).

Table 3.8. Correlation coefficients of the association between sweet hedonic liking of sweet taste and total intake of sweet food groups in obese and normal body mass index (BMI) groups.

	Sweet taste concentration															
	163mM				325mM				650mM				1300mM			
	Obese[a] (N = 70)		Normal[a] (N = 78)		Obese[a] (N = 70)		Normal[a] (N = 78)		Obese[a] (N = 70)		Normal[a] (N = 78)		Obese[a] (N = 70)		Normal[a] (N = 78)	
Sweet food categories	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**
Fruit	-0.021	0.866	0.084	0.464	0.132	0.276	0.159	0.165	0.243	**0.042**	0.030	0.797	0.207	0.086	0.068	0.556
Baking/ sweets	-0.106	0.381	-0.033	0.771	-0.047	0.700	-0.069	0.546	0.144	0.234	0.042	0.715	0.167	0.168	0.107	0.351
Beverages	0.217	0.072	0.034	0.770	0.034	0.779	0.171	0.135	-0.093	0.445	0.237	**0.037**	-0.142	0.241	0.329	**0.003**
Spreads/ sweeteners	0.003	0.982	0.096	0.403	0.102	0.401	0.062	0.587	0.117	0.334	0.061	0.593	0.125	0.303	-0.120	0.295
Starchy vegetables	0.283	**0.018**	0.277	**0.014**	-0.005	0.967	-0.056	0.626	0.053	0.665	-0.065	0.573	-0.062	0.612	-0.150	0.190
Cereals	0.047	0.701	-0.037	0.750	0.056	0.645	0.059	0.610	0.001	0.994	0.144	0.208	0.066	0.585	0.231	**0.041**
Dairy	0.110	0.366	-0.083	0.469	0.042	0.733	0.054	0.640	0.138	0.256	-0.131	0.254	-0.081	0.505	-0.163	0.155
Dessert	0.060	0.623	0.248	**0.028**	0.019	0.877	0.138	0.228	0.171	0.157	0.012	0.915	0.257	**0.032**	0.153	0.181

r = correlation coefficient; P = P-value;

Data analysed using Pearson's correlation, statistically significant correlations are highlighted in bold;

[a]BMI groups: Obese: ≥30 kg/m^2, Normal: ≥18.5 - 24.9 kg/m^2 (World Health Organization, 2006).

Table 3.9. Correlation coefficients of the association between perceived sweet taste intensity ratings and total intake of sweet food groups in obese and normal body mass index (BMI) groups.

	Sweet taste concentration															
	163mM				**325mM**				**650mM**				**1300mM**			
	Obese[a] (N = 70)		**Normal[a] (N = 78)**		**Obese[a] (N = 70)**		**Normal[a] (N = 78)**		**Obese[a] (N = 70)**		**Normal[a] (N = 78)**		**Obese[a] (N = 70)**		**Normal[a] (N = 78)**	
Sweet food categories	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**
Fruit	0.028	0.815	-0.168	0.141	-0.008	0.948	-0.128	0.265	-0.182	0.131	-0.012	0.918	-0.042	0.729	0.080	0.485
Baking/ sweets	0.005	0.969	-0.112	0.328	-0.120	0.322	-0.105	0.361	-0.102	0.403	-0.040	0.728	-0.120	0.320	-0.049	0.672
Beverages	0.028	0.817	-0.036	0.755	0.017	0.891	-0.022	0.847	0.089	0.462	-0.012	0.917	0.098	0.419	-0.042	0.716
Spreads/ sweeteners	-0.114	0.347	0.023	0.838	-0.092	0.448	-0.023	0.843	0.160	0.187	-0.120	0.296	0.155	0.201	-0.079	0.493
Starchy vegetables	0.213	0.076	-0.001	0.996	0.125	0.301	-0.059	0.607	0.263	**0.028**	-0.039	0.733	0.298	**0.012**	0.039	0.733
Cereals	0.052	0.671	0.206	0.070	0.004	0.975	0.131	0.253	0.106	0.381	0.003	0.981	0.076	0.533	-0.112	0.329
Dairy	0.071	0.561	-0.053	0.645	0.025	0.835	-0.034	0.767	-0.008	0.950	-0.083	0.469	0.055	0.649	-0.056	0.627
Dessert	0.018	0.883	0.000	1.000	0.027	0.822	0.065	0.570	-0.046	0.706	0.052	0.651	-0.047	0.697	-0.006	0.961

r = correlation coefficient; P = P-value;

Data analysed using Pearson's correlation, statistically significant correlations are highlighted in bold;

[a]BMI groups: Obese: ≥30 kg/m^2, Normal: ≥18.5 - 24.9 kg/m^2 (World Health Organization, 2006).

3.5 Discussion

To the best of our knowledge this is the first study to report significant associations between sweet hedonic liking and perceived sweet taste intensity and habitual dietary intake in NZ European women of two BMI groups. This study expanded on previous findings from our research team by comparing women of obese BMI to women of normal BMI, contributing to the knowledge of the underlying factors influencing obesity and long-term health (Jayasinghe et al., 2017). The results show that women of obese BMI have a lower sweet taste sensitivity compared to women of normal BMI. Further, associations between hedonic liking ratings and intakes of carbohydrates and sugar, and higher intakes of sweet food items were observed for the obese group. These findings suggest that individual taste perception may influence food selection and dietary intakes or vice versa, with potential long-term consequences in regards to the development of obesity and related chronic diseases.

3.5.1 Hedonic liking and perceived sweet taste intensity

Our findings highlighted an inverse association between hedonic liking and perceived intensity of sweet taste at increasing glucose concentrations, regardless of BMI. However, women with normal BMI experienced a higher perceived sweet intensity at the highest glucose concentration, compared to the obese group at the same concentration. Additionally, there were positive associations between the normal BMI group and their intake of total, monounsaturated, and polyunsaturated fat (total intake in grams), but not with their intake of sweet food categories. Interestingly, women with obese BMI had a markedly higher intake of sweet beverages, diet soft drink, lollies/sweets and sweet pies/pastries, indicating that the women who had a lower perceived sweet taste intensity at high glucose concentrations also reported a higher intake of sweet foods. Intake of carbohydrate and sugars were positively correlated with hedonic liking ratings with the obese BMI group, but not which perceived intensity ratings.

A significant difference between intensity ratings for the two BMI groups was present at the highest concentration, supporting previous findings which suggested obese participants have a weakened sweet taste perception, thus report lower intensity ratings (Bartoshuk et al., 2006; Hardikar, Höchenberger, Villringer, & Ohla, 2017). This weakened sweet taste perception could be due to single nucleotide polymorphisms (SNP) on the taste receptor subunits (TAS1R2 and TAS1R3), which lead to decreased sweet ligand binding and leading to a reduced sweet taste sensitivity (Eny et al., 2010; Nie, Vigues, Hobbs, Conn, & Munger, 2005). This is an area for future research to assess taste-specific genetic differences between BMI groups, and to determine if associations exist between these differences and measures of sweet taste perception. The present study illustrated a decreased hedonic liking and increased perceived sweet taste intensity towards the highest glucose concentration, regardless of BMI, highlighting a concentration-dependent relationship observed in previous studies (Jayasinghe et al., 2017).

The present study found negative associations between hedonic liking and perceived sweet taste intensity at all four glucose concentrations for the normal BMI group, and at the two highest concentrations for the obese group. This finding differed from the inverted U-shaped relationship detailed previously (Drewnowski, 1997; Jayasinghe et al., 2017; Tuorila, 1996), with an initial positive association between hedonic liking and perceived sweet taste intensity at lower glucose concentrations, shifting to a negative association at higher concentrations. Differences in sweet taste perception between individuals can potentially be explained by the concept of repeated exposure, where an adaptation in taste perception is observed in those who are regularly exposed to highly sweet foods, leading to a lower perceived sweet taste intensity and greater preference at higher glucose concentrations (Drewnowski, Mennella, Johnson, & Bellisle, 2012; Wise et al., 2016). These findings suggest that a reduction in the sugar content of sugar-sweetened food items and beverages, could maintain, if not increase, preference levels and consumer satisfaction, while reducing the negative health effects of a high sugar intake.

3.5.2 Energy and macronutrient distribution profiles

The average daily energy intake was higher than the Estimated Energy Requirement (EER) for both BMI groups in the present study (9058 kJ for the obese group vs 8923 kJ for the normal group). This was an especially interesting finding for the normal group, as firstly, energy intakes would be expected to fall within the EER for these women, preventing excessive weight gain and secondly, a limitation of a FFQ is the high prevalence of underreporting, therefore energy intakes could be expected to be reported below the EER. This may be explained by differences in physical activity and energy expenditure levels, however this was beyond the scope of this study and is an area for future research. Protein was the only macronutrient to be found within the Acceptable Macronutrient Distribution Range (AMDR) for both BMI groups (18.1% for the obese group vs 18.2% for the normal group). Comparatively, carbohydrate intakes were below the AMDR for both groups (38.2% for the obese group vs 37.4% for the normal group); a pattern which was also previously observed in a similar group of NZ European women (Schrijvers, McNaughton, Beck, & Kruger, 2016). The AMDR for total fat and saturated fat was exceeded by both groups (39.7% and 16.2% for the obese group vs 39.6% and 15.7% for the normal group, respectively), which was consistent with findings from the NZ National Nutrition Survey and with previous research (Schrijvers et al., 2016; University of Otago and Ministry of Health, 2011a). These macronutrient distributions indicate these women are consuming foods higher in total and saturated fat at the expense of carbohydrates, resulting in excessive energy intakes. The "low carbohydrate high fat diet" is currently trending as a diet for weight loss, which may explain the distributions observed in the present study (Austin, Ogden, & Hill, 2011). Evidence suggests that undertaking a low carbohydrate diet may be beneficial for weight loss, however controversy remains about long-term weight maintenance. Further, the type of fat consumed to compensate for a low carbohydrate intake is of importance, with saturated fats found to promote chronic disease development, whereas unsaturated fats provide cardiovascular benefits (Shai et al., 2008; University of Otago and Ministry of Health, 2011a).

3.5.3 Differences between intake of sweet foods

In the present study, the top sweet categories were fruit and baking/sweets for both BMI groups, with starchy vegetables replacing beverages as the 3rd ranked category for the normal BMI group, reflecting findings from previous studies (Jayasinghe et al., 2017; Rivers, 2015; University of Otago and Ministry of Health, 2011a). Nationally, fruit had the highest contribution to total sugar intake (17.8%), thus was expected to be highly ranked, however both groups consumed less fruit than the recommended two servings per day (University of Otago and Ministry of Health, 2011a). Fruit primarily contains fructose, a fruit sugar, but also varying amounts of glucose, and sucrose (Sivakumaran et al., 2017). A number of review articles have explored the potential role of fructose in the development of obesity and other metabolic diseases, with conflicting evidence found (Alinia, Hels, & Tetens, 2009; Bray, 2010; Johnson et al., 2007). Apart from fructose, fruit also contains vitamins, minerals and fibre, thus when energy-dense items such as sweetened beverages are replaced with fruit, the risk of obesity and chronic disease may be reduced (University of Otago and Ministry of Health, 2011a).

Items in the beverages category are energy-dense, high in sugar, thus contribute to weight gain and obesity. Therefore, it was not surprising that the obese BMI group consumed significantly more beverages than the normal BMI group. Interestingly, diet soft drinks were consumed twice as often by the obese group compared to the normal group. These drinks are perceived to be better alternative to regular soft drinks due to a lower sugar and energy content. However research suggests the artificial sweeteners used to sweeten diet drinks may lead to the same poor health outcomes observed with regular sugar-sweetened beverages, due to alterations in metabolic and digestive pathways (Swithers, 2013). The obese BMI group also reported a higher intake of discretionary items, such as lollies/sweets and sweet pies/pastries which, much like sweet beverages, are nutrient-poor. These findings justify the need for public health campaigns to promote adequate fruit intake in the place of high-energy 'snack' foods, due to the myriad of potential health benefits gained.

3.5.4 Associations between sweet taste perception, hedonic preference, energy and macronutrient profiles and intake of sweet foods

Conflicting research regarding the relationship between perceived sweet taste intensity and dietary intake exists, with significant correlations found in one study (Jayasinghe et al., 2017), however not in others (Cicerale et al., 2012). In the present study, positive correlations were found between hedonic liking at the highest glucose concentration and carbohydrate (as a percentage of total energy) for both BMI groups, and only carbohydrate (in grams) and sugar intake for the obese group. This suggests that women with obese BMI who liked highly sweet samples also consumed more carbohydrates and importantly, more sugars, compared to those who displayed a lower liking towards the same concentration. Women with obese BMI also reported a lower perceived sweet taste intensity compared to those with normal BMI at the highest concentration, suggesting that this can be credited to a low sweet sensitivity requiring a greater sugar intake to reach adequate levels of sweetness (Dias et al., 2015; Noel et al., 2017).

Interestingly, in women with normal BMI, negative correlations between hedonic liking ratings at highest glucose concentration and intake of total, mono-, and polyunsaturated fats were observed, whereas positive correlations were observed between intensity ratings at the same concentration and the same fats. The combination of sweet and fat compounds in foods has been identified as leading to an increased palatability and improved mouthfeel of food, which influences habitual dietary intake and BMI (Besnard et al., 2016; Kindleysides et al., 2017). However, the women with normal BMI reported negative association between hedonic liking and perceived sweet taste intensity at all four glucose concentrations, potentially indicating that savoury, high fat foods are favoured over highly sweet foods in this group.

These findings suggests a deviation from the traditional role of sweet and fat in increasing palatability, and rather a liking towards savoury, higher fat foods as a result of higher levels of sweet sensitivity and decreased liking at highly sweet concentrations (Bartoshuk et al., 2006).

Previous research has sought to explore associations between fat taste sensitivity and dietary intake, however no associations were found (Kindleysides et al., 2017).

Previous research suggests those with an elevated liking for sweet taste are more likely to have a greater intake of carbohydrates and sugar-rich foods (Cicerale et al., 2012). The present study had similar findings, where intake of the desserts category was positively correlated with hedonic liking ratings for the highest glucose concentration in the obese BMI group. This indicates that those who displayed a liking towards the highest glucose concentration also had a higher intake of foods from the desserts category, compared to those who preferred the glucose concentration less. This finding further reinforces the idea that those with higher BMI have a lower sensitivity to sweet stimuli, thus requiring a higher sugar intake to reach certain perception levels (Dias et al., 2015; Jayasinghe et al., 2017; Noel et al., 2017).

Interestingly, intake of starchy vegetables was positively associated with hedonic liking at the lowest glucose concentration for both BMI groups, and with perceived sweet taste intensity at the two highest glucose concentrations in the obese group only. Although starchy vegetables are not traditionally classified as sweet foods, the vegetables included in this category are of low sweetness and are less bitter than other vegetables. An increased hedonic liking towards these vegetables can potentially be explained by the negative association observed between liking and intensity, with high sweetness associated with decreased liking for both BMI groups. Similarly, dessert intake was found to positively correlate with hedonic liking ratings at the lowest glucose concentration for women with normal BMI. This suggests that these women may prefer desserts of a lower sweetness, however further investigation would be required to focus on a broader range of sweet food items to confirm this.

The significant positive association between liking of the highest glucose concentration and beverages intake observed for the normal BMI group, suggests that those who have a higher liking towards higher glucose concentrations may have a greater liking towards the intake of sweet beverages. The intake of beverages was higher for the women with obese BMI, therefore it is surprising that no significant associations were present between liking and beverages intake with these women. However, this may be due to the glucose samples not representing their usual sweet beverages, for example soft drinks are carbonated providing a different sensory experience compared to a still sample.

3.5.5 Additional limitations of the study

Further research is needed to explore the associations between taste-specific gene expression and dietary intake in women of different BMIs, to determine the extent to which differences in taste receptors can impact dietary intake and vice-versa. Further, employing a different method for quantifying dietary intake, such as a weighed food record which is considered the 'gold standard', will improve data accuracy and validity. However, the FFQ provided valuable information regarding associations between intake of sweet food items and energy and macronutrient profiles. Lastly, as the study design was cross-sectional, causation cannot be inferred from the associations.

3.6 Conclusions

The present study has several important findings about the associations between sweet taste perception and habitual dietary intake in women of in obese or normal BMI groups. The negative association between sweet hedonic liking and perceived sweet taste intensity indicated that highly-sweet glucose concentrations are not liked by both BMI groups.

The normal BMI group displayed a higher sweet intensity perception at the highest glucose concentration compared to the obese group, highlighting that those with higher BMI perceive higher sweet concentrations as less sweet, therefore may consume more sugars or require a higher sweet concentration to meet the same intensity perception levels. The associations between intake of carbohydrate and sugars for the obese group and their liking ratings, supporting evidence that a higher liking for sweet tasting foods can lead to an increased intake of sugar-containing foods, which are more energy-dense and nutrient-poor compared to other food items. Interestingly, dietary data from the present study suggests that many participants may be following 'fad' diets currently trending, such as a "low carbohydrate high fat" diet, which promotes altering intakes of macronutrients to evoke weight loss. However, this can have potential negative health outcomes, for example if intakes of saturated fat are higher than recommended intakes. A greater understanding of the relationship between sweet taste perception and energy and macronutrient profiles and intake of sweet food items would contribute to the underlying aetiology leading to obesity and potentially provide a more robust basis for public health promotions to be developed.

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Chapter 4 - Conclusion-recommendations

4.1 Study summary

This study had four main objectives related to investigating the associations between sweet taste perception and habitual dietary intake in a group of New Zealand (NZ) European women, aged 18-45 years, categorised into two distinct Body Mass Index (BMI) classes; obese with a BMI ≥30 kg/m^2 or normal with a BMI ≥18.5 - 24.9 kg/m^2. By considering the two BMI groups, this study could contribute to existing knowledge about the potential taste- and diet- specific contributors leading to the development of obesity, specific to the NZ European population.

Firstly, differences in sweet hedonic liking and perceived sweet taste intensity were observed between the two groups, with the obese group displaying a higher liking towards sweet concentrations compared to the normal group, supporting evidence from previous studies. The normal group also displayed a higher perceived intensity rating compared to the obese group, suggesting that the obese group is less sensitive to the stimuli. Secondly, no differences in energy or macronutrient intakes was observed between the two BMI groups, however women of obese BMI reported higher intakes of sweet food items and categories. This was to be expected as an excessive intake of these nutrients will likely lead to weight gain and obesity. Thirdly, when taken in the context of sweet taste perception measures, the higher intake could potentially be explained by a higher liking and lower intensity perception towards sweet tasting compounds. Fourthly, this study also sought to explore the intake of sweet food groups, with an association found between the intake of desserts and liking ratings towards the highest sweet concentration for the obese group. Interestingly, an association was also found between desserts and liking towards the lowest sweet concentration for the normal BMI group, potentially suggesting that this group prefers the sweetness of less-sweet dessert options, compared to the obese group who potentially prefer desserts of a higher sweetness.

Of important consideration is that total energy intake did not significantly differ between the two BMI groups despite differences in mean body weight, highlighting implications for the results, while suggesting that other factors impacting energy balance could be discussed in future research.

4.2 Study strengths

There are several strengths to this study. They include the specificity of the study population, the sample size, the use of a validated FFQ and the sensory methodology employed in this study.

4.2.1 Specificity of the study population

Due to the knowledge that differences in taste perception are present across genders and age groups, the specific participant group selected for this study was NZ European females, aged 18-45 years. This excluded potentially confounding variables, such as gender and age, while increasing the reliability of the study findings (Cohen & Gitman, 1959; Drewnowski, 1997; Fikentscher et al., 1977; Mennella, 2014). Also, by placing a focus on a NZ-specific population ensures that food availability is similar for all participants improving data accuracy. Including a relatively similar number of both obese and normal BMI participants ensured that both groups were fairly represented.

4.2.2 Sample size

The study population included a large sample of 148 females. Larger sample sizes give better approximations of a population's habits and have a lower sampling error, therefore ensuring that data collected can be representative of the population (Field, 2013). Further, the central limit theorem is a statistical theory that suggests large sample sizes (greater than 30) will have a mean approximately equal to that of the overall population, and will be approximately normally distributed (Field, 2013).

4.2.3 Validated food frequency questionnaire

The FFQ employed in this study has been validated for NZ women, and has been identified as an effective and accurate tool to assess dietary intake patterns and subsequent levels of nutritional risk (Houston, 2014). The data acquired from the questionnaire is robust, thus can be considered to accurately represent the habitual dietary intakes of the study population. NZ-specific foods and appropriate portion sizes were included in the questionnaire, improving the validity of the data.

4.2.4 Sensory methodology employed

The methodology used to assess taste perception has been used in previous studies, where accurate data was observed (Henderson, 2016; Jayasinghe et al., 2017; Kindleysides et al., 2017; Rivers, 2015). The test conditions were well-controlled, following strict protocol at the sensory testing booths at Massey University, Albany. This included a standardised taste-and-spit test for each sample and a requirement for participants to be fasted before testing to reduce any confounding variables.

4.3 Limitations

The study also has several limitations which has the potential to reduce the reliability of the data obtained. The main limitation being the cross-sectional design of the study meaning that causation was unable to be established. Further limitations include the BMI groupings, the use of a FFQ, and the identification of under- or over-reporters.

4.3.1 BMI groupings

Selecting participants in two distinct, non-overlapping BMI groups decreased the methods of statistical analysis which could be used and was not representative of the general NZ population. The data was valid when comparing the two BMI groups, however when assessing the study population as one, data validity and accuracy decreased.

4.3.2 Food frequency questionnaire

Although the FFQ has been validated for NZ women, there are a number of limitations to this method. Firstly, the portion sizes and food selections may not be representative of those normally selected or consumed by subjects, leading to inaccurate reporting (Gibson, 2005). Secondly, the nature of these questionnaires involves the grouping of similar food items together, however this will lead to inaccurate reporting if the subject does not consume the majority of foods in this group. However, the use of a food frequency questionnaire was the most appropriate method for this population group due to low subject burden and a relatively quick data collection process.

4.3.3 Identification of under or over reporters

The identification of under and over reporters of energy intake is also a limitation of this study. The energy expenditure of each participant was estimated considering basal metabolic rate (BMR), diet-induced thermogenesis (DIT), and physical activity level (PAL). BMR is an estimated value, and DIT and PAL are general values used for all participants, introducing a margin of error. This value was used in conjunction with set international guidelines detailing plausible energy intakes to identify those participants who misreported their energy intake from the FFQ (Rhee et al., 2015; Willett, 2012). Thus, these estimations could lead to participants being wrongly excluded from statistical analysis if their reported energy intakes appeared to be inadequate or excessive.

4.4 Recommendations for future research

The current study provided highly valuable information related to the potential influence that sweet taste perception may have on the dietary intakes of NZ European women from two distinct BMI groups. Further areas for research are detailed below.

- Using additional statistical modelling techniques, such as ANOVA or multiple regressions to further explore key attributes of the data.
- Establish dietary patterns in the same population group to holistically explore the habitual dietary intakes of the group in relation to sweet taste perception. Patterns of intake may provide a better understanding of the influence of individual sweet taste perception on dietary intake.
- Include a variety of sweet compounds, such sucrose and fructose alongside glucose, to explore if these are perceived differently, and investigate further if different relationships are observed.
- Include participants in the overweight BMI category (>24.9 – 29.9 kg/m^2) to investigate the sweet taste perception and habitual dietary intake in a wider, more representative population group. Although clear differences were observed between the obese and normal BMI groups, this study may have under- or over-estimated the associations between sweet taste sensitivity and dietary intake due to the exclusion of a significant proportion of the population.
- Further utilise data from the PROMISE study to include results from Pacific women, which was the second ethnicity explored, to establish ethnic-specific differences in taste perception and potentially identify different relationships with habitual dietary intake.
- Given the role of fat intake and sugar intake in contributing to an excessive energy intake and subsequent weight gain, further investigation combining fat taste perception with sweet taste perception could provide a greater insight and strengthen the associations observed in the current study.
- Utilise three to seven day weighed food records for dietary assessment, as these are considered the "Gold standard" and potentially may yield highly accurate dietary intake data, compared to a FFQ. However, this method leads to high subject burden, therefore could lead to significant under reporting or may inaccurately represent the intake of participants.
- Extend findings to the wider New Zealand population, by including males and other demographic groups for future studies. However, given the knowledge that gender

and ethnicity influences taste perception, variables would need to be controlled for, and different groups may need to be analysed separately.

4.5 Conclusion

Despite the identified limitations of this study, the associations described indicate a relationship between sweet taste perception and habitual dietary intake in NZ European women, aged 18-45 years, in both BMI groups. Firstly, the obese BMI group perceived varying concentrations of sweet stimuli as less intense and displayed a greater liking, compared to the normal BMI group. Secondly, it was found that obese women reported higher intakes of carbohydrates and sugars, which was positively associated with their liking towards the highest sweet taste concentrations. This follows suggestions in the literature that obesity can lead to a weakened taste response, and as a consequence, a higher intake of sugar-containing foods in order to meet an acceptable level of sweetness.

These findings provide support that sweet taste perception is related to the habitual dietary intakes of these NZ European women, with clear differences observed between BMI groups, suggesting that certain patterns of habitual intake, such as higher carbohydrate or sugar intakes, lead to excessive weight gain. Sweet taste perception has the ability to be altered by a gradual reduction in sugar intake, leading to the acceptance and preference of less-sweet food items. Obesity is a national and global epidemic, therefore these findings could be utilised by the food industry and the government to modify the current obesogenic food environment, in order to reduce national obesity rates and decrease subsequent morbidity and mortality.

Further research should be conducted to investigate dietary patterns within this study's population to provide a holistic approach to assessing habitual dietary intake patterns, which may lead to clearer associations observed between intake and sweet taste perception. Additionally, functional Magnetic Resonance Imaging (fMRI) may be considered for future research to explore the effect of different sweet-tasting foods on brain activity in different population groups. A better understanding of this relationship will provide clearer insights and justification for interventions and education strategies required to combat obesity and improve long-term health outcomes for New Zealanders.

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Appendix A – Supplementary methods

A.1 Further detail regarding anthropometric measurements

Table A.1. Standardised protocol for anthropometric measurements.

Measurement, reference	Equipment	Procedure	Outcome
Body weight, (Ling et al., 2011)	Calibrated scale	Shoes removed, measure taken twice	Weight (kg), body mass index (BMI) calculation (kg/m^2)
Height, (Ling et al., 2011)	Standard wall-mounted	Shoes removed, standing upright, measure taken twice	Height (m), BMI calculation (kg/m^2)
Body composition distribution measurements, (Ling et al., 2011)	Bioelectrical Impendence Analysis (BIA) device (InBody230, Biospace Co. Ltd, Seoul, Korea).	Shoes removed, standing upright, holding hand grips	Weight (kg), total body fat (kg) and lean mass (kg)
Waist and hip measurements, (Ling et al., 2011)	Metal measuring tape	Following International Society for the Advancement of Kinanthropometry (ISAK) protocols	Waist and hip circumference (cm) and waist-to-hip ratio

BMI = body mass index, BIA = Bioelectrical Impendence Analysis.

A.2 Assessing sweet taste perception

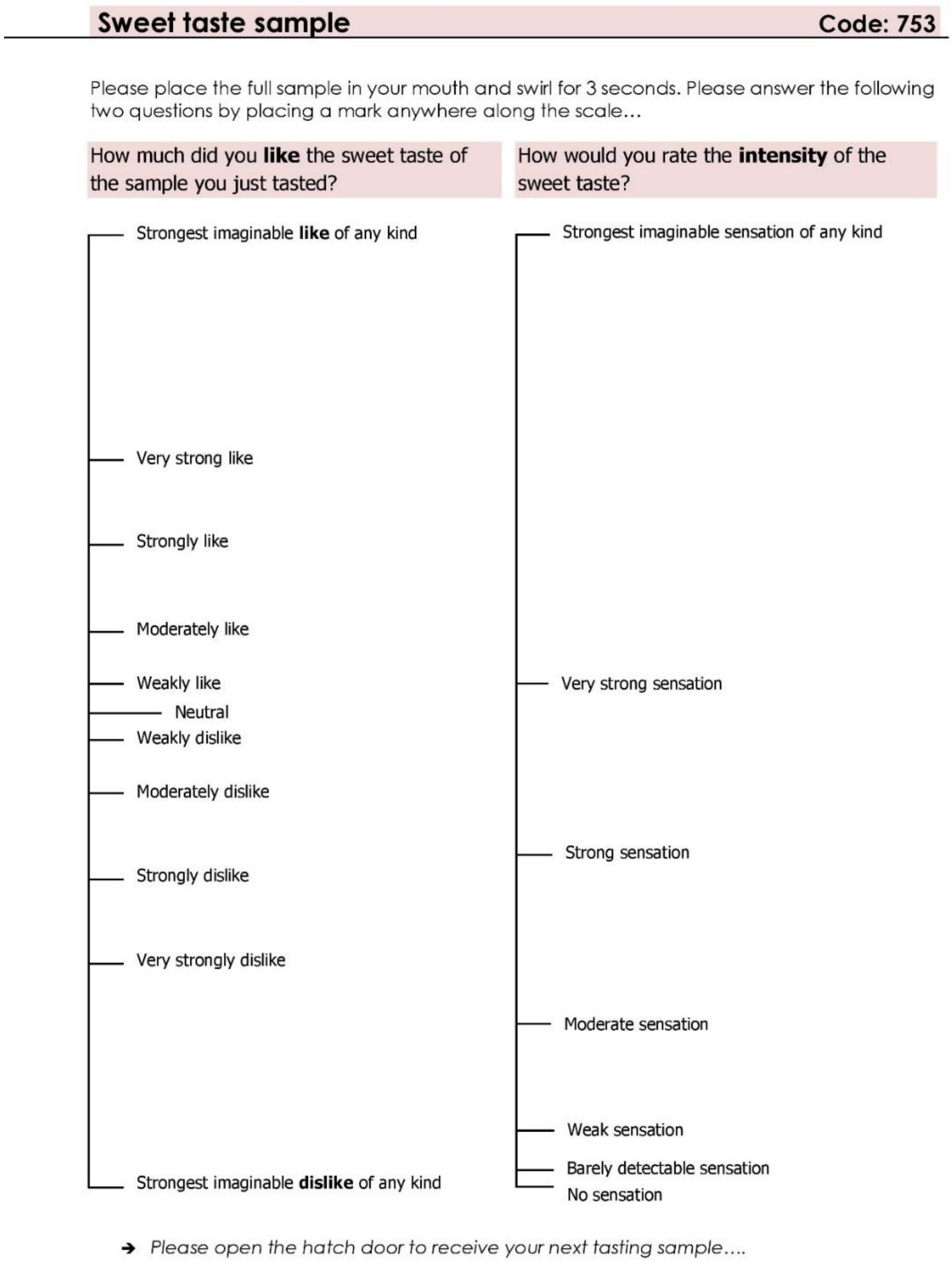


Figure A.1. Example of the general Labelled Magnitude Scale (gLMS) used to assess hedonic preference and perceived intensity of sweet taste (Bartoshuk et al., 2004).

A.3 Sweet taste sample preparation – serial dilution

Sweet taste testing protocol was designed by members of the PROMISE study research team and followed methods utilised in similar studies (Jayasinghe et al., 2017).

Table A.2. Aqueous sample preparation for sweet taste perception testing for greater than five participants.

Molarity	Glucose solution required	Water required
1,300mM	115.4g glucose powder	400ml (final volume = 480mL)
650mM	200ml from 1,300mM	200ml
325mM	200ml from 650mM	200ml
163mM	200ml from 325mM	200ml

A.4 Daily frequency equivalent (DFE) conversions

Following methodology utilised in previous studies, food frequency responses were converted into DFEs (da Silva, Neutzling, Camey, & Olinto, 2014; Hu et al., 1999).

Table A.3. Conversion of food frequency responses to daily frequency equivalents (DFE).

Food frequency questionnaire response	Frequency	DFE
Never	0m	0
<1x/month	0.25m	0.01
1-3x/month	2m	0.07
1x/week	1w	0.14
2-3x/week	2.5w	0.36
4-6x/week	5w	0.71
Once/day	1d	1.0
2-3x/day	2.5d	2.5
4+x/day	4d	4.0

m = month, w = week, d = day.

A.5 Food frequency questionnaire (FFQ) assumptions

Assumptions were modelled off previous research and decisions made by the PROMISE research team (Kruger et al., 2015).

Table A.4. Assumptions for entering food frequency questionnaire data into FoodWorks.

Category	FFQ item	FoodWorks 8 selection
Milk	Full cream milk (purple top)	Milk,cow,whole 4% fat,fluid,non-homogenised
	Standard milk (blue top)	Milk,cow,standard 3.3% fat,fluid
	Skim milk (light blue)	Milk,cow,lite 1.5% fat,fluid
	Trim milk (green top)	Milk,cow,trim 0.5% fat,fluid
	Super trim milk (light green top)	Milk,cow,trim 0.3% fat,fluid
	Calcium enriched milk (yellow top)	Milk,cow,high calcium 0.1% fat,fluid,fortified
	Calcium and vitamin enriched milk	Milk,cow,2% fat,fluid,Mega milk,Anchor,fortified
	Calcium and protein enriched milk	Milk,cow,low fat 0.2%,fluid,ultra filtered,Sun Latte,fortified
	Standard soy milk (blue)	Soy milk,So Good Regular Soy Milk,Sanitarium,fortified
	Light soy milk (light blue)	Soy milk,So Good Lite Soy Milk,Sanitarium,fortified
	Calcium enriched soy milk (purple)	Soy milk,plain,regular fat,commercial,added ca*
	Rice milk	Rice milk,Rice Drink Original,Rice Dream,fortified
Others	Almond milk	Milk, almond*
	Lactose free milk	Milk,lactose free,regular fat
	Trim lactose free milk	Milk,lactose free,reduced fat
	Coconut milk	Sanitarium So Good Almond Coconut Milk Unsweetened
	Not applicable/no selection	Milk,cow,standard 3.3% fat,fluid, 0m
Spreads	Butter	Butter,salted
	Monounsaturated fat margarine	Margarine,canola,monounsaturated,70% fat

Category	FFQ item	FoodWorks 8 selection
Spreads	Polyunsaturated fat margarine	Margarine,polyunsaturated,60% fat,Sunrise
	Light monounsaturated fat margarine	Margarine,canola,monounsaturated,50% fat
	Light polyunsaturated fat margarine	Margarine,light,polyunsaturated,50% fat,Flora,fortified
	Plant sterol enriched margarine	Margarine spread,monounsaturated (70%),reduced salt,added phytosterols
	Light plant sterol enriched margarine	Margarine,polyunsaturated,reduced fat,25% fat,added phytosterols*
	Butter and margarine blend	Semi soft butter,butter & canola oil,spreadable
	Not applicable/no selection	Margarine,canola,monounsaturated,70% fat, 0m
Others	Nutella	Spread,hazelnut,Nutella,Ferrero
Dressings	Butter	Butter,salted
	Margarines	Margarine,canola,monounsaturated,70% fat
	Cooking oils	Oil,vegetable,blend
	Lard, Dripping, Coconut oil, Ghee	Lard
	Cooking spray	Oil,vegetable,blend
Others	Olive oil	Oil, olive
	Not applicable/no selection	Oil,vegetable,blend, 0m

*Items not found in NZ FOODfiles selected from Australian database (AusFoods 2017).

A.6 Estimating daily energy expenditure

The daily energy expenditure was estimated for each participant, considering basal metabolic rate (BMR), diet-induced thermogenesis (DIT), and physical activity level (PAL) energy costs, summarised as BMR x PAL + DIT, which was compared to their estimated energy intake, from the FFQ, for any discrepancies (Gibson, 2005).

Basal metabolic rate

Table A.5 Equations for estimating basal metabolic rate (BMR) in megajoules (MJ) from body weight for females.

Age range	BMR equation (MJ/d)
18-30	(0.062 x kg) + 2.036
30-60	(0.034 x kg) + 3.538

MJ/d = megajoules per day; Above table adapted from Schofield (1984).

Diet-induced thermogenesis

The thermic effect of food, otherwise known as diet-induced thermogenesis (DIT), is defined as the stimulation of digestion processes which require energy, thus must be considered when estimating energy expenditure (Westerterp, 2004). The DIT value used for all participants was 10% of BMR.

Physical activity level energy costs

A meta-analysis, where authors described the population as having a “predominantly sedentary Western lifestyle”, found the physical activity levels (PAL) ranged between 1.55 to 1.65, with a modal value of 1.6 (Black, 2000). As the population of this study can be described similarly, a PAL of 1.6 was used, further described in National Health and Medical Research Council (2006)

International guidelines

The estimated daily energy intake of each participant was also compared to international guidelines, suggesting that cut-off margins for reported energy intake should be set at <2100kJ and >21000kJ, as these are the minimum and maximum plausible values for energy intake respectively (Rhee et al., 2015; Willett, 2012).

Appendix B – Supplementary results

Table B.1. Correlation coefficients of the association between sweet hedonic liking of sweet taste and macronutrient profiles in obese and normal body mass index (BMI) groups.

	Sweet taste concentration															
	163mM				325mM				650mM				1300mM			
	Obese[a] (N = 70)		Normal[a] (N = 78)		Obese[a] (N = 70)		Normal[a] (N = 78)		Obese[a] (N = 70)		Normal[a] (N = 78)		Obese[a] (N = 70)		Normal[a] (N = 78)	
Energy/Nutrient	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**
Total energy (kJ)	0.047	0.699	0.173	0.129	-0.001	0.992	-0.049	0.671	0.044	0.720	-0.136	0.235	0.208	0.084	-0.199	0.080
Protein (g)	0.097	0.427	0.171	0.135	-0.010	0.935	-0.047	0.680	-0.058	0.634	-0.093	0.420	0.067	0.583	-0.197	0.084
% of TE	0.127	0.295	0.017	0.882	-0.063	0.603	0.012	0.914	-0.182	0.132	0.051	0.657	-0.247	**0.039**	-0.064	0.580
Carbohydrate (g)	0.047	0.698	0.076	0.510	0.025	0.838	0.002	0.983	0.197	0.102	-0.070	0.541	0.337	**0.004**	-0.023	0.843
% of TE	-0.007	0.955	-0.129	0.259	0.062	0.612	0.063	0.585	0.281	**0.018**	0.062	0.591	0.272	**0.023**	0.286	**0.011**
Total sugars (g)[b]	0.078	0.523	0.171	0.134	0.128	0.291	0.110	0.336	0.257	**0.032**	-0.009	0.935	0.313	**0.008**	0.030	0.798
Dietary fibre	0.073	0.551	0.146	0.203	0.020	0.870	-0.118	0.304	0.099	0.417	-0.210	0.065	0.148	0.221	-0.191	0.093
Total fat (g)	0.033	0.787	0.185	0.104	-0.026	0.830	-0.079	0.493	-0.087	0.475	-0.151	0.186	0.109	0.370	-0.255	**0.024**
% of TE	-0.008	0.948	0.107	0.351	-0.056	0.643	-0.095	0.409	-0.250	**0.037**	-0.065	0.575	-0.116	0.339	-0.221	0.052
Saturated fat (g)	0.077	0.527	0.123	0.284	-0.049	0.686	-0.007	0.953	-0.061	0.618	-0.124	0.280	0.120	0.324	-0.208	0.068
% of TE	0.029	0.821	0.045	0.712	-0.069	0.588	-0.040	0.741	-0.163	0.199	-0.029	0.811	0.038	0.766	-0.088	0.466
Monounsaturated fat (g)	0.094	0.441	0.165	0.148	-0.031	0.801	-0.027	0.811	-0.041	0.736	-0.151	0.187	0.067	0.580	-0.259	**0.022**
% of TE	-0.015	0.905	0.129	0.283	-0.024	0.850	-0.135	0.262	-0.175	0.168	-0.059	0.628	-0.091	0.474	-0.208	0.081
Polyunsaturated fat (g)	0.065	0.594	0.159	0.166	0.013	0.912	-0.063	0.585	-0.042	0.731	-0.155	0.176	0.035	0.775	-0.270	**0.017**
% of TE	-0.114	0.368	0.087	0.469	0.072	0.574	-0.168	0.161	-0.134	0.292	-0.063	0.602	-0.106	0.405	-0.172	0.151

r = correlation coefficient; P = P-value; kJ = kilojoules; g = grams; TE = total energy;
Data analysed using Pearson's correlation, statistically significant correlations are highlighted in bold;
[a]BMI groups: Obese: ≥30 kg/m^2, Normal: ≥18.5 - 24.9 kg/m^2 (World Health Organization, 2006);
[b]Total sugars includes glucose, fructose, sucrose, lactose, and maltose.

Table B.2. Correlation coefficients of the association between perceived sweet taste intensity ratings and macronutrient profiles in obese and normal body mass index (BMI) groups.

	Sweet taste concentration															
	163mM				**325mM**				**650mM**				**1300mM**			
	Obese[a] (N = 70)		**Normal[a] (N = 78)**		**Obese[a] (N = 70)**		**Normal[a] (N = 78)**		**Obese[a] (N = 70)**		**Normal[a] (N = 78)**		**Obese[a] (N = 70)**		**Normal[a] (N = 78)**	
Energy/Nutrient	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**	**r**	**P**
Total energy (kJ)	-0.051	0.676	-0.017	0.881	-0.023	0.852	0.128	0.264	-0.066	0.585	0.111	0.332	-0.098	0.418	0.220	0.053
Protein (g)	-0.106	0.382	-0.047	0.681	-0.033	0.788	0.125	0.274	-0.003	0.983	0.083	0.472	-0.080	0.513	0.190	0.096
% of TE	-.0139	0.251	-0.052	0.648	-0.041	0.738	0.019	0.868	0.133	0.271	-0.045	0.694	-0.001	0.992	0.013	0.908
Carbohydrate (g)	-0.029	0.814	-0.025	0.828	-0.040	0.743	0.063	0.586	-0.128	0.292	0.058	0.613	-0.099	0.413	0.054	0.637
% of TE	0.062	0.607	-0.014	0.901	-0.010	0.934	-0.055	0.634	-0.148	0.222	-0.022	0.849	-0.008	0.945	-0.217	0.056
Total sugars (g)[b]	-0.033	0.786	-0.131	0.252	-0.057	0.641	-0.033	0.777	-0.147	0.226	-0.021	0.855	-0.082	0.502	-0.076	0.510
Dietary fibre	-0.008	0.946	-0.017	0.882	-0.128	0.290	0.096	0.402	-0.181	0.133	0.064	0.576	-0.084	0.491	0.185	0.105
Total fat (g)	-0.029	0.812	0.016	0.888	0.020	0.867	0.157	0.171	0.004	0.974	0.126	0.271	-0.086	0.480	0.272	**0.016**
% of TE	0.006	0.963	0.085	0.461	0.047	0.697	0.082	0.477	0.141	0.245	0.039	0.732	-0.016	0.897	0.189	0.098
Saturated fat (g)	0.091	0.455	0.061	0.598	0.083	0.496	0.122	0.286	-0.020	0.868	0.123	0.285	-0.142	0.241	0.200	0.079
% of TE	-0.038	0.767	0.023	0.846	0.088	0.491	0.069	0.566	0.134	0.291	-0.022	0.854	-0.096	0.451	0.039	0.744
Monounsaturated fat (g)	0.133	0.271	0.039	0.736	0.049	0.689	0.111	0.335	-0.019	0.879	0.158	0.168	-0.120	0.322	0.289	**0.010**
% of TE	0.024	0.848	-0.009	0.943	-0.005	0.967	0.062	0.610	0.153	0.228	0.044	0.718	-0.029	0.818	0.197	0.099
Polyunsaturated fat (g)	0.148	0.223	0.081	0.481	0.037	0.764	0.097	0.399	-0.020	0.868	0.158	0.168	-0.069	0.572	0.300	**0.008**
% of TE	0.066	0.605	0.082	0.497	-0.032	0.805	0.045	0.711	0.092	0.471	0.067	0.580	0.103	0.416	0.183	0.126

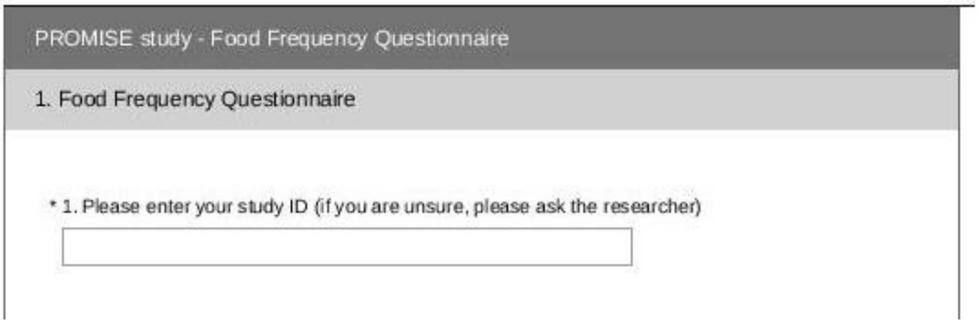
r = correlation coefficient; P = P-value; kJ = kilojoules; g = grams; TE = total energy;
Data analysed using Pearson's correlation, statistically significant correlations are highlighted in bold;
[a]BMI groups: Obese: ≥30 kg/m², Normal: ≥18.5 - 24.9 kg/m² (World Health Organization, 2006);
[b]Total sugars includes glucose, fructose, sucrose, lactose, and maltose.

Appendix C- Questionnaires and materials used

Food frequency questionnaire

The food frequency questionnaire utilised in the PROMISE study was designed as part of a previous Master's thesis, and was used in previous research assessing dietary intakes in a population of New Zealand women (Houston, 2014; Kruger et al., 2015).

Note: Images have been cropped in the interest of layout


PROMISE study - Food Frequency Questionnaire

1. Food Frequency Questionnaire

* 1. Please enter your study ID (if you are unsure, please ask the researcher)

PROMISE study - Food Frequency Questionnaire

2. Please read carefully before you begin:

Please make sure when filling out this questionnaire that you:

- **Tell us what YOU usually eat (not someone else in your household!).**
- **Fill in the form YOURSELF.**
- **Don't spend too much time on each food.**
- **Answer EVERY question; the asterisk symbol (*) at the beginning of each question means that you must answer before moving onto the next question.**

This will help us to get the most accurate information about your usual food intake.

Please answer by ticking the box which best describes HOW OFTEN you ate or drank a particular food or drink in the LAST MONTH and HOW MUCH you would usually have.

For example:

1. EXAMPLE: How often do you usually have sugar? (Please do not fill out)

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Sugar - 1 tsp	○	○	○	○	○	○	○	○	○

If every day you have 2 cups of coffee with 1 tsp sugar, 4 cups of tea with 1 tsp sugar, one bowl of cereal with 1 tsp sugar and sugar on pancakes at dinner, you would choose four or more times per day = '4+ x / day'.

Adjust your portion size and frequency of intake to suit your eating habits.

2. EXAMPLE: How often do you usually eat bread? (Please do not fill out)

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Bread - 1 slice	○	○	○	○	○	○	○	○	○

If every day you have two slices of toast for breakfast, and you have a sandwich for lunch three times per week, you would choose two - three times per day = '2-3x / day'.

Adjust your portion size and frequency of intake to suit your eating habits.

PROMISE study - Food Frequency Questionnaire

3. Eating Pattern

* 1. How would you describe your eating pattern? (Please choose one only)

- ◯ Eat a variety of all foods, including animal products
- ◯ Eat eggs, dairy products, fish and chicken but avoid other meats
- ◯ Eat eggs, dairy products and fish, but avoid chicken and other red meats
- ◯ Eat eggs and dairy products, but avoid all meats, chicken and fish
- ◯ Eat eggs, but avoid dairy products, all meats and fish
- ◯ Eat dairy products, but avoid eggs, all meats and fish
- ◯ Eat no animal products
- ◯ None of the above

Other (please state)

____

PROMISE study - Food Frequency Questionnaire

4. Milk

1. Do you use milk? (e.g. fresh, UHT, powdered)

- ◯ Yes
- ◯ No

PROMISE study - Food Frequency Questionnaire

5. Milk

* 1. What type(s) of milk do you have most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- [ ] Not applicable
- [ ] Full cream milk (purple top)
- [ ] Standard milk (blue top)
- [ ] Skim milk (light blue top)
- [ ] Trim milk (green top)
- [ ] Super trim milk (light green top)
- [ ] Calcium enriched milk (yellow top) e.g. Xtra, Calci-Trim
- [ ] Calcium and vitamin enriched milk e.g. Mega, Anlene
- [ ] Calcium and protein enriched milk e.g. Sun Latte
- [ ] Standard soy milk (blue)
- [ ] Light soy milk (light blue)
- [ ] Calcium enriched soy milk (purple) e.g. Calci-Forte, Calci-Plus
- [ ] Calcium, vitamin and omega 3 enriched soy milk e.g. Essential
- [ ] Calcium and high fibre enriched soy milk e.g. Calci-Plus High Fibre
- [ ] Rice milk

Other (please state)

* 2. Choose the one milk you have the most

- [ ] Not applicable
- [ ] Full cream milk (purple top)
- [ ] Standard milk (blue top)
- [ ] Skim milk (light blue)
- [ ] Trim milk (green top)
- [ ] Super trim milk (light green top)
- [ ] Calcium enriched milk (yellow top) e.g. Xtra, Calci-Trim
- [ ] Calcium and vitamin enriched milk e.g. Mega, Anlene
- [ ] Calcium and protein enriched milk e.g. Sun Latte
- [ ] Standard soy milk (blue)
- [ ] Light soy milk (light blue)
- [ ] Calcium enriched soy milk (purple) e.g. Calci-Forte, Calci-Plus
- [ ] Calcium, vitamin and omega 3 enriched soy milk e.g. Essential
- [ ] Calcium and high fibre enriched soy milk e.g. Calci-Plus High Fibre
- [ ] Rice milk

Other (please state)

____

* 3. On average, how many servings of milk do you have per day? (Please choose one only)
(A 'serving' = 250 mL or 1 cup/glass)
e.g. 5 cups of coffee/tea using 50 mL of milk + ½ cup of milk on cereal = 1 ½ servings per day

- ○ Not applicable
- ○ Less than 1 serving
- ○ 1-2 servings
- ○ 3-4 servings
- ○ 5 or more servings

* 4. How often do you usually have milk?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Flavoured milk (milkshake, iced coffee, Primo, Nesquik) - 250 mL/ 1 cup	○	○	○	○	○	○	○	○	○
Milk as a drink - 250 mL / 1 cup	○	○	○	○	○	○	○	○	○
Milk on breakfast cereals or porridge - 125 mL/ 1/2 cup	○	○	○	○	○	○	○	○	○
Milk added to water-based hot drinks (coffee, tea) - 50 mL / 1/5 cup	○	○	○	○	○	○	○	○	○
Milk-based hot drinks (Latte, Milo) - 250 mL / 1 cup	○	○	○	○	○	○	○	○	○

PROMISE study - Food Frequency Questionnaire

6. Milk products

* 1. How often do you usually eat cheese?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day	4+ x / day
Cheddar (tasty, mild, colby) - 2 heaped Tbsp / matchbox cube										
Edam, Gouda, Swiss - 2 heaped Tbsp / matchbox cube										
Feta, Mozarella, Camembert - 1 heaped Tbsp / 1 med wedge										
Brie, blue and other specialty cheese - 1 heaped Tbsp / 1 med wedge										
Processed cheese slices - 1 slice										
Cream cheese - 2 heaped Tbsp										
Cottage or ricotta cheese - 2 heaped Tbsp										

* 2. How often do you usually eat these dairy based foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Ice cream - 2 scoops									
Custard or dairy food - 1 pottle / ½ cup									
Yoghurt, plain or flavour - 1 pottle / ½ cup									
Milk puddings (semolina, instant) - ½ cup									
Fermented or evaporated milk (buttermilk) - ½ cup									

PROMISE study - Food Frequency Questionnaire

7. Bread

* 1. Do you eat bread?

- ◯ No
- ◯ Yes

* 2. What type(s) of bread, rolls or toast do you eat most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- ☐ Not applicable
- ☐ White
- ☐ White – high fibre
- ☐ Wholemeal or wheat meal
- ☐ Wholegrain

Other (please state)

* 3. What type of bread slice do you usually have? (Please choose one only)

- ◯ Not applicable
- ◯ Sandwich slice
- ◯ Toast slice
- ◯ Mixture of both sandwich and toast slices

* 4. On average, how many servings of bread do eat per day? (Please choose one only)
(A 'serving' = 1 slice of bread or 1 small roll)

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1–2 servings
- ◯ 3–4 servings
- ◯ 5–6 servings
- ◯ 7 or more servings

* 5. How often do you usually eat these bread based foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Plain white bread - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
High fibre white bread - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Wholemeal or wheat meal - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Wholegrain bread - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Fruit bread or fruit bun - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Wrap - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯
Focaccia, bagel, pita, panini or other speciality breads - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯
Paraoa Parai (fry bread) - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Rewena bread - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Doughboys or Maori bread - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯

* 6. How often do you usually eat these other bread based foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Crumpet or muffin split - 1 crumpet / 1 whole muffin split	◯	◯	◯	◯	◯	◯	◯	◯	◯
Scone - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯
Bran muffin or savoury muffin - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯
Croissant - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯
Waffle, pancakes or pikelets - 1 medium / 2 small	◯	◯	◯	◯	◯	◯	◯	◯	◯
Iced buns - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯
Crackers (cream crackers, cruskits, corn / rice crackers, vitawheat) - 2 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯

* 7. Do you have butter, margarine or spreads on bread or crackers?

◯ No

◯ Yes

* 8. What type(s) do you have most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- [ ] Not applicable
- [ ] Butter (all varieties)
- [ ] Monounsaturated fat margarine e.g. Olive, Rice Bran, Canola Oil Spreads
- [ ] Polyunsaturated fat margarine e.g. Sunflower Oil Spreads
- [ ] Light monounsaturated fat margarine e.g. Olivio Spread Light
- [ ] Light polyunsaturated fat margarine e.g. Flora Spread Light
- [ ] Plant sterol enriched margarine e.g. Pro Active, Logical Spreads
- [ ] Light plant sterol enriched margarine e.g. Pro Active Spread Light
- [ ] Butter and margarine blend e.g. Country Soft, Butter Lea

Other (please state)

* 9. Choose the one you have the most

- [ ] Not applicable
- [ ] Butter (all varieties)
- [ ] Monounsaturated fat margarine e.g. Olive, Rice Bran, Canola Oil Spreads
- [ ] Polyunsaturated fat margarine e.g. Sunflower Oil Spreads
- [ ] Light monounsaturated fat margarine e.g. Olivio Spread Light
- [ ] Light polyunsaturated fat margarine e.g. Flora Spread Light
- [ ] Plant sterol enriched margarine e.g. Pro Active, Logical Spreads
- [ ] Light plant sterol enriched margarine e.g. Pro Active Spread Light
- [ ] Butter and margarine blend e.g. Country Soft, Butter Lea
- [ ] Other (please state)

* 10. On average, how many servings of butter, margarine or spreads do you have per day? (Please choose one only)
(A 'serving' = 1 level teaspoon or 5 mL)
e.g. 1 sandwich with butter thinly spread on two pieces of bread = 2 servings

- ○ Not applicable
- ○ Less than 1 serving
- ○ 1–2 servings
- ○ 3–4 servings
- ○ 5–6 servings
- ○ 7 or more servings

PROMISE study - Food Frequency Questionnaire

8. Breakfast Cereals and Porridge

* 1. Do you usually eat breakfast cereal and/or porridge?

- ◯ No
- ◯ Yes

* 2. What breakfast cereal(s) do you eat most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- ☐ Not applicable
- ☐ Weetbix
- ☐ Refined cereals e.g. Cornflakes or Rice Bubbles
- ☐ Bran based cereals including fruity varieties e.g. Special K, Muesli, All Bran
- ☐ Sweetened e.g. Nutrigrain, Cocoa Pops
- ☐ Porridge

Other (please state)

* 3. On average, how many servings of breakfast cereal or porridge do you have per week? (Please choose one only)
(A 'serving' = ½ cup porridge, muesli, cornflakes or 2 weetbix)
e.g. ½ cup of porridge 3 times per week + 2 weetbix 4 times a week = 7 servings per week

- ◯ Not applicable
- ◯ Less than 4 servings
- ◯ 4–6 servings
- ◯ 7–9 servings
- ◯ 10–12 servings
- ◯ 13–15 servings
- ◯ 16 or more servings

* 4. How often do you usually eat porridge or these cereal foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Porridge, rolled oats, oat bran, oat meal - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Muesli (all varieties) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Weetbix (all varieties) - 2 weetbix	◯	◯	◯	◯	◯	◯	◯	◯	◯
Cornflakes or rice bubbles - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Bran cereals (All Bran, Bran Flakes) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Bran based cereals (Sultana Bran, Sultana Bran Extra) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Light and fruity cereals (Special K, Light and Tasty) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Chocolate based cereals (Milo cereal, Coco Pops) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sweetened cereals (Nutrigrain, Fruit Loops, Honey Puffs, Frosties) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Breakfast drinks (Up and Go) - Small carton / 250 mL	◯	◯	◯	◯	◯	◯	◯	◯	◯

PROMISE study - Food Frequency Questionnaire

9. Starchy Foods

* 1. Do you eat any type of starchy foods such as rice, pasta, noodles and couscous?

- No
- Yes

* 2. On average, how many servings of starchy foods such as rice, pasta, noodles and couscous do you eat per week? (Please choose one only)
(A 'serving' = 1 cup cooked rice / pasta)
e.g. 1 cup of rice + ½ cup of pasta included in a lasagne pasta dish + 1 cup of spaghetti = 2.5 servings

- Not applicable
- Less than 4 servings
- 4–6 servings
- 7–9 servings
- 10–12 servings
- 13–15 servings
- 16 or more servings

* 3. How often do you usually eat these starchy foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Rice, white - 1 cup									
Rice, brown or wild - 1 cup									
Pasta, white or wholegrain (spaghetti, vermicelli) - 1 cup									
Canned spaghetti (Watties) - 1 cup									
Instant noodles (2 minute noodles) - 1 packet									
Egg and rice noodles (hokkien noodles, udon) - 1 cup									
Other grain (quinoa, couscous, bulgar wheat) - 1 cup									

PROMISE study - Food Frequency Questionnaire

10. Meat

* 1. Do you eat beef, mutton, hogget, lamb, or pork

- ◯ No
- ◯ Yes

* 2. Do you trim any excess fat (fat you can see) off these meats? (Please choose one only)

- ◯ Not applicable
- ◯ Always
- ◯ Often
- ◯ Occasionally
- ◯ Never cut the fat off meat

* 3. On average, how many servings of meat e.g. beef, mutton, hogget, lamb or pork do you eat per week? (Please choose one only)
(A 'serving' = palm size or ½ a cup of meat without bone)
e.g. ½ cup of savoury mince + 2 small lamb chops = 2 servings

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1-3 servings
- ◯ 4-6 servings
- ◯ 7 or more servings

* 4. How often do you usually eat meat?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Beef mince dishes (rissoles, meatloaf, hamburger pattie) - 1 slice / patty / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Beef or veal mixed dishes (casserole, stir-fry) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Beef or veal (roast, chop, steak, schnitzel, corned beef) - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Lamb, hogget or mutton mixed dishes (stews, casserole, stir-fry) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Lamb, hogget or mutton (roast, chops, steak) - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pork (roast, chop, steak) - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Canned corned beef - 1 medium slice	◯	◯	◯	◯	◯	◯	◯	◯	◯

* 5. How often do you usually eat these other meats?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Sausage, frankfurter or saveloy - 1 sausage / frankfurter/ 2 saveloys	◯	◯	◯	◯	◯	◯	◯	◯	◯
Bacon - 2 rashers	◯	◯	◯	◯	◯	◯	◯	◯	◯
Ham - 1 medium slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Luncheon meats or brawn - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Salami or chorizo - 1 slice / cube	◯	◯	◯	◯	◯	◯	◯	◯	◯
Offal (liver, kidneys, pate) - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Venison/game - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

PROMISE study - Food Frequency Questionnaire

11. Poultry

* 1. Do you eat poultry e.g. chicken, turkey or duck?

- No
- Yes

* 2. Do you remove the skin from chicken? (Please choose one only)

- Not applicable
- Always
- Often
- Occasionally
- Never remove the skin from chicken

* 3. On average, how many servings of chicken do you eat per week? (Please choose one only)
(A 'serving' = palm size of chicken or ½ cup)
e.g. 1 chicken breast + 2 chicken drumsticks + 1 chicken thigh = 4 servings per week

- Not applicable
- Less than1 serving
- 1-3 servings
- 4-6 servings
- 7 or more servings

* 4. How often do you usually eat poultry?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Chicken legs or wings - palm size / ½ cup / 1 unit (wing, drumstick)	○	○	○	○	○	○	○	○	○
Chicken breast - palm size / ½ cup / ½ breast	○	○	○	○	○	○	○	○	○
Chicken mixed dishes (casserole, stir-fry) - palm size / ½ cup	○	○	○	○	○	○	○	○	○
Crumbed chicken (nuggets, patties, schnitzel) - 1 medium / 4 nuggets	○	○	○	○	○	○	○	○	○
Turkey or quail - palm size / ½ cup	○	○	○	○	○	○	○	○	○
Mutton bird or duck - palm size / ½ cup	○	○	○	○	○	○	○	○	○

PROMISE study - Food Frequency Questionnaire

12. Fish and Seafood

* 1. Do you eat any type of fish or seafood?

- ◯ No
- ◯ Yes

* 2. On average, how many servings of fish and seafood (all types; fresh, frozen, tinned) do you eat per week? (Please choose one only)
(A 'serving' = 80 - 120g or palm size or small tin (85g))
e.g. 1 fish fillet and 1 small tin of tuna = 2 servings per week.

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1-3 servings
- ◯ 4-6 servings
- ◯ 7 or more servings

* 3. How do you normally cook / eat fish? (You can choose up to 3 options, but please only choose the ones you usually have)

- ☐ Not applicable
- ☐ Raw / I don't cook it
- ☐ Oven baked / Grilled
- ☐ Deep fried
- ☐ Shallow fry
- ☐ Micro waved
- ☐ Steamed
- ☐ Poached
- ☐ Smoked

* 4. How often do you usually eat seafood?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Canned Salmon - 1 small can (85-95g)	◯	◯	◯	◯	◯	◯	◯	◯	◯
Canned Tuna - 1 small can (85-95g)	◯	◯	◯	◯	◯	◯	◯	◯	◯
Canned Mackerel, sardines, anchovies, herring - 1 small can (85-95g)	◯	◯	◯	◯	◯	◯	◯	◯	◯
Frozen crumbed fish (patties, fillets, cakes, fingers, nuggets) - 1 medium / 4 nuggets	◯	◯	◯	◯	◯	◯	◯	◯	◯
Snapper, Tarakihi, Hoki, Cod, Flounder - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Gurnard, Kahawai or Trevally - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Lemon fish or Shark - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Tuna - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Salmon, trout or eel - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

* 5. How often do you usually eat seafood?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Shrimp, prawn, lobster or crayfish - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Crab or surumi - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Scallops, mussels, oysters, paua or clams - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pipi or cockle - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Kina - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Whitebait - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Roe - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Squid, octopus, calamari, cuttlefish - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

PROMISE study - Food Frequency Questionnaire

13. Fats and Oils

* 1. Do you cook meat, chicken, fish, eggs and/or vegetables with fat or oil?

- ◯ No
- ◯ Yes

* 2. What type(s) do you use most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- ☐ Not applicable
- ☐ Butter (all varieties)
- ☐ Margarines (all varieties)
- ☐ Cooking oils (all varieties)
- ☐ Lard, Dripping, Coconut oil, Ghee (clarified butter)
- ☐ Cooking spray

Other (please state)

____

* 3. Chose the one you use the most

- ☐ Not applicable
- ☐ Butter (all varieties)
- ☐ Margarines (all varieties)
- ☐ Cooking oils (all varieties)
- ☐ Lard, Dripping, Coconut oil, Ghee (clarified butter)
- ☐ Cooking spray
- ☐ Other (please state)

____

* 4. When you use fat or oil to cook, how many servings of fat or oil do you use per dish? (Please choose one only)
(A 'serving' = 1 level teaspoon or 5 mL)

- Not applicable
- Less than 1 serving
- 1 serving
- 2 servings
- 3 servings
- 4 servings
- 5 or more servings

* 5. On average, how many servings of fat or oil do you use to cook per week? (Please choose one only)

- Not applicable
- Less than 1 serving
- 1-3 servings
- 4-7 servings
- 8-10 servings
- 11-14 servings
- 15 or more servings

PROMISE study - Food Frequency Questionnaire

14. Eggs

* 1. Do you eat eggs?

- No
- Yes

* 2. On average, not counting eggs used in baking / cooking, how many eggs do you usually eat per week? (Please choose one only)

- Not applicable
- Less than 1 egg
- 1 egg
- 2 eggs
- 3 eggs
- 4 eggs
- 5 or more eggs

* 3. How often do you usually eat eggs?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Whole eggs (hard-boiled, poached, fried, mashed, omelette, scrambled) - 1 egg	◯	◯	◯	◯	◯	◯	◯	◯	◯
Mixed egg dish (quiche, frittata, other baked egg) - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯

PROMISE study - Food Frequency Questionnaire

15. Legumes

* 1. Do you eat legumes e.g. chickpeas/dried peas, soybeans, dried/canned beans, baked beans, lentils or Dahl?

- ◯ No
- ◯ Yes

* 2. On average, how many servings of legumes (fresh, frozen, canned, dried) do you eat per week? (Please choose one only)
(A 'serving' = ½ cup or 125g of cooked legumes)

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1 serving
- ◯ 2 servings
- ◯ 3 servings
- ◯ 4-5 servings
- ◯ 6-7 servings
- ◯ 8 or more servings

* 3. How often do you usually eat these legumes?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Soybeans - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Tofu - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Dahl - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Canned or dried legumes, beans (baked beans, chickpeas, lentils, peas, beans) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Hummus - 2 Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯

PROMISE study - Food Frequency Questionnaire

16. Vegetables

* 1. Do you eat vegetables?

- ◯ No
- ◯ Yes

* 2. On average, how many servings of vegetables (fresh, frozen, canned) do you eat per day? Do NOT include vegetable juices. (Please choose one only)
(A 'serving' = 1 medium potato / kumara or ½ cup cooked vegetables or 1/2 cup of lettuce)
e.g. 2 medium potatoes + ½ cup of peas = 3 servings

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1 serving
- ◯ 2 servings
- ◯ 3 servings
- ◯ 4 or more servings

* 3. How often do you usually eat these vegetables?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Potato (boiled, mashed, baked, roasted) - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pumpkin (boiled, mashed, baked, roasted) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Kumara (boiled, mashed, baked, roasted) - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Mixed frozen vegetables - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Green beans - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Silver beet, spinach - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Carrots - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sweet corn - 1 medium cob / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Mushrooms - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Tomatoes - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Beetroot - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Taro, cassava or breadfruit - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

* 4. How often do you usually eat these vegetables?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Green bananas (plantain) - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sprouts (alfalfa, mung) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pacific Island yams - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Turnips, swedes, parsnip or yams - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Onions, celery or leeks - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Cauliflower, broccoli or broccoflower - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Brussel sprouts, cabbage, red cabbage or kale - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Courgette/zucchini, marrow, eggplant, squash, kamo kamo, asparagus, cucumber - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Capsicum (peppers) - ½ medium / ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Avocado - ¼ avocado	◯	◯	◯	◯	◯	◯	◯	◯	◯
Lettuce greens (mesculin, cos, iceberg) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Other green leafy vegetables (whitloof, watercress, taro leaves, puha) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

17. Fruit

* 1. Do you eat fruit?

◯ No

◯ Yes

* 2. On average, how many servings of fruit (fresh, frozen, canned or stewed) do you eat per day? Do NOT include fruit juice. (Please choose one only)
(A 'serving' = 1 medium or 2 small pieces of fruit or 1/2 cup of chopped fruit)
e.g. 1 apple + 2 small apricots = 2 servings)

◯ Not applicable

◯ Less than one serving

◯ 1 serving

◯ 2 servings

◯ 3 or more servings

* 3. How often do you usually eat these fruits?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Apple - 1 medium / ½ cup									
Pear - 1 medium / ½ cup									
Banana - 1 medium / ½ cup									
Orange, mandarin, tangelo, grapefruit - 1 medium / 2 small									
Peach, nectarine, plum or apricot - 1 medium / ½ cup / 2 small									
Mango, paw-paw or persimmons / ½ cup									
Pineapple - ½ cup									
Grapes - ½ cup / 8-10 grapes									
Strawberries, other berries, cherries - ½ cup									
Melon (watermelon, rockmelon) - ½ cup									
Kiwifruit - 1 medium / 2 small									
Feijoas - 1 medium / 2 small									
Tamarillos - 1 medium / ½ cup									
Sultanas, raisins or currants - 1 small box									
Other dried fruit (apricots, prunes, dates) - 4 pieces									

PROMISE study - Food Frequency Questionnaire

18. Drinks

* 1. On average, how many drinks do you have per day? (Please choose one only)
(A 'serving' = 250 mL or one cup/glass)

- ◯ Less than 1 serving
- ◯ 1-3 servings
- ◯ 4-5 servings
- ◯ 6-8 servings
- ◯ 9-10 servings
- ◯ 11 or more servings

* 2. How often do you usually have these drinks?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Instant soup (Cup of soup) - 250 mL / 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Fruit juice (Just Juice, Fresh-up, Charlie's, Rio Gold) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Fruit drink (Choice, Rio Splice) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Vegetable juice (tomato juice, V8 juice) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Iced Tea (Lipton ice tea) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Cordial or Powdered drinks (Thriftee, Raro, Vita-fresh) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Low-calorie cordial - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Energy drinks small-medium can (V, Red Bull) - 250-350 mL	◯	◯	◯	◯	◯	◯	◯	◯	◯
Energy drinks large can (Monster, Mother, Demon, large V) - 450-550 mL	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sugar-free Energy drinks (sugar-free V, Monster, Red Bull) - 1 small can	◯	◯	◯	◯	◯	◯	◯	◯	◯
Diet soft/fizzy/carbonated drink (diet sprite) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Soft/fizzy/carbonated drinks (Coke, Sprite) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sport's drinks (Gatorade, Powerade) - 1 bottle	◯	◯	◯	◯	◯	◯	◯	◯	◯
Flavoured water (Mizone, H2Go flavoured) - 1 bottle	◯	◯	◯	◯	◯	◯	◯	◯	◯
Water (unflavoured mineral water, soda water, tap water) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯

* 3. How often do you usually have these drinks?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Coffee instant or brewed with or without milk (Nescafe, espresso) - 1 cup									
Specialty coffees (flat white, cappuccino, lattes) - 1 small cup									
Coffee decaffeinated or substitute (Inka) - 1 cup									
Hot chocolate drinks (drinking chocolate, hot chocolate, Koko) - 1 cup									
Milo - 1 tsp									
Tea (English breakfast tea, Earl Grey) - 1 cup									
Herbal tea or Green tea - 1 cup									
Soy drinks - 1 cup									

* 4. How often do you usually have these alcoholic drinks?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Beer – low alcohol - 1 can or bottle									
Beer – ordinary - 1 can or bottle									
Red wine - 1 small glass									
White wine, champagne, sparkling wine - 1 small glass									
Wine cooler - 1 small glass / bottle									
Sparkling grape juice - 1 glass / cup									
Sherry or port - 100 mL									
Spirits, liqueurs - 1 shot or 30 mL									
RTD (KGB, Vodka Cruiser, Woodstock bourbon) - 1 bottle / can									
Cider - 1 glass / cup / bottle									
Kava - 1 glass / cup									

PROMISE study - Food Frequency Questionnaire

19. Dressings and Sauces

* 1. How often do you usually have these dressings or sauces?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Butter (all varieties) - 1 tsp									
Margarine (all varieties) - 1 tsp									
Oil (all varieties) - 1 tsp									
Cream or sour cream - 1 Tbsp									
Mayonnaise or creamy dressings (aioli, tartae sauce) - 1 Tbsp									
Low fat/calorie dressing (reduced fat mayonnaise) - 1 Tbsp									
Salad dressing (french, italian) - 1 Tbsp									
Sauces (tomato, BBQ, sweet chilli, mint) - 1 Tbsp									
Mustard - 1 Tbsp									
Soy sauce - 1 Tbsp									
Chutney or relish - 1 Tbsp									
Gravy homemade - ¼ cup									
Instant Gravy (e.g. Maggi) - ¼ cup									
White sauce/cheese sauce - ¼ cup									

PROMISE study - Food Frequency Questionnaire

20. Miscellaneous - Cakes, Biscuits and Puddings

* 1. How often do you usually eat these baked products?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Cakes, loaves, sweet muffins - 1 slice / 1 muffin									
Sweet pies or pastries, tarts, doughnuts - 1 medium									
Other puddings or desserts - not including milk-based puddings (sticky date pudding, pavlova) - ½ cup									
Plain biscuits, cookies (Round wine, Ginger nut) - 2 biscuits									
Fancy biscuits (chocolate, cream) - 2 biscuits									

PROMISE study - Food Frequency Questionnaire

21. Miscellaneous

* 1. How often do you usually eat these other foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Jelly - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Ice blocks - 1 ice block	◯	◯	◯	◯	◯	◯	◯	◯	◯
Lollies - 2 lollies	◯	◯	◯	◯	◯	◯	◯	◯	◯
Chocolate - including chocolate bars (Moro bars) - 1 small bar	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sugar added to food and drinks - 1 level tsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Jam, honey, marmalade or syrup - 1 level tsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Vegemite or marmite - 1 level tsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Peanut butter or other nut spreads - 1 level Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Brazil nuts or walnuts - 2	◯	◯	◯	◯	◯	◯	◯	◯	◯
Peanuts - 10	◯	◯	◯	◯	◯	◯	◯	◯	◯
Other nuts (almonds, cashew, pistachio, macadamia) - 10	◯	◯	◯	◯	◯	◯	◯	◯	◯
Seeds (pumpkin, sunflower)	◯	◯	◯	◯	◯	◯	◯	◯	◯
Muesli bars - 1 bar	◯	◯	◯	◯	◯	◯	◯	◯	◯
Coconut cream - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Coconut milk - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Lite coconut milk - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Potato crisps, corn chips, Twisties - ½ cup / handful	◯	◯	◯	◯	◯	◯	◯	◯	◯

* 2. Do you use salt in cooking?

◯ Never
◯ Rarely
◯ Sometimes
◯ Usually
◯ Always

* 3. Do you use salt at the table?

◯ Never
◯ Rarely
◯ Sometimes
◯ Usually
◯ Always

PROMISE study - Food Frequency Questionnaire

22. Miscellaneous - Takeaways

* 1. On average, how often do you eat takeaways per week? (Please choose one only)

- ◯ Never
- ◯ Less than 1 times
- ◯ 1-2 times
- ◯ 3-4 times
- ◯ 4-6 times
- ◯ More than 7 times

* 2. How often do you usually eat these takeaway foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Meat pie, sausage roll, other savouries - 1 pie / 2 small sausage rolls or savouries	◯	◯	◯	◯	◯	◯	◯	◯	◯
Hot potato chips, kumara chips, french fries, wedges - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Chinese - 1 serve	◯	◯	◯	◯	◯	◯	◯	◯	◯
Indian - 1 serve	◯	◯	◯	◯	◯	◯	◯	◯	◯
Thai - 1 serve	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pizza - 1 medium slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Burgers - 1 medium burger	◯	◯	◯	◯	◯	◯	◯	◯	◯
Battered fish - 1 piece	◯	◯	◯	◯	◯	◯	◯	◯	◯
Fried chicken (KFC, Country fried chicken) - 1 medium piece	◯	◯	◯	◯	◯	◯	◯	◯	◯
Bread based (Kebab, sandwiches, wraps, Pita Pit, Subway) - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯

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23. Other

* 1. Are there any other foods or drinks that you can think of that you have on a regular basis that was not covered by this questionnaire?

- ◯ No
- ◯ Yes

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24. Other

1. Please list these foods and drinks including; the serving size, and how many times per week you eat or drink these items (e.g. Pizza, 4 slices, one time per week)

PROMISE study - Food Frequency Questionnaire

25.

Thank you for completing this questionnaire!