The PEAR Tool: Evaluating portion sizes of food and beverages in food advertising in children's neighbourhoods using Google Street View

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Abstract

Background: Food and beverage advertising has been shown to influence the purchasing and nutrition behaviours of children. Previous research has established where and what types of advertising are in children's neighbourhoods. However, no prior research has evaluated the portion sizes in advertisements or how these compare with national dietary recommendations. The purpose of the study was to evaluate portion sizes in advertising on bus shelters within a 500m road network boundary of schools around Auckland using images captured on Google Street View.

Methods: A literature search was conducted to examine children's exposure to food and beverage advertising and portion size trends influencing an individual's portion size estimations. An evaluation to identify a suitable methodology to assess portion sizes in advertising was conducted. Then the successful features were integrated into the design and development of a new portion size estimation tool. Portion sizes for 265 foods or beverages in 172 advertisements on bus shelters within 500m of Auckland schools were analysed in an ancillary study to determine the discrepancy with nutritional guidelines. School type, decile, distance from school boundary, Walk Score® and Transit Score were analysed.

Results: A lack of appropriate portion sizes estimation tools that could be applied to images of advertisements was identified. Thus, the Portion size Estimation in Advertising Reckoner (PEAR) Tool was developed to calculate the scale of advertised food and beverages. The key findings showed 1) the majority of food and beverage products in advertisements were enlarged, 2) double the mean number of recommended portions were found in non-core food and beverages, 3) a greater proportion of advertisements were found near low decile schools, but the portions were greater near high decile schools and 4) most advertisements were found >300m from school boundaries, but at more proximate distances the portions for non-core food advertisements were greater.

Conclusion: Advertised food and beverage items are generally exaggerated, with the depicted portion sizes exceeding national dietary recommendations. Further research is needed to demonstrate the relationship between advertised portion sizes and health outcomes in children. Stricter national and local advertising policies are needed to improve the food environments surrounding schools.

Acknowledgements and Statements of Contributions

The completion of this thesis was only possible due to the help and support of several people. Firstly, words cannot express my gratitude to my amazing supervisors, Dr Victoria Egli and Dr Rajshri Roy, for their invaluable insight, expertise and guidance. With their patience, constructive feedback and a challenge to consider other perspectives on health throughout the writing process, I was able to get across the finish line and produce a piece of work to the best of my abilities. I would also like to thank Craig Porter for sharing your developer knowledge and for your collaboration with aspects of the research, including the Portion size Estimation in Advertising Reckoner (PEAR) Tool development (as detailed within the document). This research would not have been possible without Donna Huang, who generously provided me with access to the 'Bus Stops Near Schools Advertising Junk Food and Sugary Drinks' study data. I would like to extend my appreciation to the University of Auckland Nutrition and Dietetics team; for always being available to offer their support and for offering a range of unique opportunities over the past two years to build upon my nutrition knowledge. Thanks should go to my professors, Lindsay Plank and Dr David Musson, for coordinating the thesis paper. Lastly, I would be remiss in not mentioning my family and friends. Their ongoing love and support have kept my motivation high throughout this process and reaffirmed my passions when things seemed doubtful. Thank you all for believing in me. This would not have been possible without you all.

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Glossary

Advertisement	Marketing method used for commercial communication and messages with the intent to influence the choice, opinion or behaviour for the products and services included (Advertising Standards Authority, 2017)
Child	Any person under 18 years of age (United Nations General Assembly, 1989)
Fiducial marker	Visual object used as a reference point to facilitate locating points of correspondence
Core	Recommended to be marketed to children based on the WHO Regional Office for Europe Nutrient Profiling Model (World Health Organization, 2015).
Food environment	Physical, socio-cultural, economic and political context people engage with to influence people's decisions around food and drink choices and diet quality (Swinburn et al., 2013)
Outdoor advertisement	"All stationary objects containing either a recognisable logo and/or an intended message" (Maher et al., 2005, p. 3)
Non-core	Not recommended (non-core) to be marketed to children based on the WHO Regional Office for Europe Nutrient Profiling Model (2015).
Portion size	Amount of food offered at a single eating occasion (Ministry of Health, 2015)

Serving size	Standard quantities of food or drink to indicate how much to eat to meet energy and nutrient requirements (Ministry of Health, 2015).
Unhealthy food	Food and beverages with energy, sugar, salt and/or fat contents exceeding the thresholds set out in nutrient profile systems (World Health Organization, 2015)

Abbreviations

ADHD - Attention Deficit Hyperactivity Disorder

ASA – Advertising Standards Authority

B4SC – Before School Check

BMI – Body Mass Index

CVD – Cardiovascular Diseases

FBCS – Food and Beverage Classification System

GSV – Google Street View

HFSS – High fat, salt and/or sugar

MoH – Ministry of Health

NZ – New Zealand

PSEA – Portion Size Estimation Aid

RGB – Red, green and blue

SSB – Sugar Sweetened Beverages

UK – United kingdom

USA – United States of America

WHO – World Health Organisation.

1. Introduction

1.1. Background to research

Exposure to the presence of food and drink advertisements in areas children visit every day impacts children's dietary choices and intake, purchase behaviour and diet-related health (Cairns et al., 2013; Sadeghirad et al., 2016). In Aotearoa New Zealand, hereafter NZ, children are exposed to an abundance of food advertising with the further implication of greater inequities in neighbourhoods of greater socio-economic deprivation (Egli et al., 2018; Egli, Hobbs, et al., 2020; Sushil et al., 2017; Vandevijvere et al., 2016). Schools are an important environment in children's everyday lives and are key to supporting behavioural changes beyond an individual level. The industry-led advertising policies related to foods and beverages for children in NZ are largely voluntary, ambiguously worded and poorly enforced (Sing et al., 2020). It was in this context of ineffective policies in the neighbourhoods in which children live, play and go to school that this study was undertaken.

This study will use data from the cross-sectional observational study conducted in 2019 by Huang et al. (2020), which aimed to quantify the extent of bus stop advertisements promoting non-core food and beverages within 500m from schools in Tāmaki Makarau, Auckland hereafter Auckland, NZ. Data was collected from August 2019 and January 2020 using Google Street View (GSV). The full study protocol including methods of data collection, coding and analysis by Huang et al. (2020) is detailed elsewhere. This study identified 190 schools with advertisements within a 500 m boundary, out of the 573 schools in the Auckland region. Huang et al. (2020) concluded that more effective policies and enforcement are necessary to ensure children are not compromised by the abundant advertising of unhealthy food and drinks on their travelling routes to and from school.

The research to date has focused on the extent of advertising in children's neighbourhoods. To the best of my, and my supervisors knowledge, no prior research has investigated if the portion sizes of the advertised foods and drinks is in line with children's dietary recommendations. As portion distortion is common in high fat, sugar and salt (HFSS) foods, there is a need to address if children in Auckland are exposed to this portion distortion, which is so far lacking in the literature. By utilising images of outdoor advertisements around Auckland schools, this thesis will evaluate portion sizes in advertising to children to answer the question, "*How do portion sizes for food and beverages depicted in outdoor advertising compare to reference portion sizes set by national standards?*"

1.2. Thesis outline

This thesis is presented in six chapters. The flow between these chapters is illustrated in Figure 1. Together these chapters report on a project undertaken as part of a Master of Nutrition and Dietetics at the University of Auckland.

Chapter One: Above is a background to the research and an overview of the study the data used in this research has been collected from. The purpose of the study and research question are discussed.

Chapter Two: A review of the academic literature examining our current understanding of outdoor advertising for unhealthy food and beverages in children's neighbourhoods and portion sizes on children's dietary intake and health, including national and international sources. A paucity in the evaluation of portion sizes in outdoor food advertising around children's neighbourhoods or the effect this has on consumption in children was identified as a knowledge gap. The research objectives are then presented.

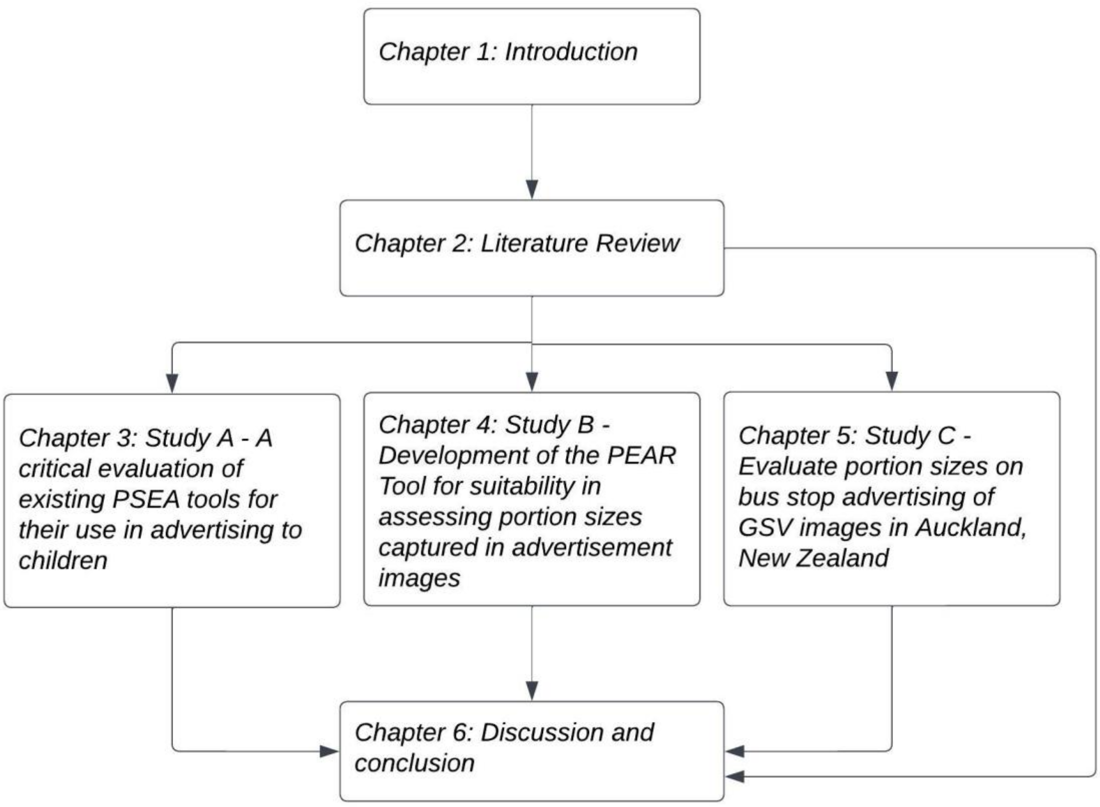
Chapter Three: Outlines the methods and key findings of the critical evaluation on available portion size estimation aids (PSEAs). This is followed by a discussion of the implications of these findings and the identification of a lack of accurate methods to assess portion sizes depicted in advertising.

Chapter Four: The findings of Chapter 3 guided the researcher in the core functional and non-functional requirements of developing a suitable portion size estimation tool for children in NZ using images captured by GSV. Following this, the various steps involved in using the developed PEAR Tool are outlined in detail.

Chapter Five: Outlines the methods and results of the portion size analysis of bus stop advertisements around schools in Auckland, NZ; including methods of data collection and image selection, as well as a detailed description of the development of relevant fiducial marker and portion size databases. The procedure for data analysis is then outlined in detail. The key findings of the research are then presented, with key differences in core and non-core food and beverages assessed according to school decile, distance from school boundary, Walk Score®, and Transit Score.

Chapter Six: provides a discussion of the key findings from Chapters 2, 3, 4 and 5 and an analysis of these results in relation to other literature. The implications of these findings for policy and future research are considered before exploring the strengths and limitations of this research. Finally, the research conclusions are presented.

Figure 1. Thesis Structure



2. Literature Review

2.1. Introduction

The purpose of this thesis is to gain insight into the nature of advertised portion sizes in children's neighbourhoods. Auckland is the most populous city in NZ and is ethnically diverse (Auckland Council, 2018); home to 34% of persons under 15 years in 2018, with 49.8% of children identifying as European, followed by 28.3% Asian, 23.5% Pacific and 16.9% Māori (Roberts, 2020). This thesis will adopt the definition provided by the United Nations Convention on the Rights of the Child (UNCRC) (1989), and defines a child as any person under 18 years of age. The neighbourhoods in which children live, play and go to school can influence the nutrition behaviours of children. Aspects of the food environments within these neighbourhoods, including larger portions and advertising, influence preferences, purchasing, and dietary behaviours, by mechanisms including the normalisation of the consumption of these products (Cairns et al., 2013; Ogba & Johnson, 2010; Sadeghirad et al., 2016; Schwartz & Byrd-Bredbenner, 2006). Undertaking research to evaluate the existing portion sizes in food and beverage advertising located in children’s neighbourhoods is needed.

This review will explore the existing international and NZ literature related to advertising in children's neighbourhoods. Consideration is given to the extent of exposure and how this influences child purchasing and consumption norms, as well as portion size trends, including visual cues, which may shape an individual’s estimation of an appropriate portion size (Geier et al., 2006; Herman et al., 2015; Neyens et al., 2015; Robinson & Kersbergen, 2018; Rolls et al., 2002). A background on aids developed to assist individuals in estimating portion sizes is also included.

The review included searching databases available through the University of Auckland library. Databases searched included Scopus, Embase, Medline and Web of Science. Literature was sourced using a flexible search process; using a series of keywords in various combinations, as detailed in Figure 2. Relevant references were also sourced by reference lists within articles and article suggestions provided by my supervisors.

Figure 2. Search Strategy for Scopus

(TITLE-ABS-KEY ("Portion size*") OR TITLE-ABS-KEY (portion*) OR TITLE-ABS-KEY (serving*) AND TITLE-ABS-KEY (advertis*) OR TITLE-ABS-KEY (marketing) OR TITLE-ABS-KEY (outdoor AND advertising) OR TITLE-ABS-KEY (promotion*) AND TITLE-ABS-KEY (food*) OR TITLE-ABS-KEY (drink*) OR TITLE-ABS-KEY (beverage*) OR TITLE-ABS-KEY (nutrition) OR TITLE-ABS-KEY (intake) OR TITLE-ABS-KEY (diet*) OR TITLE-ABS-KEY (eat*) OR TITLE-ABS-KEY (consumption) AND TITLE-ABS-KEY (child*) OR TITLE-ABS-KEY (adolescent*) OR TITLE-ABS-KEY (youth) OR TITLE-ABS-KEY ("Young People*"))

2.2. Suboptimal nutrition intakes in NZ children

Globally, evidence shows that children's dietary intakes do not meet the recommendations of international dietary guidelines (Afshin et al., 2019; Krebs-Smith et al., 2010; Whitrow et al., 2016). Nutrition guidelines set out evidence-based recommendations required for optimum growth and development, prevention of nutritional deficiencies and reducing the incidence of nutrition-related chronic diseases (Ministry of Health, 2015). A diet rich in fruits and vegetables is associated with reductions in the risk of developing cardiovascular diseases, all-cause mortality and cancer (Aune et al., 2017).

Suboptimal healthy food consumption is often paralleled by excessive unhealthy food and beverage intake (Afshin et al., 2019); with studies in NZ demonstrating a similar trend (Maddison et al., 2010; Ministry of Health, 2003). The Nutrition Guidelines for NZ children aged 2–18 recommend limiting HFSS foods to less than one serving a week (Ministry of Health, 2015). However, the 2002 National Children's Nutrition Survey found that at least once a week, 85% of children consumed chips and around 50% consumed chocolate, confectionery and soft drinks (Ministry of Health, 2003). Only two out of five children met the recommended servings of fruit and three out of five children for servings of vegetables (Ministry of Health, 2003). These findings are from 20 years ago, in children aged 5-14 years. A more recent National Survey was conducted in 2008/09; however, recruited slightly fewer participants and extended beyond children to include people 5-24 years, who are likely to have different nutrient needs than children under 14 years (Maddison et al., 2010). Similar findings found 50% ate fast food or takeaways more than once a week, 39.6% ate chocolate or sweets 1-2 times a week and 52.6% drank soft drinks at least once a week (Maddison et al., 2010). Regular and frequent consumption of nutrient-poor and ultra-processed foods contributing to 20% of total energy intakes in NZ children aged 5-14 years suggests a greater contribution of poor-quality nutrients from HFSS foods, leaving more nutritious foods, such as fruits and vegetables, prone to displacement (Ministry of Health, 2015). Leaving children at a greater risk for developing chronic nutrition-related diseases (Juul et al., 2021).

2.2.1. Health impacts of unhealthy food and beverages

A poor diet and excessive consumption are associated with several adverse health outcomes, including diabetes, cardiovascular disease, obesity and oral health disease (Marmot & Wilkinson, 2005).

The incidence of type 2 diabetes cases among NZ children increases each year (Sjardin et al., 2018). Uncontrolled diabetes can increase an individual's risk of several long-term complications, including heart disease, stroke, kidney failure, blindness, amputations, and nerve damage (Naidu, 2011). The prevention and management of diabetes encompasses healthy lifestyle changes involving a diet rich in wholegrains, fruits, vegetables, legumes, and nuts (Ley et al., 2014). Similarly, a cardio-protective diet emphasises limiting processed meats, dairy foods, refined grains and ultra-processed foods (Yu et al., 2016). As such, a higher-quality diet during childhood plays a key role in modifying cardiovascular risk and vascular health in adulthood (Kaikkonen et al., 2013). Yet, these recommendations are not reflected in the dietary patterns of NZ children (Maddison et al., 2010; Ministry of Health, 2003).

10.1% of NZ children aged 1-14 years have experienced tooth decay, abscess or infection, leading to teeth removal (Ministry of Health, 2021a). Reduced risk of developing dental caries is highly correlated with lower free sugar intake (Moynihan & Kelly, 2014). NZ’s largest longitudinal study found white bread, fruit juice, refined breakfast cereals and sugar-sweetened beverages (SSB) to be the most commonly consumed cariogenic foods (Thornley et al., 2021). Alongside availability, the role of associated advertising and portion sizes for these products in the risk of carie development should therefore be considered.

Such nutrient-poor dietary patterns, including the frequent intake of junk food and energy drinks, have further been associated with poorer mental health outcomes and obesity in children

(Khalid et al., 2016; Park et al., 2016; Sahoo et al., 2015). Being overweight or obese in childhood is associated with greater risk and earlier onset of diabetes, hypertension, heart disease, stroke, cancer and osteoarthritis (Llewellyn et al., 2016; Swinburn et al., 1997). The cause of obesity is often over-simplified and attributed to an energy imbalance, whereby an excess number of calories are consumed compared to energy expended (Arora et al., 2019; Rolls et al., 2002). However, obesity is a complicated network of genetic, physiological, psychological, and environmental variables (Arora et al., 2019). 1 in 8 children aged 2–14 years were classified as obese in 2021, up 3.2% since 2019/20 (Ministry of Health, 2021b). Contrary to the global rise in obesity rates, several high-income countries have found obesity rates among children plateau (Moss et al., 2012; Ogden et al., 2012; Olds et al., 2011). Supporting proposals that public health initiatives to support healthy food environments are effective (Shackleton et al., 2018). Similar findings were demonstrated using a near-whole population of NZ 4-year-olds (Daniels et al., 2022; Shackleton et al., 2018). B4 School Check (B4SC) data is not directly comparable to NZ Health Survey data, recruiting a smaller population over a wider age range (Ministry of Health, 2021a). Furthermore, these reductions are small, and the prevalence of obesity remains high (Ministry of Health, 2021b). Further investigation into the factors, such as advertising, which may be influencing the portion sizes of HFSS food products consumed by children is warranted to improve the diet quality and health of NZ children.

2.3. Children's food environments in NZ

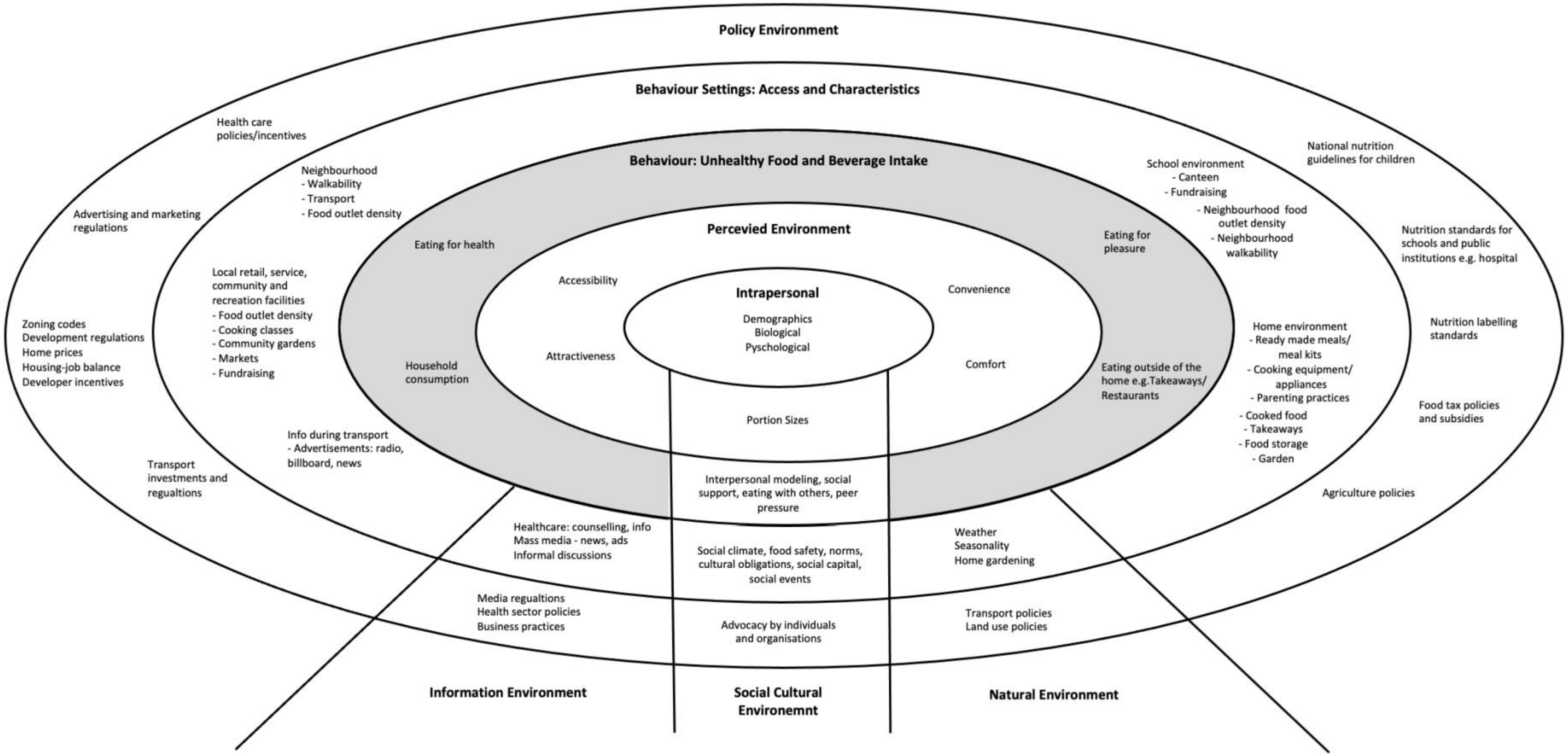
2.3.1. Socio-ecological model

Studies indicate food outlets and advertising are important components of children’s neighbourhood environments and may influence NZ children’s health outcomes (Signal et al., 2017; Vandevijvere et al., 2018). Furthermore, portion sizes and food advertising have been shown to influence the children’s nutrition behaviours (Birch et al., 2015; Chou et al., 2008; Fisher et al., 2007; Pettigrew et al., 2013; Rolls et al., 2000; Sadeghirad et al., 2016). However, little is known about the portion sizes depicted in the abundant presence of outdoor advertising. It is unknown whether exaggerated portion sizes in advertising warrant public health concerns.

Individual-level interventions assume that everyone has the circumstances to rationally select what, when and how much to eat, which is often not the case for children. Thus, individuals are left prone to short-term changes in behaviour due to the lack of a supportive wider environment for the maintenance of health-promoting behaviours (Sallis & Owen, 2015). Furthermore, individual-level interventions are proposed to be more expensive because they only influence the persons receiving treatment (Seymour et al., 2004). Due to the limited efficacy of interventions targeted to the individual, interventions to improve health behaviours have shifted their focus to the environment (Lake & Townshend, 2006; Seymour et al., 2004).

The socio-ecological framework developed by Sallis et al. (2015) offers a clear understanding of environmental influences on health behaviours and outcomes, including nutrition; demonstrating the myriad of interacting determinants of health behaviours and outcomes, of which all levels, from the individual through to wider policy influences, are deemed important. Furthermore, it brings awareness to social determinants of health, such as deprivation. In Figure 3 below, an adaption of the model demonstrates factors influencing unhealthy dietary intake in children. In this framework, health behaviours are influenced by the interplay of intrapersonal, interpersonal, organizational, community, physical environment, and public policy levels (Sallis & Owen, 2015). The intrapersonal environment comprises of socio-economic status, age, gender, ethnicity and family situation (Sallis & Owen, 2015). The social environment refers to knowledge, attitudes, beliefs and cultural obligations towards food. Behaviour settings include communities such as the home, school and community facilities (Sallis & Owen, 2015). The environment comprises all social, cultural, political and physical features, such as health systems and transport infrastructure (Sallis & Owen, 2015). Finally, the political environment refers to rules, laws and policies which influence food choice and consumption (Sallis & Owen, 2015). Rather than being linear in cause and effect, each level interacts and influences the others. Thereby, socio-ecological approaches provide a valuable foundation when evaluating an individual's ability to access and select healthy food given the constraints of their environment (Hill, 1998). Acknowledging the reciprocal relationship between an individual's behaviour and their environment through an ecological perspective contributes insights to a more comprehensive understanding of the influences impacting nutrition behaviours and health across the life course.

Figure 3. Theoretical Foundation of The Research (adapted from Sallis & Owen, 2015)



2.3.2. Unhealthy food and beverage advertising to children

Advertising is one feature of the current environment influencing unhealthy food availability and choice. A range of advertising mediums exposes an individual to marketing messages, such as magazines, billboards, brochures, packaging, radio, advergames, social media, websites, broadcast media and within apps (Boyland & Whalen, 2015). Using non-broadcast channels, such as outdoor advertising, allows marketers to inexpensively promote their products widely in places where young people spend a large amount of time, frequently and routinely exposing children to the advertised products and messages (Schor & Ford, 2007).

Advertising of unhealthy food products encompasses the placement of HFSS food and beverages in different mediums. The MoH Food and Beverage Classification System (FBCS) (2013) outlines examples of occasional foods and drinks such as confectionery, ice cream, crisps, biscuits/cakes/muffins/pastries, deep-fried foods, pies, burgers/pizzas, SSB's, and energy and sports drinks. A review by Finlay et al. (2022) found that 22.1% of outdoor advertisements are for food products, of which 63% are unhealthy. However, only some studies utilised a nutrient profiling model to classify the healthiness of depicted foods.

Research to determine the exposure of NZ children to food advertising was undertaken in 2017. The Kids Cam cross-sectional study examined the exposure of children aged 11-13 years to food advertising using wearable cameras over four consecutive days (Signal et al., 2017). Children were exposed to unhealthy food advertisements 27.3 times per day across all settings, double the average exposure to core food advertising. The majority of advertising for non-core food items occurred either at home, in public spaces or in school (Signal et al., 2017). While these findings provide valuable insight into the actual exposure to food advertising in children's everyday environments, these findings are likely to be underestimated, which may have implications for the ratio of categorisations to core or non-core. Firstly, advertising was only coded if 50% of the brand were determinable (Signal et al., 2017). Secondly, still photography records imagery every 7 seconds, which may have missed some exposures. Finally, advertising in convenience stores, supermarkets and on screens was excluded after being deemed too numerous to count. Thus, the usefulness of these results is limited in regard to informing which advertising platforms and settings are effective to act on to reduce NZ children's exposure to unhealthy food advertising.

The generalizability of the findings is constrained by the study's geographical scope and small sample size. Furthermore, no data was collected on child consumption behaviours. It is unknown whether this frequent exposure of NZ children to food advertisements in their everyday environment directly links to the normalisation and reinforcement of unhealthy dietary behaviours. Understanding the actual exposure of NZ children to outdoor food advertising is the first step toward understanding the role of children's neighbourhood environments on the nutrition and health behaviours of children in NZ. An opportunity was missed to assess the nature of advertised portion sizes to which children are exposed, of which future research should explore. Thus, limiting our understanding of the intersection between advertising in children’s neighbourhoods and the implications of enforcing stricter advertising regulations. It is in this way that future research can begin to define the influence of portion sizes in outdoor advertising on the consumption patterns of NZ children and how it may be consequential to health outcomes.

2.4. Consumer characteristics

Globally, companies invest heavily in market research to gain insight into what influences children's purchasing decisions. In 2018 it was estimated that advertisers worldwide spent 4.2 billion U.S. dollars to reach the child market (Guttmann, 2020). A cross-sectional study exploring advertising outside convenience stores surrounding primary schools in Auckland found that 93.8% of advertising was considered advertising to children (Brien et al., 2022).

Children aged 2-3 years can recognise familiar characters and products; however, it is not until children reach the age of 7 or 8 years that they understand the intention behind advertisements (Sadeghirad et al., 2016; Story & French, 2004; Wilcox et al., 2004). Interviews conducted in a qualitative NZ study found that children aged 11-13 years had the nutrition knowledge to differentiate between healthy and unhealthy foods and beverages, could recall persuasive advertising techniques and recognised financial gain as the purpose of the advertisement (Signal et al., 2019). However, all but one child reported sometimes believing the advertised messages (Signal et al., 2019).

The effect of advertising on children's purchasing preferences has been widely demonstrated (Cairns et al., 2013; Calvert, 2008; McKerchar et al., 2020; Story & French, 2004; Wilcox et al., 2004; Wilson & Wood, 2004). Investments in food advertising actively encourage children to purchase and consume their products by using attractive themes rather than promoting nutrition and health messages (Boyland & Halford, 2013). Techniques that have been considered appealing to children include the use of sportspersons, popular characters, such as Santa Claus, other children and emojis (Sing et al., 2020). Brand awareness and preference for the advertised products are established at a young age, strengthening with exposure (Ogba & Johnson, 2010; Story & French, 2004; Wilcox et al., 2004). Although older children may develop an awareness of brand substitutes, brand preference has a strong affinity with children of all ages (Elliott et al., 2013; McNeal, 1979). Thus, children are considered a present, and future, consumer market.

Children of all ages are a vulnerable population to the influence of advertising and require appropriate protection from features in children's neighbourhoods that encourage unhealthy nutrition behaviours. In 2010, the World Health Organisation (WHO) adopted a set of recommendations to regulate the marketing of unhealthy foods and non-alcoholic beverages to children and young people (World Health Organization, 2007). These are as follows:

- The intent of the type of product or service and if children would find it very interesting to them
- Design choices such as colours or characters that may appeal to children
- Campaigns that are conducted in places frequented mainly by children

While policymakers have generally focused on the physical health impacts of unhealthy products being marketed to children, the commercial exploitation of all products and industries impacting the holistic health, behaviours, knowledge, and identities of children requires greater consideration (Powell, 2020). It is also important for research and policy to acknowledge that children may be influenced by advertising not wholly directed at children. As well as building upon our current understanding of children's exposure to unhealthy advertising, this research aims to describe the advertisements in children's neighbourhoods through an analysis of portion size depictions.

2.4.1. Purchasing power of children

Children are a lucrative customer base for advertising. In a survey of 400 British parents, 91% of respondents preferred a weekly allowance by the age of six (Furnham, 2010). Many adolescents begin generating disposable income from part-time jobs (Scully et al., 2012). Thus, gaining increasing accessibility to make independent purchasing decisions (Scully et al., 2012). An ancillary study of the Kids' Cam study by Signal et al. (2017) found exposure to non-core packaging, signs, branded displays and price promotions were substantially higher than all marketing mediums for core foods; subsequently, 94.6% of purchased items were non-core and all items consumed were non-core (McKerchar et al., 2020). Further detail is needed to comprehensively understand the influences impacting children's purchasing decisions, including when this is done independently or when accompanied by a parent. Additionally, the inclusion of images from 37 children and purchasing from one type of food outlet limits the generalizability of these results (McKerchar et al., 2020).

Children are also considered lucrative because of their influence on parental purchasing decisions (Calvert, 2008; Wilson & Wood, 2004). In 2007, 12-17 year-olds in the United States (USA) had $80 billion in disposable income, with an additional $110 billion spent by parents on apparel, food, personal care items, and entertainment (Montgomery, 2007). Purchase request behaviour, also coined 'pester power' by Young et al. (1996), describes a child's ability to overcome their limited economic power to consume goods and services by negotiation. A child's purchase-influence-attempt has been demonstrated to frequently influence parental purchasing decisions, particularly regarding unhealthy foods (Cairns et al., 2009; Wilson & Wood, 2004). The extent of a child's choice and independence in food purchasing and consumption behaviours is unclear. Further research into the purchasing behaviour of children following exposure to food advertisements would generate important insights into the subsequent influence on children's nutrition behaviours.

2.5. Neighbourhood environments

Neighbourhoods are a key environment in a child's everyday experiences. Children have a strong engagement in their immediate surroundings as they have less mobility than adults who may travel between neighbourhoods to fill daily commitments (Egli, Villanueva, et al., 2020). Aspects of the built environment in children's neighbourhoods, such as food outlets and advertising, have been shown to affect dietary behaviours in several studies (Pitt et al., 2017; Thornton et al., 2016; Vandevijvere et al., 2016), and therefore play an important role in promoting health behaviours.

The location of schools has become an increasingly important neighbourhood setting (Swinburn et al., 1999). In NZ, children six years of age must be enrolled in school or at home school. In a scoping review by Finlay et al. (2022), examining the exposure of children to food advertising, a high prevalence of outdoor food advertisements was found around schools. One study found low exposure to bus shelter advertisements surrounding schools but acknowledged outdoor food advertisements were likely to be encountered while walking, cycling, bussing, or being driven to school (Finlay et al., 2022; Olsen et al., 2021). Walkability is the extent to which the built environment facilitates or encumbers walking and is often a proxy measure for the supportiveness of active transport, such as walking, cycling, scootering or skating, in children's neighbourhoods (Genter et al., 2009; Walk Score, 2022). Transit Score® indicates the public transport accessibility to and from the school (Walk Score, 2022). The repeated exposure to messages promoted among several advertising mediums within or en route to destinations in children's environments combines and contributes to normalising and encouraging the consumption of unhealthy products (Pettigrew et al., 2013; Swinburn et al., 2011). As such, the neighbourhood environment is an integral mediator in promoting or inhibiting healthy eating (Swinburn et al., 1999). There is a call for action to reduce unhealthy food and drink advertising in children's neighbourhood environments in NZ (Garton et al., 2022).

2.5.1. Food environment and deprivation

The neighbourhood food environment has a significant influence on food accessibility and nutrition behaviours (Ellaway & Macintyre, 2000). Swinburn et al. (2013, p. 14) defined the food environment as the "collective physical, economic, policy and socio-cultural surroundings, opportunities and conditions that influence people's food choices and nutritional status." Today's food environment is characterised by highly palatable and energy-dense foods that are inexpensive, readily available and abundant (Hill, 1998; Ministry of Health, 2015). Multinational food companies influence diet by determining the availability, accessibility and price of food and beverages (Young & Nestle, 2007). Noticeably lacking is the concern for the associated advertising of these food products, which acts to reinforce the availability, accessibility and price of these food products. The role of the modern food environment on children's consumption is complex and influenced by many factors.

Globally, access to unhealthy food outlets has increased significantly (Cooksey-Stowers et al., 2017; Thornton et al., 2016). A 'food desert' describes a food environment that lacks access to healthy and affordable food (Luan et al., 2015). Similarly, a 'food swamp' refers to a food environment with an overwhelming abundance of energy-dense, nutrient-poor foods, typically from fast food outlets and restaurant dining (Rose et al., 2010). The combination of these environments promotes easy access and availability to affordable energy-dense foods leading to a greater likelihood of unhealthy food availability, purchasing and consumption (Sushil et al., 2017). While there are few prominent food deserts in NZ, research has found several food swamps associated with areas of greater deprivation (Day & Pearce, 2011; Sushil et al., 2017; Wiki et al., 2019).

Several studies have established that lower socio-economic neighbourhoods are more likely to experience a greater density of unhealthy food and drink outlets (Burns & Inglis, 2007; Fleischhacker et al., 2011; Sushil et al., 2017; Thornton et al., 2016). A nationwide spatial analysis in NZ identified the most deprived neighbourhoods had a 73% higher availability of fast food and takeaway outlets and a 64% higher availability of convenience stores, compared to the more affluent neighbourhoods (Sushil et al., 2017). Outlet categorisation was only conducted in 1% of all outlets (Sushil et al., 2017). Therefore, the true nature of the service may not be accurately reflected. Egli et al. (2020) conducted a study to quantitatively examine neighbourhood deprivation, unhealthy food outlets, unhealthy dietary behaviours, and excess body size in children aged 8-13 years by self-reporting purchasing behaviour en route to and from school and frequency of consumption of unhealthy snacks and SSB's. While associations between neighbourhood deprivation and unhealthy dietary behaviours were made, no associations between unhealthy dietary behaviours and unhealthy outlet density were found.

Quantitative survey data with Pacific mothers in NZ found 65.1% reported having high health literacy and wanting to lead a healthy lifestyle (Sa'uLilo et al., 2018). Yet, focus group findings demonstrated food purchasing is primarily determined by perceived food palatability and price (Sa'uLilo et al., 2018). Current research highlights the importance of acknowledging neighbourhood deprivation when investigating neighbourhood influences, such as unhealthy food outlets and associated advertising, on child health outcomes.

School decile ratings demonstrate the socio-economic circumstances of schools compared to the rest of the country (Ministry of Education, 2022). Lower decile ratings, on a scale from one to ten, represent a more significant proportion of students from low socio-economic communities (Ministry of Education, 2022). Findings from Vandevijvere et al. (2018) support the observation that schools in areas of high deprivation experience greater density and closer proximity to unhealthy food outlets. Not all studies have supported this relationship. A regression analysis investigating food outlets around schools and dietary quality found that high outlet density within a walkable distance to schools was associated with higher diet quality for the boys (Clark et al., 2014). However, the perceived access to healthy food from a supermarket is likely outweighed by the lack of affordability. It is clear that the cost of food has become an increasingly important factor in dietary behaviours (Clark et al., 2014). The study by Clark et al. (2014) recruited a large majority of NZ European participants and thus, may not be generalisable to the wider NZ population. Each of these studies used varied criteria to classify food outlets as healthy and unhealthy; where Clark et al. (2014) included cafés and restaurants as a category, Sushil et al. (2017) excluded these outlets as they were not considered to be healthy or unhealthy. Further, the classification of fast food as one group is painted with a broad brush that generalises and overlooks food outlets that provide typically more nutrient-dense meals, such as poke bowls, sushi or filled pitas, by merging these with juxtaposing outlets offering HFSS items such as deep-fried chicken, hot chips or butter chicken curry and rice. While some food companies have made a small effort to offer a selection of healthier items, the extent of advertising for these items in comparison to other menu items requires further investigation. No conclusions on the use of outlets or consumption can be made from the data. A cross-sectional study examining the association between the presence of food retailers and lunchtime eating behaviours of children in grade 9 and 10 found a strong relationship between the location of unhealthy food outlets and lunchtime food purchasing behaviour and consumption (Seliske et al., 2013). While the purchasing and nutrition behaviours put forward by Seliske et al. (2013) are in response to unhealthy food outlets, it is possible the relationship may extend from food outlets to the associated advertising.

As the presence of unhealthy food outlets has increased in density, so has the prevalence of associated advertising. Recognising the strategic placement of unhealthy food and beverage advertisements is important to understand better how the food environments can be modified to support healthy nutrition behaviours (Lesser et al., 2013). Various studies have measured the prevalence of food advertisements near schools and found a high prevalence of unhealthy food advertisements in the areas surrounding schools (Brien et al., 2022; Egli et al., 2018; Huang et al., 2020; Maher et al., 2005; Vandevijvere et al., 2018). Advertising outside convenience stores within a 500m boundary of primary schools within Auckland found that half of the advertisements were for unhealthy food and beverages (Brien et al., 2022). A pilot study in the Wellington region examined the extent and content of outdoor food advertisements from outlets around NZ secondary schools (Maher et al., 2005). 61.5% of advertisements were for food products, of these, 70.2% were unhealthy (Maher et al., 2005). The extent of unhealthy food advertising children are exposed to may have been underestimated as the developed food classification system categorised foods with a varying degree of desirable nutrient content, such as sports drinks, diet SSBs and food from bakeries, cafes and restaurants as healthy (Maher et al., 2005). Further, findings limited to the Wellington region may not be generalisable to more ethnically and culturally diverse areas of NZ. The relationship between the local food environment and consumption in children is currently understudied and requires further investigation. An understanding of the diet quality, including the depicted portion sizes, of advertising associated in children's neighbourhoods, is needed to inform policies to protect children from the impacts of exposure to food advertisements.

2.6. Impact of food advertising on dietary intake

International evidence indicates that most food products promoted are energy-dense and ultra-processed HFSS food and beverage items such as sugar-sweetened breakfast cereals, soft drinks, confectionery, snacks and fast food (Cairns et al., 2009; Frazão, 1999). These findings were similar to a cross-sectional study conducted in NZ children aged 11-13 years, with the greatest exposure to sugary drinks followed by fast food, confectionery and snack foods (Signal et al., 2017). Therefore, making it understandable that children's food preferences are influenced by the advertisements they are exposed to (Cobb et al., 2015; Ogba & Johnson, 2010).

A systematic review identified several factors influencing food selection and consumption in children; these include price and affordability, preferences, family eating patterns, convenience, social norms and advertising of foods through various platforms (Cobb et al., 2015). Marketing messages provide information on what a person thinks people normally do and are subsequently passively accepted into an individual's beliefs in a manner that is outside of their awareness (Gunter, 2016). The repetition of subtle messages in food advertising act as a prime to the corresponding nutrition behaviours (Harris, Bargh, et al., 2009; Pettigrew et al., 2013). If advertisements are seen frequently enough by young consumers, everyday reality can become distorted (Gunter, 2016, 2016; Hoek & Gendall, 2006; Sadeghirad et al., 2016). Thus, the learnt norms determining appropriate types and amounts of food have the potential to turn an occasional treat into a pervasive prompt for more frequent consumption (Smith et al., 2019). Given the perceptions generated by advertisements, more effective regulation is required to reduce the exposure of children to unhealthy food advertisements.

Much of the research available suggests that exposure to unhealthy food advertising in children across several advertising mediums is positively linked to greater dietary intake for these products (Chou et al., 2008; Dixon et al., 2007; Kelly et al., 2016; Pettigrew et al., 2013; Sadeghirad et al., 2016; Scully et al., 2012; Smith et al., 2019). A study examining the impact of television advertising, as distinct from television viewing, on the consumption of Australian children aged 10-16 years found a strong association between commercial television viewing and unhealthy diet scores (Kelly et al., 2016). Additionally, research shows adverts for 'healthy' meal packages from fast food outlets promoted a liking for fast food in children, not the healthy alternative (Boyland et al., 2015). Such research is significant as it highlights the possible effects of this relationship to extend to longer-term food advertising, such as outdoor advertising.

One study looking at outdoor food advertising found a 6% increase in the consumption of SSBs following a 10% increase in outdoor food advertisements (Lesser et al., 2013). In Indonesia, caregivers reported the frequency of exposure to food advertising on public transport and their children's consumption of confectionary at home in the last week; an association was found with two out of ten HFSS products (Meilan et al., 2019). Findings from Lesser et al. (2013) and Meilan et al. (2019) were measured using self-reported data, which may not reflect the true impact due to the unconscious influence of marketing techniques or altered responses for social desirability. A shift in the environment to minimise unhealthy food and drink advertising would normalise and reinforce healthy dietary behaviours (Dixon et al., 2007). This proposal put forward by Dixon et al. (2007) is concerned with food advertising on television but may also have applications in this context of work.

We cannot make conclusions on the effect of outdoor advertising on dietary intake. The portion sizes of food in advertisements were not assessed in any of the above studies. Thus, its relationship in advertising to dietary intake is unclear and an area this thesis will explore further. It is in this way that research assessing portion sizes depicted in outdoor advertising can begin to understand the role of outdoor advertising on children's consumption patterns and how it may be consequential to health.

2.7. Advertising policies in NZ

Despite criticism from public health experts regarding the heavy advertising of unhealthy food and beverages, there is a lack of regulation and enforceable policies in NZ on outdoor food advertising (Brien et al., 2022; Garton et al., 2022). There are three approaches to reduce and regulate advertisements to children: Mandatory regulation, self-regulation and co-regulation (World Cancer Research Fund International, 2017). These are detailed in Table 1.

Table 1. Regulatory Forms of Commercial Food Advertising to Children

Mandatory regulation	Managed by the government and followed by all companies
Self-regulation	Managed by industry and followed by some or all food companies
Co-regulation	Combines both mandatory and self-regulatory action

Food advertising in NZ is currently self-regulated under voluntary codes, administered by an industry-funded body, the Advertising Standards Authority (ASA) (Advertising Standards Authority, 2017). The Children and Young People's Advertising Code applies to all advertisements that target children (below 14 years) or young people (14-18 years) (Advertising Standards Authority, 2017). The code states that advertisements for 'occasional food and beverage products', as defined under the MoH FBCS (2013), must not target children or imply that the frequency and healthfulness of such foods are acceptable. This framework identifies foods that are suitable for every day, sometimes and occasional consumption; with automatic categorisation to occasional if they provide minimal nutritional value and are HFSS. Unlike the WHO Regional Office For Europe Nutrient Profile Model (2015), which was purposefully created to restrict the advertising of foods to children, the MoH FBCS was designed for food promotions within schools and early childhood education services.

The Advertising code further specifies that advertised portion sizes should not exceed those deemed appropriate by the national nutrition guidelines for the depicted person's age (Advertising Standards Authority, 2017). Currently, little is known about the portion sizes in food advertising to NZ children or their compliance with the Children and Young People's Advertising Code. Beyond recommending children limit HFSS foods to less than one serving a week, the MoH Nutrition Guidelines have limited reference to what being low in fat, sugar and salt means or what an acceptable amount of HFSS foods to consume on one occasion are (Ministry of Health, 2015). For example, fruit is known to contain various amounts of sugar. Similarly, foods such as fish and nuts are known to contain fats that are considered 'healthy'. Thus, a relatively high degree of food literacy is required to interpret this statement. As such, advertising may facilitate the growth of portion sizes in the food environment and allow for exorbitant exposure to unhealthy nutrition behaviours by children. How to measure this relationship, however, is unknown. It is for this reason that portion sizes of food advertising to children will be explored.

Compliance with the code relies on members of the public to make complaints about a specific advertisement and to state which code is breached. As the complaints process is not monitored by an independent body, the ASA has the power to dismiss complaints without taking further action. A review of the ASA complaints system found the regulatory regime is not effective or accountable in reducing children's exposure to advertising (Sing et al., 2020). Only one of the sixteen complaints investigated was upheld; the most common grounds for complaints not being upheld included the expected average audience not making up a significant proportion of children or young people and a narrow interpretation of 'targeting' children and young people (Sing et al., 2020). No reference was made to the adherence of advertisements to national nutrition guidelines or the ambiguity of how these are defined in the code. Furthermore, there is no imposed penalty for breaching the code. Thus, the code does little to protect children from the persuasive effects of food advertising.

Additional NZ policies include the Auckland Transport Advertising Policy and Auckland Signs Bylaw. Auckland Transport does not permit the promotion of lifestyle choices such as gambling, alcohol or tobacco products and brands (Auckland Transport, 2021). However, it was not until recently that a new standard stating to 'support health and healthy lifestyle choices' was included. The policy specifies that it will not permit advertisements for HFSS products within 300 metres of schools. Enforcement of this policy requires reviewing each advertisement for compliance before publishing; with non-compliant advertisements rejected or removed. However, with no monetary penalty, there is no disincentive to deter companies from breaching the criteria. A 2020 study assessing the extent of bus stop advertisements surrounding Auckland schools demonstrated breaches of this code; finding 382 (45.3%) advertisements on Auckland Transport-owned bus shelters within 300m of school gates (Huang et al., 2020). These findings further support the lack of protection current policies offer from the persuasive influence of food advertising on children.

In 2015, the Auckland Council and the Board of Auckland Transport jointly made the Auckland Signs Bylaw to regulate promotional signs (Council Auckland, 2022). This bylaw outlines the rules for signage to ensure signage is safe, does not present a hazard or cause a nuisance and protects public safety. The wording of this bylaw is ambiguous in that it references protecting public health but lacks sufficient stipulation as to whether this solely applies to the construction of the signage or also addresses the advertised messages. A lack of enforcement in current advertising policies signifies the need for local council bylaws to become more transparent. Strengthening definitions such as public health to recognise wellbeing alongside safety is one example of how local councils can exert their control to effectively influence the healthfulness of children's neighbourhoods.

International and national research has consistently shown that self-regulation is ineffective at controlling the extent of children's exposure to food advertising (Harris, Pomeranz, et al., 2009; Kent et al., 2011; Lumley et al., 2012). Compared to international best practices, the implementation of unhealthy advertising restrictions to children using the Healthy Food Environment Policy Index was rated as low (Vandevijvere et al., 2017). A recommendation put forward for immediate action was to regulate unhealthy food advertising in children's neighbourhoods (Vandevijvere et al., 2017). Yet, little work has resulted from this recommendation (Brien et al., 2022; Egli et al., 2018; Garton et al., 2022; Huang et al., 2020). Political action to overcome current advertising policies, which are poorly regulated and ambiguously worded, and mitigate the influence of food advertising to children in NZ remains warranted (Brien et al., 2022). To date, there is no literature illustrating the compliance of portion sizes in advertisements. This may be grounded in the challenge of inaccurate methodology to measure the depicted portion sizes against national nutrition guidelines. Measuring the compliance of current advertisement exposure to NZ children with independent research will support the evaluation of the effectiveness of current policies and how existing policies can be updated to promote healthy and age-appropriate portion sizes in food advertisements to children.

2.8. Portion size

A key consideration for this research is the portion sizes of commonly consumed foods. Portion and serving sizes are often used interchangeably (Division of Nutrition and Physical Activity, 2006). Serving sizes are standard quantities of food or drink, such as usual servings used in dietary guidance to indicate how much to eat to meet energy and nutrient requirements or those dictated on the nutrition information panels of food packaging (Ministry of Health, 2015). However, the total number of servings can be consumed in several smaller or larger portions. The MoH (2015) defines a portion size as the amount of food offered or consumed on a single eating occasion. Due to the innate tendencies and developmental stages of children, it is recommended that portion sizes offered should be age-appropriate (Benton, 2004). Examples of variances in recommended portion sizes for NZ children and adults are outlined in Table 2.

Table 2. Recommended Portion Sizes for Children and Adults

Food item	Recommended portion sizes for NZ children 2-18 years	Recommended portion sizes for NZ adults 19-64 years
Scones, cake and dessert	<100g	<120g
Salted nuts and seeds	<30g	<50g
Processed fish, chicken, meat	<120g	<120g
Pies and quiches	<140g	<180g
Crackers	4	3

Note. (Ministry of Health, 2015, 2020a, 2020b; National District Health Board Food and Drink Environments Network, 2019).

Usually, the person serving the food or the manufacturer deciding on the package size defines the portion sizes (Benton, 2015; Geier et al., 2006). Since the late 1970s, the USA food industry has introduced new larger-sized portions for several foods and beverages; including burgers, pizza, desserts, candy, soft drinks and fruit drinks (Matthiessen et al., 2003; Nielsen & Popkin, 2003; Young & Nestle, 2012). Little work has been done in NZ to evaluate the trends in portion size. Between 2012 and 2016, cross-sectional surveys collecting data on fast foods sold at chain restaurants in NZ demonstrated a 4.8% increase in the serving size of products; with greater than 10% increases in chicken, dessert and pizza (Eyles et al., 2018). However, in Australia between 1995 and 2007, portion sizes from two national cross-sectional nutrition surveys were found to have decreased in 24% of the foods studied, followed by an increase in 15% of foods (Collins et al., 2014). Methods to obtain these trends in portion sizes included contacting the food manufacturer for product information (Eyles et al., 2018; Matthiessen et al., 2003; Young & Nestle, 2012), and self-reports retrieved from dietary assessment data (Collins et al., 2014; Nielsen & Popkin, 2003). While the size of portions was evaluated, there were no comparisons made to reference portion sizes set out in nutrition guidelines. There is a need for further research to monitor how portion sizes are changing within the NZ environment. Further research investigating portion sizes in advertisements would contribute to our understanding of the influence portion sizes have on the dietary behaviours of children.

The normalisation of larger portions may be regarded by food companies as a response to consumer demand. The USA is known for its trend of ‘super-sizing’ menu items (Hill, 1998).

Descriptors such as ‘Supersize’ and ‘Biggie’ have been removed, yet food companies continue to sell large portions under descriptors such as ‘Medium’ or ‘Large’ (Young & Nestle, 2007). As a result, international evidence has shown consumers select portions much larger than the national recommendations (Schwartz & Byrd-Bredbenner, 2006; Young & Nestle, 2002). The rationalisation for persistent large portion sizes by food companies overlooks its accountability and serves to harm children by shaping food preferences and social norms.

The augmentation of portion sizes in food outlets, and associated advertising, add to the complexity and intensity of the effects of the current food environment on the dietary behaviours and nutrition status of children. Although no previous research has evaluated the portion sizes of food advertising to children in NZ, being able to accurately assess the portion sizes depicted in advertising in children’s neighbourhoods is important in order to be able to conduct future research into the effect of portion size advertising on consumption.

2.8.1. Portion size effect

Portion size is believed to be a strong environmental contributor to children's food choices and consumption. There is a vast body of literature demonstrating that larger portions are associated with increased food consumption and energy intake in both adult (Rolls et al., 2002; Steenhuis & Vermeer, 2009; Wansink et al., 2006) and child populations (Birch et al., 2015; Fisher et al., 2007; Fisher & Kral, 2008; Kral & Rolls, 2004; Mathias et al., 2012; Mrdjenovic & Levitsky, 2005; Piernas & Popkin, 2011; Raynor & Wing, 2007; Wansink & van Ittersum, 2007).

The initial evidence for portion sizes stimulating children’s intake comes from a study that provided preschool children with small, medium and large portions on three separate lunch occasions (Rolls et al., 2000). While intake did not differ significantly among children 2-3 years, both the weight of food consumed and energy intake increased in children 4-6 years. Following this research, children aged 4-5 years were recruited and served two normal and two large meals (Fisher et al., 2003). Intake significantly increased by 25% as the portion size increased (Fisher et al., 2003, p. 200). No association with age as a categorical variable was found. However, when analysed as a continuous variable, age significantly influenced the total amount consumed. Suggesting older children may consume a greater total amount (Fisher et al., 2003). Following these findings, Fisher et al. (2007) designed a study to assess age as a moderator of self-selected portions. Children aged 2-9 years (age 2-3 years; age 5-6 years; age 8-9 years) were provided three portions of a meal on three separate occasions; accounting for differential energy requirements, each age group were served a reference portion size of 200, 250, and 450 grams, respectively. All children consumed larger amounts when served the large portion size (Fisher, 2007). Thus, no significant effect between the age groups demonstrated the magnitude of susceptibility to the portion size effect among different ages is smaller than previously suspected.

These studies have all shown that portion size is an important factor affecting children's control of energy intake. What is less clear is at what point does size generate changes in dietary intake? These studies were only conducted at one mealtime, with no monitoring or standardisation for breakfast or overnight conditions. Thus, the magnitude of influence beyond one eating occasion on consumption requires further investigation. Additionally, participants' intakes were measured in laboratories. Future research should measure portion sizes out of laboratory settings for greater ecological validity, with greater consideration for the frequency of meals, energy compensation between meals and prompting by parents in determining an appropriate portion size. Two of these studies utilised predetermined portion sizes (Fisher, 2007; Rolls et al., 2000) and one study employed self-served portion sizes (Fisher et al., 2003). However, all assessed an amorphous food, macaroni and cheese, for the reference portion. Applying these findings to portion sizes depicted in advertising may be complicated by foods that come in predetermined portions, such as packets of chips or bottles of SSBs, of which the product may not be offered in portion sizes recommended for children.

In addition, evidence from a systematic review demonstrates larger effect sizes in more energy-dense foods, indicating intake can be moderated by the energy density of the food (Hollands et al., 2015). It is interesting to see the consumption of fruit and vegetables in children increase when portions are doubled, but this effect was limited to children who had a preference for the food (Mathias et al., 2012). Energy-dense foods are typically found to be more attractive to children (Zeinstra et al., 2007). This may be explained by nutrient-dense foods being perceived to have fewer appealing sensory characteristics, such as taste or texture (Zeinstra et al., 2007). These findings support the proposition that the selection of large portion sizes and the choice of energy-dense foods synergise to increase energy intake (Fisher et al., 2007). Contrary to indications, young children possess an innate ability to self-regulate their daily energy intake, this suggests the environment limits this innate response (Savage et al., 2007). This suggestion of moderation by Hollands et al. (2015) is concerned with portion sizes served during mealtimes. Posed as a question, do children moderate energy density of intake following exposure to depicted portion sizes in advertising?

From a public health perspective, advertised portion sizes larger than those set out in national recommendations may be connected to an increase in energy-dense, nutrient-poor diets in populations, which have known links to several nutrition-related health conditions (Marmot & Wilkinson, 2005). Studies suggest that these effects could be counteracted when age-appropriate consumption, representative of their energy requirements, for children are encouraged (Dixon et al., 2007; Hollands et al., 2015; Robinson & Kersbergen, 2018; Steenhuis & Vermeer, 2009; Vermeer et al., 2014). Interventions reducing the size, availability and appeal of larger-sized portions to improve dietary behaviours at the population level have been identified yet produced mixed results (Hollands et al., 2015; Steenhuis & Vermeer, 2009). Further research to determine what portion sizes are currently advertised is needed to understand what interventions targeting portion sizes are appropriate and effective among children in NZ.

2.8.2. Portion distortion

An important mechanism explaining why larger portions are purchased and consumed is “portion distortion”. Portion distortion refers to an individual's perception that their portion sizes do not commonly exceed recommended portions (Schwartz & Byrd-Bredbenner, 2006; Steenhuis & Vermeer, 2009). Predispositions and knowledge about food are shaped by psychological, social, and cultural factors and play an important role in portion size selection (Benton, 2015). Thus, the external cues which individuals often rely on to determine an appropriate amount have become increasingly important (Herman et al., 2015; Rolls et al., 2002). However, this is based on arbitrary criteria, which can lead to misconceptions or contradictory messages (Benton, 2015). With the increase in consumption of unhealthy food, pervasive advertising targeting children and inaccurate portion size estimations leading to passive overconsumption of larger portions, experts have become interested in the role of portion sizes in advertising and how this affects children's consumption of unhealthy foods.

Several international studies demonstrate children and adolescents' ability to estimate portion sizes is relatively poor (Frobisher & Maxwell, 2003; Guthrie, 1984; Schwartz & Byrd-Bredbenner, 2006). Children aged 6-16 years assessed the portion sizes of nine self-served food items using food photographs and standard descriptions of portion sizes as aids (Frobisher & Maxwell, 2003). There was a tendency for overestimation, with ±10 % of the actual weights ranging from 3 to 31% and 3 to 32%, using descriptions and the atlas, respectively. In another study, participants aged 16-26 years self-selected portions of eight foods at breakfast or six foods at lunch or dinner, which were then weighed and scored for the variance from the reference portion sizes (Schwartz & Byrd-Bredbenner, 2006). 45% of breakfast and 32% of lunch/dinner portions selected were within 25% of the reference portion size (Schwartz & Byrd-Bredbenner, 2006). This inability to accurately estimate and self-select portion sizes larger than national dietary recommendations may lead to increased energy consumption (Wansink & van Ittersum, 2007). Reduced portion sizes may recalibrate views of a 'normal' amount of food and reduce how much individuals choose to eat (Robinson & Kersbergen, 2018). In an environment where normative nutrition behaviours are shaped by the surrounding environment, it is crucial for future research to understand how portion sizes are depicted in advertising to inform advertising policies and promote healthy eating behaviours in children.

Unit bias influences the perception that a single food package contains a single serving, consequently, consumption will stay the same as the unit size increases. Under conditions where children are offered un-restricted food, several studies have found that energy intake decreases when a smaller food size is selected (Geier et al., 2006; Marchiori et al., 2011; Weijzen et al., 2008). When candies were served to young adults in their original form or cut in two, it was found that the total amount of candies consumed remained equal but cutting the candy significantly lowered energy intake (Marchiori et al., 2011). If the size of a food item increases, an individual is likely to still regard the item as one unit and the item is consumed in whole. Thus, unit bias influences the perception that a single unit offers an appropriate amount (Geier et al., 2006). However, not all studies have found this effect (Raynor & Wing, 2007; van Kleef et al., 2015). When children aged 8-13 years were offered cucumber in two unit sizes, small and large, more cucumber was consumed when smaller units of cucumber, more convenient for children, were served in the larger portion (van Kleef et al., 2015). This study was designed to examine if vegetable consumption can be improved by altering the portion and unit size of foods. Hence, individuals may be more inclined to consume the full unit when food is considered attractive. As well as building upon our current understanding of portion sizes served in the current food environment, this research aims to highlight the influence of size manipulation on visual depictions of portion sizes.

Advertising techniques, such as front-of-pack image size depictions, frequently alter an individual's reference and imply the depicted image to be an appropriate portion size (Neyens et al., 2015; Tal et al., 2017). Several studies altering the front-of-pack portion size depictions on cereal boxes have found children poured and consumed significantly more cereal when exposed to larger image sizes (McGale et al., 2020; Neyens et al., 2015; Tal et al., 2017). 22 Dutch children were exposed to two different cereal packages, enlarging the image size of cereal, and asked to self-serve themselves (Neyens et al., 2015). Significantly greater servings and mean consumption was found when exposed to a larger image size (Neyens et al., 2015). In a similar study, Tal et al. (2017) found the depictions were 65.26% greater than the nutrition information panel serving sizes and resulted in a 17.8% increase in cereal served among students aged 18-55 years. This study modified the packaging graphics to reflect a single serving as suggested on the nutrition information panel. Results from McGale et al. (2020) show that 63% of children perceived the packaging to display an appropriate portion size; despite the depicted servings containing three times the recommended servings. This acceptance of image sizes depicting an appropriate portion size has the potential to transfer to larger image size manipulations, such as those in outdoor advertising.

To understand the underlying mechanisms of image size manipulation and consumption Huang et al. (2022) designed three studies in university-aged students evaluating the impact of image size on purchase likelihood, mental imagery on purchase likelihood and how this applies to foods with high palatability and foods with lower perceived palatability. In the first study, a significant association between purchase likelihood and larger food image size was found after 123 students viewed packaging displaying a large or small food image size and subsequently rated how likely they were to purchase the product (Huang et al., 2022). To test the mechanism of this relationship, 139 participants from a Chinese crowdsourcing platform were asked to determine their purchase likelihood following viewing packaging with a large or small food image and indicating their mental imagery experiences (Huang et al., 2022). While food image size significantly generated a higher purchasing likelihood via more mental imagery, the direct effect on purchase likelihood was insignificant (Huang et al., 2022). In the final study, half of the participants viewed a food package for a highly palatable unhealthy food item and the other half a healthy food item with a lower perceived palatability; the association between food image size and purchase likelihood through mental imagery was only found for the unhealthy food item (Huang et al., 2022). While this paper generated insightful findings into the product attitudes of consumers, the small sample size and limited range of foods examined warrant the conduction of further research to validate these findings and their generalisability to children (Huang et al., 2022). The impact of image size manipulation on purchase likelihood and consumption put forward by Huang et al. (2022) is concerned with food packaging but may have applications to larger image size depictions such as those in outdoor food advertising.

The findings above support the notion that children are vulnerable to manipulations of visual cues. Digital photographs of advertisements around NZ secondary schools found 68.9% were categorised as large, of which there were proportionately more food advertisements (Maher et al., 2005). To date no research has been conducted to determine the impact of image size manipulations in advertising targeted to children. It is unknown if a constraint exists where depicted images are deemed too unrealistic and hinder the generation of mental imagery by an individual. However, the results of such research if substantiating, opens opportunities for policymakers to ensure depicted portion sizes better match the recommended portion sizes set out in national guidelines to positively influence nutrition behaviours and health in children.

2.9. PSEAs

Typical dietary intake assessments used in nutrition research to determine the dietary behaviours and the role of diet in health include self-reported methods such as 24-hour dietary recall (Wiehl, 1942), food frequency questionnaires (Block et al., 1986) and diet histories (Burke, 1947). However, intake data possess limited usefulness if quantities of foods consumed cannot be accurately estimated (Karkeck, 1987). Further, dietary recalls detailing all foods and beverages consumed in the past 24 hours have been shown to produce inaccurate estimations of portion sizes eaten due to reports of frequent recall bias (R. Gibson et al., 2017). The gold standard methods for nutritional assessment in children are weighted food records; this method is expensive, time-consuming and requires a high level of literacy (Gibson, 2005).

PSEAs provide a useful tool in facilitating an individual's ability to accurately estimate volumes of food servings. A number of PSEAs have been developed for use in dietary assessment research to inform portion size descriptions in children and adults; including household measurements (Faulkner et al., 2016; A. Gibson et al., 2016), food models (Bradley et al., 2021; Bucher et al., 2017; Byrd-Bredbenner & Schwartz, 2004; Friedman et al., 2012; Steyn et al., 2006; Yuhas et al., 1989), food photographs (Baranowski et al., 2011; Bradley et al., 2021; De Keyzer et al., 2011; Foster et al., 2014, 2014; Howes et al., 2017; Nelson et al., 1994; Riley et al., 2007), mobile photography (Chae et al., 2011; Jia et al., 2014; Lee et al., 2012; Woo et al., 2010) and augmented reality (Chun et al., 2021; Mellos & Probst, 2022; Rollo et al., 2017; Saha et al., 2022). Early PSEAs have focused on determining portion sizes by assisting an individual’s ability to conceptualise actual amounts of food against an aid (Matheson et al., 2002; Nelson et al., 1994; Steyn et al., 2006; Yuhas et al., 1989). More recent developments have led to applications that allow for digital volume estimation (Chae et al., 2011; Chun et al., 2021; Jia et al., 2014; Lee et al., 2012; Mellos & Probst, 2022; Raju & Sazonov, 2022; Riley et al., 2007; Rollo et al., 2017; Saha et al., 2022; Stütz et al., 2014; Woo et al., 2010). A detailed overview of the application and a critique of these PSEAs is presented in Chapter Three.

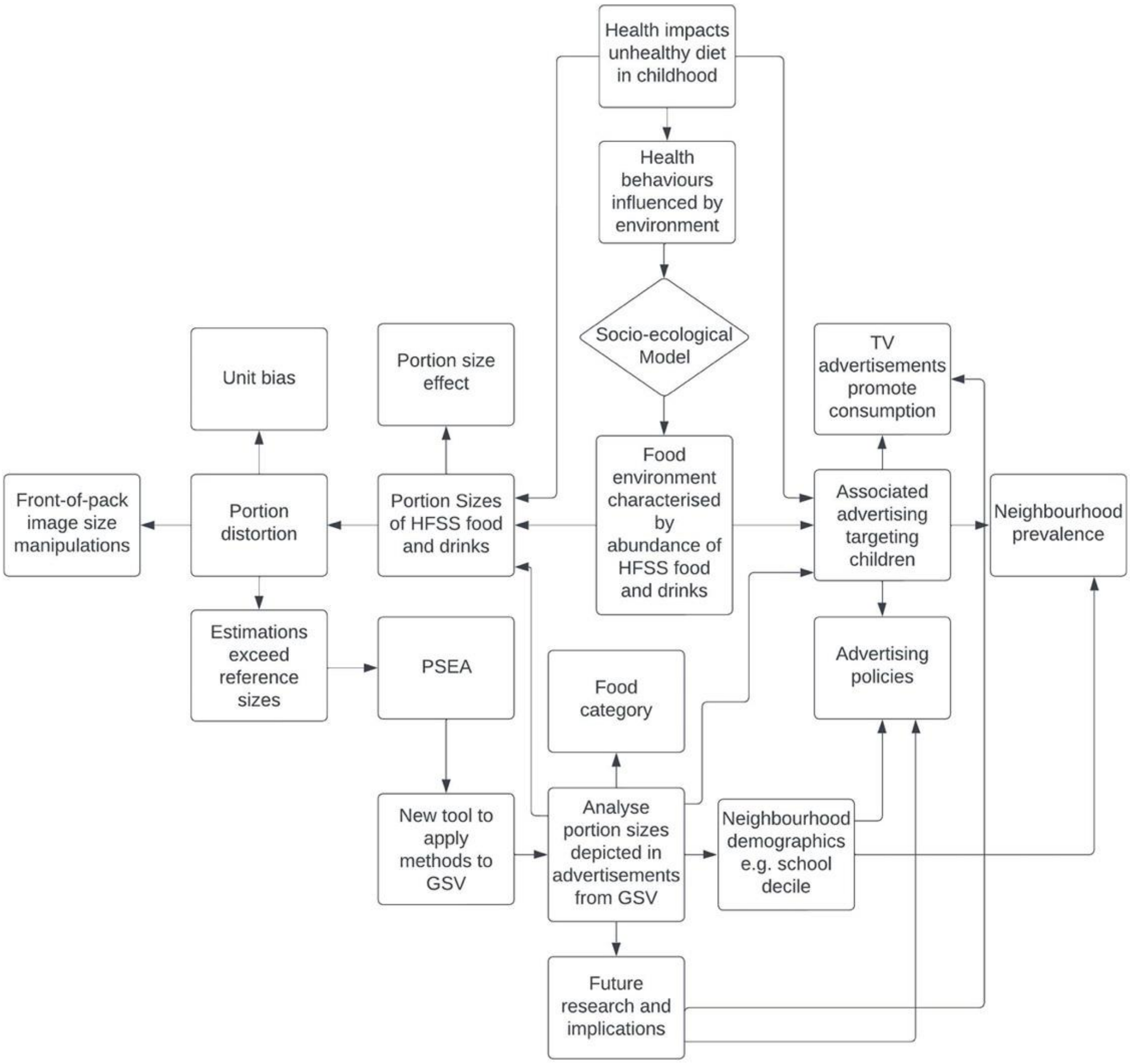
Compared to weighed portions, estimations of portion size have been associated with a loss of precision (Frobisher & Maxwell, 2003). Despite these over- and under-estimations, many PSEAs have been validated in their effectiveness in increasing the accuracy of consumers' reports (Amoutzopoulos et al., 2020; Bradley et al., 2021; Foster, Matthews, et al., 2008). Despite the application of PSEAs use intended for dietary assessment, the methods within these tools may also have applications in the context of advertising. The methods to make such evaluations are often carried out with standardised procedures that utilise fiducial markers and camera set-ups as a directional measure or reference point. However, the paucity of research to date evaluating advertised portion sizes may be related to the difficulty of obtaining accurate volume estimates from a single image. Therefore, novel methods are required to develop a PSEA suitable for assessing the nature of portion sizes in advertising. It is unknown if the portion sizes in advertisements targeted at children are in line with or beyond those outlined in national recommendations. An understanding of existing portion sizes in advertising is needed to inform policy to reduce the exposure of children to food advertisements. Further research may investigate the extent of contribution portion sizes in outdoor advertising have on the health outcomes of NZ children, including direct links to the consumption of HFSS foods.

2.10. Summary

There is a paucity of research on portion size evaluation of outdoor food advertising to children. Future research to understand this relationship is warranted. There have been significant changes to the dietary patterns of children over the past 50 years, which has caused elements of the food environment to contribute synergistically to the nutrition and health behaviours of children. Suboptimal nutrient intake and frequent HFSS food consumption have been linked to several negative health outcomes, including dental caries, mental health and cardiovascular disease, impacting both the present and future health of children in NZ. Public health research is taking a greater interest in the environmental factors influencing nutrition and health behaviours to guide policy interventions that target change in whole populations. Neighbourhoods are key components in children's environment. However, the recent food environment facilitates and encourages the consumption of unhealthy foods and beverages, posing a threat to public health. Children are heavily targeted by food and drink advertisers, with strong evidence demonstrating the influence of food advertising on purchasing decisions and food preferences. Despite the influences of advertising on children’s health, current policies in NZ are ineffective and poorly regulated, leaving children susceptible to messages normalising the frequent and regular consumption of unhealthy foods and beverages. Likewise, trends in selecting and consuming larger portion sizes have been shown to passively increase the weight and energy density of foods consumed by children.

The following conceptual framework demonstrates how the study objectives of this research fit into the wider narrative of improving the health of children in NZ (see figure 4). The model outlines the different factors of the food environment influencing poor health during childhood and the flow on effects these environmental factors have on shaping the purchasing and nutrition behaviours of NZ children. It also displays the point in which insight into the nature of advertised portion sizes in children's neighbourhoods can be used to inform current advertising policies and provide the foundation for future research investigating children's consumption of HFSS foods following exposure to such advertisements. To date, relatively few studies have occurred which assess portion sizes in outdoor food advertising or the effect this has on consumption in children, leading researchers to want to investigate this topic further. This study will allow for an evaluation of the degree of distortion to portion sizes in food advertising targeted to children.

Figure 4. Conceptual Framework



2.11. Study aims and objectives

This thesis aims to develop an understanding of portion sizes in food and beverage advertising to children in Auckland, NZ.

This review of the literature on the role of portion sizes in food and beverage advertising to children resulted in the following three objectives to support the study:

1. To conduct an evaluation of available portion size estimation tools that have been validated for use in children.

2. To test existing tools or develop a new tool (based on the findings of Objective 1.) to measure portion sizes in outdoor advertisements against national dietary recommendations that are suitable for use in children and the NZ context.

3. To evaluate the portion sizes in advertising on bus shelters within a 500m road network boundary of schools around Auckland using images captured on GSV.

This study is the first step toward understanding the portion sizes of food advertising in children's neighbourhoods. It is hoped that the findings from this thesis will generate new insights into the role of portion sizes in outdoor food advertising in NZ. In doing so, it will provide further knowledge on the nature of advertising to children in NZ needed to inform the development of policy regulation regarding the advertising of food and drink in children's neighbourhoods. From here, future research may investigate the relationship between portion sizes advertised and health outcomes in NZ children, including the direct effect on children's consumption of HFSS foods.

3. Critical Evaluation of Available PSEA (Study A)

This chapter outlines and discusses the findings related to the first research objective, "*To conduct an evaluation of available portion size estimation tools that have been validated for use in children*". This chapter is organised as follows: Section 1 discusses the methodology to identify and critically appraise the PSEA tools for children currently in existence. Section 2 discusses the characteristics of the available PSEA tools and implications for their application to NZ children and portion sizes depicted in advertising captured using GSV.

3.1. Methods of the PSEA evaluation

Literature sources and search strategy

In order to propose a suitable methodology to assess portion sizes in food and beverage advertising targeted at children, a review of the literature available on PSEAs was carried out. An initial search of five databases (Scopus, Medline, Web of Science, Embase and Google Scholar) was conducted during the month of May 2022 and then updated in July 2022 to ensure any recent studies were included. The query string used for the search was: (Portion* OR "Portion size") AND (Estimation OR Measurement OR Tool OR Aid) AND (Children OR Adolescen*).

Inclusion and exclusion criteria

Inclusion criteria: only original studies which described a process or tool designed to assist individuals in their ability to estimate portion sizes of food and beverages were selected for evaluation. Due to the paucity of validated PSEAs, no restriction on the range of PSEAs, foods served, or population age was placed. Studies that described methods for portion size estimations were also included. The current review only included articles in English, with no restrictions on publication date.

Exclusion criteria: papers were excluded from the review if they were related to trends in portion size, training protocols and parental perceptions of children's portion sizes. Articles that used an estimation aid to assess portion sizes of specific nutrients (e.g. carbohydrates), estimation in older adult populations, the influence of satiety on portion size estimations, equivalence-based instruction and portion size education to treat obesity were excluded.

Study selection and data extraction

Title screening was used to identify potentially eligible articles. Then abstracts were screened to understand the content of the paper. Full-text articles were selected and evaluated as per the pre-defined criteria listed above. Two studies by Foster et al. (Foster, Matthews, et al., 2008; Foster, O'Keeffe, et al., 2008) were conducted in the same population and employed the same PSEAs. Similarly, two other studies addressed different research questions but used the same food photographic atlas (Frobisher & Maxwell, 2003; Nelson et al., 1994). The results were combined and included as one record for both of these instances.

For each study, the author, year of publication, country and age of the study population were extracted. Next, each study was compared by the type of PSEA, age of the population tool was designed for, methods used to estimate the volume of portion sizes and a summary of the characteristics of the tools. A descriptive summary was conducted to provide an overview of the characteristic variables of the tools.

All papers were then critically evaluated for their appropriateness of use; determined by the design or application of a tool in a study population of children under 18 years of age and the inclusion of a food database that was comparable to nationally representative dietary survey data of NZ children, such as the 2002 National Children's Nutrition Survey (2003). Appropriateness of use in advertisements captured using GSV was determined by the ability to estimate portions from a single omnidirectional image captured without standardised photography or reference objects.

3.2. Results of PSEA evaluation

In total, 28 studies were included in the review. Ten studies took place in Europe (including five in the UK), ten in the USA, six in Australia and one each in Malaysia and South Africa.

The studies were conducted between 1989 and 2022, with 25% (n=7) occurring before 2010. All studies (n=28) measured estimations at a single point in time rather than over days or weeks.

Six (21.4%) of the PSEAs are designed to estimate portion sizes in child populations. A total of ten studies (35.7%) assessed the use of these portion size estimation tools in children, the youngest of which was 1.5 years. The most common method used to estimate portion sizes in child populations was food photography (n=6). Four (14.3%) papers were concerned purely with the methods of the tool development and therefore did not recruit any participants in their study.

Two of the papers tested two PSEAs in their study; therefore, there were a total of 30 PSEAs analysed. Table 3 provides a summary of the included studies assessing aids to assist estimations of portion size.

Table 3. Methods Used to Estimate Portion Sizes

Author	Type of PSEA Tool	Geographical Location	Study Population (n)	Population Designed For	Tool Development	Summary of Tool Characteristics
	2-D PSEA					
Nelson et al. (1994)	Food Photography	London, UK	Adults 18-90 years (51)	Adults	Series of eight photographs (weights from 5th-95th centile of portion size in the British Adult Dietary Survey) or a single photograph of the median weight with a count for how many consumed. Identify which best represents their usual portion size.	Fiducial marker Fixed camera set-up (distance and angle) Serving count
Foster et al. (2017)	Young Persons Food Atlas	Newcastle, UK	Children 1.5-16 years (379)	Children	Printed atlas of 104 foods with an A3 life-sized image of crockery used in the images. Foods not in predetermined amounts were presented in a series of seven photographs (weights from 5th-95th centile of portion size in the NDNS). For foods in predetermined amounts, select size of item, how many and portion not consumed.	Fiducial marker Fixed camera set-up (distance and angle) Serving count
Steyn et al. (2006)	Food Photo Manual	Johannesburg, South Africa	Children 12-13 years (92)	Adults	Generic life-size drawings illustrating the volume of a food. Viewed from above and cross-sectionally. Describe proportion of depicted food actually consumed.	Reference object Serving count
	Digital 2-D PSEA					
Probst et al. (2009)	Diet Advice	No study population	No study population	Adults	Self-administered dietary assessment website. Updated to include food composition data representative of Australian foods and new portion sizes determined.	Fiducial marker Fixed camera set-up (distance and angle)

Author	Type of PSEA Tool	Geographical Location	Study Population (n)	Population Designed For	Tool Development	Summary of Tool Characteristics
De Keyzer et al. (2011)	EPIC-SOFT Picture Book	Ghent, Belgium	Adults and Students 15-91 years (156)	Adults	Computerised dietary assessment program designed for use in national food consumption surveys. Fifteen pictures of margarine on various shapes and sizes of bread in evenly distributed increments, and five cups and glasses with the possibility to choose a fraction of the depicted portion. Different weights were assigned to each picture.	Fiducial marker Fixed camera set-up (distance and angle) Serving count
Foster et al. (2014)	Interactive Portion Size Assessment System (IPSAS)	Newcastle, UK	Children 4–16 years (262)	Children	1301 food types organised by food categories. Foods not in predetermined amounts presented in a series of seven photographs (weights from 5th-95th centile of portion size in the NDNS). For foods in predetermined amounts, select size of item, how many and portion not consumed.	Fiducial marker Fixed camera set-up (distance and angle) Serving count
Bradley et al. (2021)	Intake24	Newcastle, UK	Children 11–12 years (70)	Children (11 years upward)	Online dietary assessment tool with 2500 foods in evenly distributed increments were linked to nutrient composition codes and automatically assigned a weight. Series of food portion photographs to select the most representative portion size.	Fiducial marker Fixed camera set-up (distance and angle) Serving count
Baranowski et al. (2011)	Digital Food Images	Texas, USA	Children 8-13 years (120)	Children	Portion size images based on standards defined in the Food and Nutrient Database for Dietary Studies or 5th to 95th percentile intakes from National Health and Nutrition Examination Survey. Select the size of a container and then the portion consumed, or use a scroll bar to manipulate the image size (50-150%).	Enlargement Fiducial marker

Author	Type of PSEA Tool	Geographical Location	Study Population (n)	Population Designed For	Tool Development	Summary of Tool Characteristics
Howes et al. (2017)	Image Based Dietary Assessment (IBDA)	USA and Australia	Students 21–25 years (142)	Adults	Common foods were identified using the National Health and Nutrition Examination Survey. Images contained a fiducial marker for a size reference when viewing the images on different screens. The 'What's in the Foods You Eat' search tool was used to select a variety of household measurement descriptors. A weight volume is automatically counted by multiplying the measure of a single portion to match the amount consumed.	Fiducial marker Serving count
Vereecken et al. (2010)	Young Adolescents' Nutrition Assessment on Computer (YANA-C)	Ghent, Belgium	Children 11-17 years (128)	Children	Photographs of food were taken on a standard plate of 24cm from a 42° angle. A series of nine portion sizes in sequential order or one unit of food is added to a photograph by clicking on a 'more' button. The quantity of the portion appears on the screen. These quantities are based on the Belgian Manual on Food Portions and Household Measures.	Enlargement Fiducial marker Fixed camera set-up (angle and distance)
Riley et al. (2007)	Computerized Food Portion Tutorial (CFPT)	Virginia, USA	Adults mean age 51 years (76)	Adults	A series of six portion sizes of 23 foods presented on a standard 9-inch plate with associated measures below. Images could be enlarged, reference objects dropped on the image (deck of cards, tennis ball), rotation of the image to assist depth perception.	Enlargement Fiducial marker Fixed camera set-up (angle and distance) Rotation Shape library
	3-D PSEA					

Author	Type of PSEA Tool	Geographical Location	Study Population (n)	Population Designed For	Tool Development	Summary of Tool Characteristics
Gibson et al. (2016)	Household Measures	Sydney, Australia	Adults and Students 19-77 years (67)	Adults	Measuring cups (1cup, ¾ cup, ½ cup, 1/3 cup, ¼ cup) and spoons (1tablespoon, ½ tablespoon, 1teaspoon, ½ teaspoon). Width of finger (first joint of little finger to second joint of index finger), volume of fist (up until wrist joint), thumb (tip of thumb to first joint or crease) and hand method testing (length/width/height for rectangular or prism shaped foods and diameter/height for cylinder shaped foods). Indicate in fractions or whole. Measure participants hand.	Reference object
Faulkner et al. (2016)	Household Measures	Ireland	Adults 18-64 years (120)	Adults	Matchbox, 200 ml cup, coloured portion pots; and indicators on food packets (e.g. demarcations on butter).	Reference object
Canon et al. (2015)	Household Measure Descriptions	North England, UK	Students 18-26 years (35)	Adults	Describe portion sizes using spoonful's or descriptions such as 'small', 'medium' or 'large'. Quantified using a portion size reference guide.	Reference object
Yuhas et al. (1989)	Food Models	Ohio, USA	Students University aged (145)	Adults	Models in the shape of commonly consumed foods and labelled standard portion sizes. E.g. 4 oz orange juice, 112 c macaroni, 1/2 c rice, 3 oz hamburger, 1/4 c vegetable soup, 112 c corn, 112 c green beans, and 112 c peach halves.	Reference object
Bradley et al. (2021)	Food Models	Newcastle, UK	Children 11–12 years (76)	Adults	Models in the shape of commonly consumed items, spoons, cups, bowls and glasses. A standard dinner plate provided to arrange the models. A conversion factor was used for each serving to derive a food weight.	Reference object
Steyn et al. (2006)	Food Models	Johannesburg, South Africa	Children 12-13 years (92)	Adults	Select most resembling generic models representing ¼ cup; ½ cup flat and ½ cup round, 1 cup. Made by mixing flour and water, then baking in an oven until hard.	Reference object

Author	Type of PSEA Tool	Geographical Location	Study Population (n)	Population Designed For	Tool Development	Summary of Tool Characteristics
Matheson et al. (2002)	Craft Materials	California, USA	Children 8-12 years (54)	Adults	Paper strips placed onto plates or bowls to represent spaghetti or salad. Modelling clay moulded to represent bread sticks. Water poured from a measuring cup into 1 of 3 glasses. Dietitian convert to units and enter into the Nutrition Data System for Research.	Reference object
Bucher et al. (2017)	The International Food Unit	New South Wales, Australia	Adults mean age 29.2 years (128)	Adults	4x4x4 cm cube (64 ml) that can be subdivided into eight 2 cm sub-cubes. Correlates irregularly shaped objects and easily converts into volumes of household measurement cups. Binary dimensional increments to assist in education, memory and recall, and computer processing. Food items presented on a standard plate.	Reference object
Byrd-Bredbenner et al. (2004)	3-D PSMAs (tennis and golf balls)	New Jersey, USA	Students 17–24 years (113)	Adults	Compare against a tennis ball (2/3c or 150ml) and golf ball (1/4c or 60ml). Tag attached indicating each ball's equivalent cup volume.	Reference object
	Digital 3-D PSEA					
Lee et al. (2012)	Image-Based Portion-Size Automated Estimation	Indiana, USA	Children 11 to 18 years (15)	Children	Image captured using a mobile phone running Windows Mobile 6.0. A credit card-sized item was used for size and spatial location. 3-D reconstruction using camera location, orientation, and food objects are partitioned into cylinders and squares with known parameters. The volume was estimated using computer algorithms and converted into weight using rapeseed volumeter measures of duplicate meals.	3-D reconstruction Fiducial marker Shape library
Stütz et al. (2014)	EatAR	Austria	Adults 19-32 years (28)	Adults	The smartphone is positioned to capture a plate as the fiducial marker. AR system built using Unity framework and Qualcomm's Vuforia8 platform. A slider defines 3-D points and then a touch gesture determines the height and width of the object. A ruler is positioned at the highest point of the mesh. The image is overlayed on the screen.	3-D reconstruction Fiducial marker Overlay

Author	Type of PSEA Tool	Geographical Location	Study Population (n)	Population Designed For	Tool Development	Summary of Tool Characteristics
Woo et al. (2010)	Mobile Dietary Assessment	Indiana, USA	No study population	Adults	Meal image captured with a fiducial marker in the frame. Feature points extracted from the segmented region, and a 3-D volume is reconstructed by the unprojected points (e.g. shading). Then the position of object is fixed using Dandelin spheres. Feature points from the elliptical region are projected onto the table plane and reoriented to a two-dimensional plane. Sphere radius is calculated of which the two axis points and camera centre cut through the centre. For pixels on the segmented boundary, a vertex in the world space is calculated. From here feature points are obtained. A planar polygon is triangulated and the area manually extruded towards the tangential direction of the table surface. The spherical volume estimator can be repositioned at any point that is tangent to the table surface with subsequent adjustment of the radius.	3-D reconstruction Fiducial marker Shape library
Raju et al. (2022)	FOODCAM	Basel, Switzerland	No study population	Adults	The Red, Green and Blue (RGB) wavelength and Infrared pair estimates portion size using structured light-stereo vision-based volume estimation. Four images are captured every 10s at 152.4cm from the table. The camera filters use a 90 degrees wide-angle lens (barrel distortion to image removed). The camera shifts between a transparent and infrared block filter and is synchronized with the infrared dot projector. An active transparent filter captures an infrared stereo-image pair, and an active infrared block filter captures an RGB wavelength stereo-image pair. Semiglobal matching is the stereo matching algorithm combining 1-D constraints to make an approximate global, 2-D smoothness constraint. Triangulation projects points from the 2-D images to world coordinates (calculate x and y using x). Obtain a dense point cloud from the dense disparity map. The point cloud surface represents one voxel bar, of which the surface area of one voxel is calculated by multiplying the unit lengths in the x- and y-axes.	Camera set-up (angle and distance) Infrared and RGB wavelength stereo image Multiple images

Author	Type of PSEA Tool	Geographical Location	Study Population (n)	Population Designed For	Tool Development	Summary of Tool Characteristics
Chae et al. (2011)	Mobile Image-Based Dietary Assessment	Indiana, USA	No study population	Adults	Image of food captured with a fiducial marker to calibrate camera parameters and reconstruct a 3-D shape. Food objects are partitioned into cylinders, spheres and squares. False information in the segmented region is minimised. Extract three feature points using the feature point detection algorithm and shape analysis techniques (medial axis and active contour). Interior edge detection is applied to foods with relatively flat outlines on the surfaces. Geometric information such as the height, radius and area are determined, and the shape is reconstructed into a 3-D shape to compute the food volume.	3-D reconstruction Fiducial marker Shape library
Jia et al. (2014)	Wearable Camera (eButton)	Pennsylvania, USA	Adults 27–37 years (7)	Adults	Images are taken every 2-4s (300 pictures over 10 minutes) with a circular dining plate in the frame. Each item of the meal is measured on a separate plate. Blurry images are automatically removed and a distortion algorithm is applied to account for using a wide-angle lens. Food items are identified manually. A shape model library was developed (e.g. sphere, a cap of a sphere, cuboid, truncated cone, sector of a cylinder) so that the template can be adjusted over the image. The volume of the food can be estimated by a computer program utilising the 3D localisation of the food with respect to the correspondence between the real-world spatial points and pixels in the image.	3-D reconstruction Fiducial marker Multiple images Shape library
Saha et al. (2022)	PortionSize App	Louisiana, USA	Adults 20-57 years (15)	Adults	A fiducial marker is placed in the frame and outline colour changes from red to green, signalling the card is 1.9-2.1 feet away. Foods are identified from the Food and Nutrition Dataset for Dietary Studies database and tagged. A suitable template is identified (e.g., a deck of cards). Templates are semi-transparent and can be manipulated to five times the size using a slider. Portion size estimates are calculated from the size of the template and linked to the onboard database, which contains 1150 food items, allowing feedback on how their intake compares to food group recommendations.	Enlargement Fiducial marker Overlay Shape library

Author	Type of PSEA Tool	Geographical Location	Study Population (n)	Population Designed For	Tool Development	Summary of Tool Characteristics
Rollo et al. (2017)	ServAR	Newcastle, Australia	Students mean age 25.8 years (90)	Adults	Foods are served on a standard sized plate (29.5cm diameter) and a photo was taken at a 89.5 cm distance and 45° angle with a fiducial marker (9 cm × 5 cm card) in the frame. A reference serve was determined using the Australian Guide to Healthy Eating standard serving sizes. Images were modified using editing software, backgrounds were removed and outlines applied to the fiducial marker, before being replaced. Opacity of images are reduced to 50%. Virtual food objects get uploaded into ZapWorks. A virtual object appears on the screen after a code is scanned in the app and can be overlayed onto real-world environments.	Camera set-up (angle and distance) Fiducial marker Overlay
Mellos et al. (2022)	AR tool	New South Wales, Australia	Adults 18-24 years (33)	Adults	QR code is scanned with a smartphone to access the app. Required to download and print a fiducial marker (pattern on 10 cm × 10 cm piece of paper) or use hand as a point of reference. 3-D food models were edited in Blender software and exported to the app. Virtual images of food are overlayed onto real-world environments. Users can zoom and rotate by moving their smartphones around the fiducial marker.	Enlargement Fiducial marker Overlay Rotation
Chun et al. (2021)	Virtual Atlas of Portion Sizes (VAPS)	Malaysia	Adults 21-40 years (n 36)	Adults	A plate or bowl is rotated to take photos from a minimum of three orbits with an average of 200 images using a camera mounted on a tripod 25 cm away. 3DF Zephyr software stitches multiple images to construct a 3-D model. A sparse point cloud is generated to identify the dense point cloud. The 3-D model is refined, leaving only the food in the model. A 3-D plate was created using Blender software and exported for use in the AR environment. Vuforia is used to create a VuMark which can be customized in different shape templates and associated with the corresponding 3-D models of a food item portion. Images had 50% transparency to create a semi-transparent model. Resize, rotate and overlay the semi-transparent model in the real-world environment.	3-D reconstruction Camera set-up (angle and distance) Enlargement Fiducial marker Overlay Rotation

The final studies were categorised according to the type of PSEA. Four categories of aids were determined; 2-D PSEA (n=3), digital 2-D PSEA (n=8), 3-D PSEA (n=9), digital 3-D (n=10). A summary of the tool characteristics is outlined in Table 4.

Table 4. Summary of PSEA Tool Characteristics

Tool characteristic	n (%)
3-D reconstruction	6 (20.0)
Enlargement	6 (20.0)
Fiducial marker	19 (63.3)
Fixed camera set-up	10 (33.3)
Infrared and RGB wavelength stereo image	1 (3.3)
Multiple images	3 (10.0)
Overlay	5 (16.6)
Reference object	10 (33.3)
Rotation	3 (10.0)
Serving count	7 (23.3)
Shape library	6 (20.0)

2-D PSEA

Two types of 2-D PSEAs were found; food photography (n=2) and life-size drawings (n=1). Studies assessing 2-D PSEAs focused on reducing participant burden associated with weighing of foods in traditional dietary assessment methods and to help individuals more accurately estimate portion sizes.

Food photography methods utilised national dietary survey data to identify commonly consumed foods and intakes, which were then translated into a series of photos depicting increasing increments of food portions (Foster et al., 2017; Nelson et al., 1994). 91% of the portion estimations found an appropriately representative food from the photographs (Foster et al., 2017). From here, participants selected the photo that most closely represented the amount consumed. However, this tool cannot be applied to food advertisement images captured using GSV as the methods for developing food photography tools use a standardised fiducial marker and fixed camera distances and angles in their development. Foster et al. (2006) has previously proposed that PSEAs need to be age-appropriate, and thus, three versions of the Food Atlas were created for three separate age groups; pre-school age (18 months-4 years), primary school age (4–11 years) and secondary school age (11–16 years).

These studies assessing food photography and life-size drawings demonstrated that estimating portion sizes from a series of photographs reduces error (Foster et al., 2017; Steyn et al., 2006). However, wide limits indicate large individual variability. Both food photography and life-size drawing tools utilised a serving count to allow users to select how many of a predetermined amount was consumed and reduce the burden on an individual to conceptualise portion sizes larger than those commonly served. The life-size food drawings act as a reference object, similar to that of a fiducial marker, which limits the scalability of estimating portion sizes in outdoor food advertisements to the accuracy of an individual's perception and conceptualisation abilities as the portion sizes become more augmented from the reference size. In addition, these food drawings were designed for a limited range of foods and use in an adult population. The use of age-inappropriate portion sizes may influence the accuracy of estimates.

Digital 2-D PSEA

Digital 2-D PSEAs were designed for three purposes; 1) a practical and easy to use tool to make participation in dietary assessment studies less onerous, 2) streamline data to minimise the amount of equipment and data entry required to complete a dietary assessment and 3) expand the range of portion sizes available. Food photographs were the most common digital 2-D PSEA (n=6) followed by web-based tools (n=2). All PSEAs in this category used a fiducial marker (n=8). Four of these tools employed a serving count in their design.

All of the food photography tools embedded into computerised dietary assessment programs employed fiducial markers and fixed camera set-ups (n=4), replicating the tool characteristic of printed food photography aids. While most of the digital food photography tools were designed for use in European children (Bradley et al., 2021; De Keyzer et al., 2011; Foster et al., 2014; Vereecken et al., 2010), one tool was specifically designed to include food composition data representative of Australian foods and commonly consumed portion sizes (Probst et al., 2009). However, this tool is limited by its design for use in an adult population.

Compared to the printed Food Atlas by Foster et al. (2017), the IPSAS contained 9% less suitable photographs. However, Baranowski et al. (2011), Riley et al. (2007), and Vereecken et al. (2010) added an enlargement feature to add additional units of food using a slider or 'more' button. To determine the level of augmentation, a standardised fiducial marker or known portion size is required, limiting the applicability of this feature in measuring portion sizes captured using GSV. These tools have produced mixed effects; overestimations were found by Baranowski et al. (2011) and Foster et al. (2014), while an overall underestimation was demonstrated by Vereecken et al. (2010).

Studies using web-based tools demonstrated lower accuracy in the portion size estimation (Howes et al., 2017; Riley et al., 2007). These studies were performed using a very different set of methods. Riley et al. (2007) designed a web-based tool due to other PSEAs being labour-intensive and unstandardised, demonstrating a tendency to overestimate portion sizes. Three to six various portion sizes were displayed on a plate and then calibrated to become enlarged or to overlay a reference object over the food item in the image. As mentioned above, food advertisements captured using GSV lack a standardised fiducial marker or known portion size to determine the scalability of depicted portion sizes using an overlayed reference object. Howes et al. (2017) assessed the estimation skills of dietetic students using digital image-based dietary assessment and found estimates tended to be lower than actual weights. In this PSEA, a search tool was used to identify common household descriptors for items on a plate of food served next to a fiducial marker. This requires a standardised fiducial marker to be placed in the frame when capturing the image and selecting from a database of generalised items, which may not be specific to the item depicted in the advertisement. The cause of these estimation errors in web-based PSEAs may be due to the size of images depicted on a computer screen, poor quality images and the use of foods that were not representative of the study population. These limitations are also likely to affect the identification of items and the accuracy of portion sizes in outdoor advertising captured using GSV. For example, where GSV images are blurry, or the advertisements are partially covered.

3-D PSEA

Two studies in this category used food models, four studies examined generic non-food models and another three studies evaluated portion size estimations using household measures. All 3-

D PSEAs (n=9) can be used as a reference object, to help individuals conceptualise portion sizes in images that are similar to the portions of actual food items.

One study using 3-D food models found estimation accuracy ranged from 65.7% to 92.5%, with the higher end reflecting those who received training on how to use the tool (Yuhas et al., 1989). This PSEA used non-generic replicas of food items in portions commonly consumed by adults. Studies describing the use of non-food models looked at generic shapes using flour moulds, paper strips, modelling clay and small sports balls (Byrd-Bredbenner & Schwartz, 2004; Matheson et al., 2002; Steyn et al., 2006). These reference objects were converted to household measurements by the researcher and demonstrated an increase in portion size estimation accuracy (Byrd-Bredbenner & Schwartz, 2004; Matheson et al., 2002; Steyn et al., 2006). To standardise volume estimation and increase the estimation accuracy of irregular-shaped foods, Bucher et al. (2017) designed a 4x4 cube that can be subdivided into smaller units. This method found an 18.9% error rate, increasing with larger portions. However, participants still reported difficulty estimating irregular objects differing from the reference cube (Bucher et al., 2017).

The most common feature of household measurement aids was spoons, measuring cups, pots and matchboxes (Canon & Maynard, 2015; Faulkner et al., 2016; R. Gibson, 2005). These were generally validated by actual weights of food taken by research assistants (Canon & Maynard, 2015; Faulkner et al., 2016). The accuracy of Canon et al. (2015) found household measurements to hold a 4% underestimation. Yet Gibson et al. (2016) claim hand measurements produced significantly less error when compared to household measurements, suggesting hand measurements provide a more objective measure for estimation portion sizes.

These methods could be adapted to represent foods and portion sizes commonly consumed by NZ children. However, these tools are poorly transferable to estimating portion sizes in images captured using GSV as the scalability of portion sizes in outdoor food advertisements is restricted to the accuracy of an individual’s perception and conceptualisation abilities, which the accuracy reduces as portion sizes become more augmented.

Digital 3-D PSEA

In this category, three studies assessed mobile photography, one evaluated wearable cameras and another a light-stereo imaging system. Five studies evaluated augmented reality. Only one tool was designed for children, and three papers solely described the development process. All studies (n=10) measured automatic volume estimation. However, this was performed in very different ways. Fiducial markers were a common characteristic of digital 3-D PSEAs to provide scale for volume estimation (n=9).

Studies using mobile photography and a wearable camera described the methods to capture a 2-D image, create a shape template, remove false information and then construct a 3-D image using the extracted feature points (Chae et al., 2011; Jia et al., 2014; Woo et al., 2010). The methods by Chae et al. (2011) and Woo et al. (2010) were tested in adolescents, and 50% of the estimates were found to fall within an acceptable range (Lee et al., 2012). In comparison, the wearable camera developed by Jia et al. (2014) found a mean error of -2.8% when comparing actual food purchases in adults against volumes measured using seed displacement methods. This method relies on precise segmentation to reduce noise for accurate volume estimations. Thus, the inconsistent quality of GSV images impacts the ability to apply this tool to portion size estimation in food advertisements captured using GSV. It did, however, demonstrate how a shape library of commonly identifiable items located within the GSV images could be extracted and utilised to create a database of fiducial markers with standardised dimensions.

Augmented reality has focused on developing a tool that can be used by participants in prospective or retrospective dietary assessments, with or without the presence of a food (Chun et al., 2021; Mellos & Probst, 2022; Rollo et al., 2017; Saha et al., 2022; Stütz et al., 2014). The five studies assessing augmented reality utilised methods to overlay a food image onto real-world environments (Chun et al., 2021; Mellos & Probst, 2022; Rollo et al., 2017; Saha et al., 2022; Stütz et al., 2014). These methods aim to utilise templates to remove conceptualisation errors by humans. A range of software programs were used to achieve this, including; Zephyr (Chun et al., 2021), Blender (Chun et al., 2021; Mellos & Probst, 2022), Vuforia (Chun et al., 2021; Stütz et al., 2014), Unity Framework (Stütz et al., 2014) and Zap Works (Rollo et al., 2017). Two of these studies evaluated semi-transparent models (Chun et al., 2021; Saha et al., 2022). Each of these augmented reality tools found improved accuracy in portion size estimations. However, the error rates ranged from 6% to 59% (Chun et al., 2021; Mellos & Probst, 2022; Rollo et al., 2017; Saha et al., 2022; Stütz et al., 2014). One study only assessed the estimates of two food items (Chun et al., 2021). Thus, needs further development to determine the accuracy of estimation using a wider range of food items. Using multiple images, standardised camera set-ups and fiducial markers in such tools are poorly constructed when obtaining images from GSV. Furthermore, their use in combination with a range of sophisticated software allows the tool to overlay portion sizes in real-world environments to improve users' conceptualisation of their portion size estimations. However, the relevance of this feature is restricted in its application to GSV images as it retracts from the portable and convenient nature of data collection using widely available online mapping tools.

One tool was developed to eliminate the requirement of a fiducial marker or reference object (Raju & Sazonov, 2022). This PSEA was primarily developed for estimating portion sizes in kitchens or dining areas. The RGB wavelength and Infrared camera use structured light-stereo vision-based volume estimation by capturing four images every 10s. However, the 5.4% absolute error in volume estimation was not linear across multiple trials due to fluctuations in the Infrared projector and lighting conditions (Raju & Sazonov, 2022). This tool cannot be applied to food advertisements captured in GSV images for 3-D reconstruction and volume estimation as the portion size images are required to be captured using a light-stereo imaging system.

Conclusion

This literature review has critically reviewed and evaluated the literature pertaining to PSEA tools. The evidence suggests that the range of PSEAs currently available is limited. Thus, there is a clear rationale for developing a portion size estimation tool intended for use for portion sizes depicted in advertisements captured in GSV. There are currently very few PSEAs designed with age-appropriate portion sizes for children, and none that are representative of children living in NZ. Of the tools designed for children, only one tool employed portion sizes appropriate for several age ranges of children to reflect their varying nutritional requirements.

In terms of effectiveness, it appears that the most common characteristics targeted in available PSEAs are a standardised fiducial marker, fixed camera set-up, reference object and serving count. Digital 2-D PSEA, including food photography and web-based search tools, appears to be the most likely method to provide age-appropriate portion sizes for a range of commonly consumed foods and portion sizes. However, the existing tools are deficient in requiring a standardised fiducial marker to be placed in the frame, a series created using known portion sizes, a limited range of generalised food and beverage items and inaccurate estimations influenced by poor quality images and varying screen sizes. There have also been tools developed to serve as reference objects. However, the reliance on the user's conceptualisation abilities likely leads to poor scalability of advertised portion sizes, such as those found in outdoor advertisements. Fewer research has focused on automatic volume estimation using 3-D PSEA. However, these tools are limited by their use of specialised equipment and sophisticated software to capture images, undergo precise segmentation and construct a 3-D image.

There is clearly a need for a simple method to estimate portion sizes depicted in images to assess portion sizes in outdoor food advertising. As current advertising policies in NZ are poorly regulated and ambiguously worded, a tool to estimate the compliance of portion sizes in advertisements targeted at children to the national nutrition guidelines as outlined in the advertising standards is warranted.

4. Portion size Estimation in Advertising Reckoner (PEAR) Tool Development (Study B)

This chapter relates to the second research objective, "*To test existing tools or develop a new tool (based on the findings of Objective 1.) to measure portion sizes in outdoor advertisements against national dietary recommendations that are suitable for use in children and the NZ context*". This chapter will describe the development process of the PEAR Tool; a spreadsheet application designed to estimate portion sizes in advertisements captured using GSV and compare these to NZ national dietary guidelines for children.

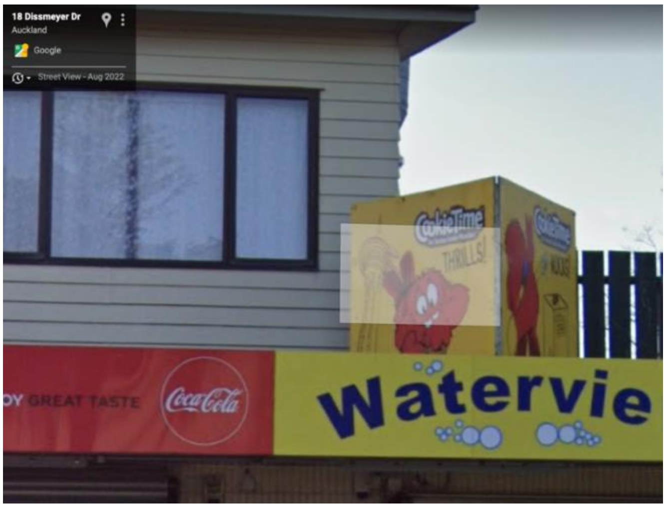
4.1. Methods of the PEAR tool development

The development of the PEAR Tool was carried out from August to September 2022. The PEAR Tool was developed to allow users to calculate the scale of advertised food and beverages captured using GSV to determine how depicted portion sizes in outdoor advertisements compare to those set out in children's nutrition guidelines. The aim was to integrate the most frequent and successful features of PSEA in studies critically evaluated in chapter 3.2, see pages 37-52, including; the development of a shape library for common objects with standardised dimensions to create a database of fiducial markers, a serving count for predetermined food and beverage items, the use of age-appropriate portion sizes of the representative population, a digital database of non-generic food and beverage items that could easily be updated and a digital tool that remains proportional to the size of screen used.

The initial tool design considered a 'measure distance' feature on Google Maps when no appropriate fiducial markers could be obtained from GSV images (see figure 5). Additionally, a semi-translucent box may have been useful (see figure 6). However, the dimensions could not be obtained after several attempts at communication with Google.

Figure 5. Distance Feature in Google Maps

Figure 6. Translucent White Box in Google Maps



The purpose of the PEAR Tool was to estimate the degree of image size manipulation and the overall number of portions depicted within the advertisement. In order to estimate the portion size of the food or beverage in the advertisement after image size manipulation, 2 components are required: 1) the scale of the food or beverage in the advertisement and 2) the portion size of the actual food or beverage serving. To determine the image size manipulation, coded formulas and functions use positioned markers to determine the scale of the actual advert and estimates the depicted portion size from a series of databases. There is also a function to add an item count for predetermined food and beverage servings to determine the overall number of portions depicted. To increase ease of use, three usability features have been incorporated into the PEAR Tool; 1) portability to run on Mac or Windows, the ability to store and add to existing databases, 2) use of lookups to retrieve database information and put it in a drop-down for the user to select from, and 3) setting a status for each image to indicate the addition of any new images and whether or not the markers have been positioned.

The design and development work on the spreadsheet application was conducted by an external software developer in collaboration with the researcher and supervisory team. During the design phase, the researcher and developer conducted face-to-face and online meetings, which occurred in August 2022. The core functional requirements proposed by the researcher that was expected to be performed by the application were to load an image, apply marker points to the image and calculate the scale between these points. The non-functional requirement of the tool was to have ease of use. Once these requirements were conveyed, the developer determined an appropriate application to tabulate, store, code and automate data.

The first version of the PEAR Tool was explored using a web browser application. However, after a lack of external resources to process the pages and the need for cross-browser functionality, it was decided to use Microsoft Excel. Additional features added to the tool included allowing the user to select the Mac or Windows function without going into the code and setting the base directory for the code to locate the study data. The initial Windows version was created with Active X, but this was not found to be portable to other operating systems.

The base code for the PEAR Tool was written using Microsoft 365 Excel, v2207 on Windows and v16.64 on Mac, and Microsoft 365 Excel Visual Basic Applications v7.1 (VBA). In order to meet the specifications set by the research team, the PEAR Tool was built in VBA programming language, and standard functionality was used with no special add-ins. Excel and VBA were chosen for their ability to tabulate data and manipulate the images. When porting from Windows to the Mac operating system, the design was changed to use portable functions to replace deprecated Microsoft functionality. Subsequently, VBA functions were developed to size and compute scaled marker points and a report to apply the information to a database of food and beverage products with their associated portion sizes. The PEAR Tool went through several revisions until the programmer, researcher and supervisory team were satisfied with the final tool.

4.2. Results of the PEAR Tool development

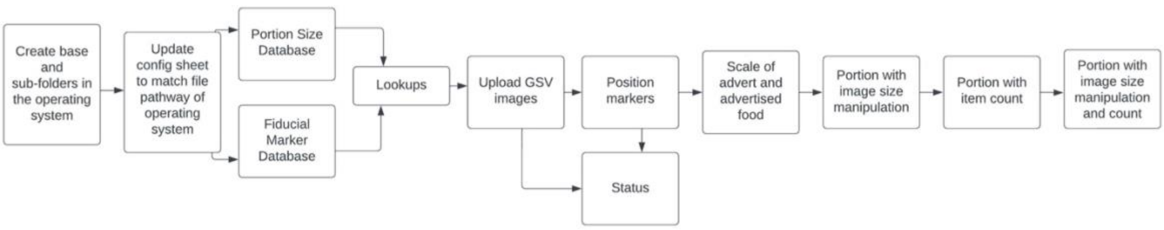
System overview of the PEAR Tool

The PEAR Tool has the following functions:

1. Configuration
2. Fiducial marker database
3. Portion size database
4. Lookups
5. Uploading images
6. Measure fiducial marker and product
7. Status message
8. Scale portion
9. Image size manipulation
10. Portion count
11. Total portions depicted

The user flow diagram to simulate the flow of the spreadsheet application is shown in figure 7. Additionally, a short, online instructional video on how to use the PEAR Tool can be viewed by visiting https://youtu.be/sAgBayK4mU8. Or, by typing "*Portion size Estimation in Advertising Reckoner (PEAR) Tool Guide Demonstration*" in the search box on YouTube.

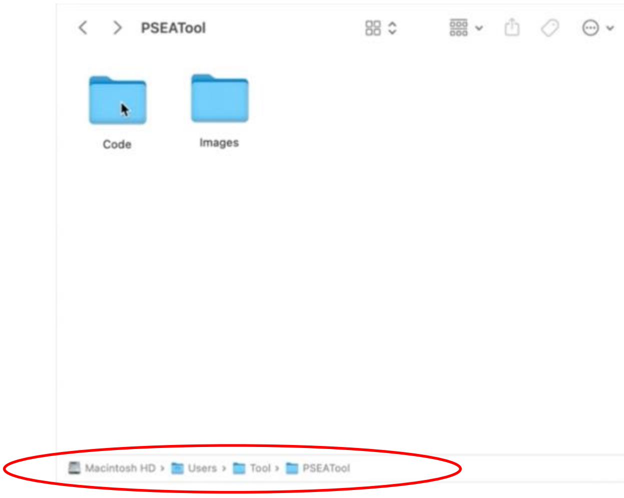
Figure 7. User Flow Diagram of The PEAR Tool



Configuration

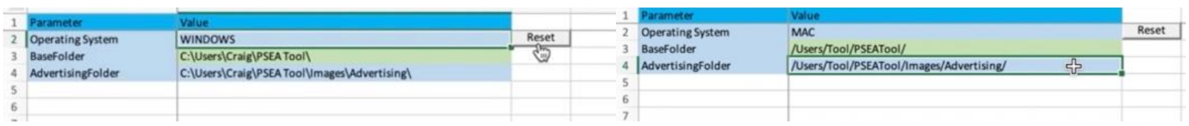
Prior to opening the PEAR Tool spreadsheet application, a base folder labelled 'PSEATool' must be set up in the Users home folder of the operating system (see figure 8). The PEAR Tool spreadsheet must then be stored in a subfolder labelled 'code'. GSV advertisement images, in a JPEG format, must then be stored in sub-folders labelled 'Images' and 'Advertising', respectively.

Figure 8. Creating The File Pathway for The PEAR Tool



Config is a sheet in the spreadsheet that holds the configuration values (see figure 9). The user selects the 'reset' button to update and match the operating system being used. Subsequently, the base folder is edited with the file pathway of the spreadsheet application location. The pathways of any sub-folders will change automatically.

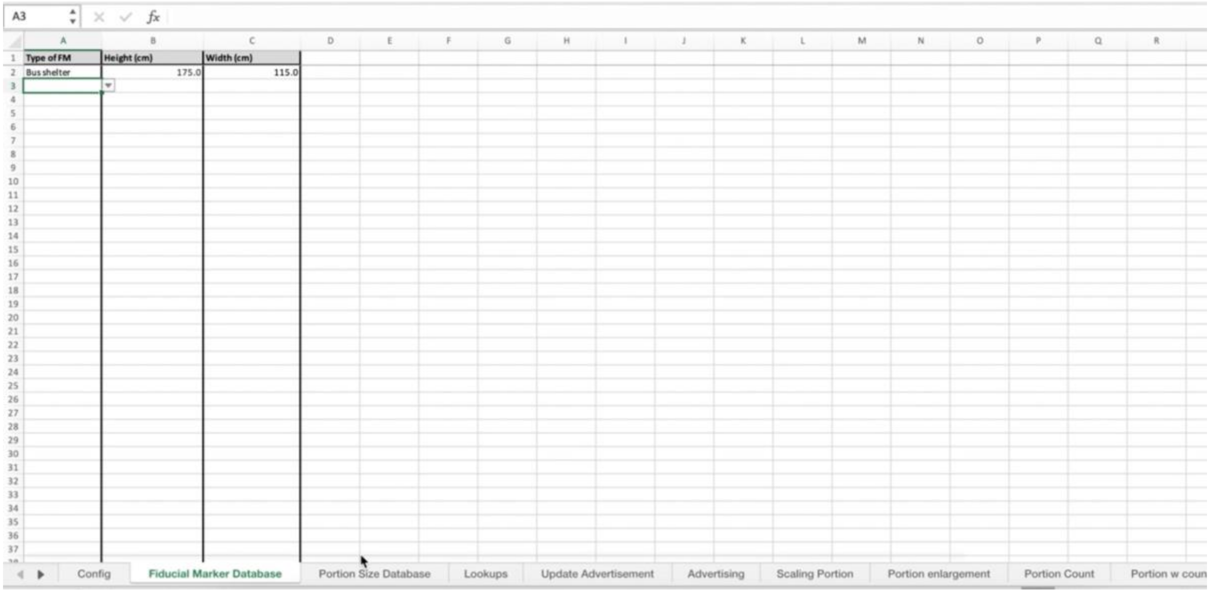
Figure 9. Setting Up The Configuration Values



Fiducial marker database

In the fiducial marker database sheet, the user enters the name, height and width (in centimetres) of an identifiable object within the advertisement images (see figure 10).

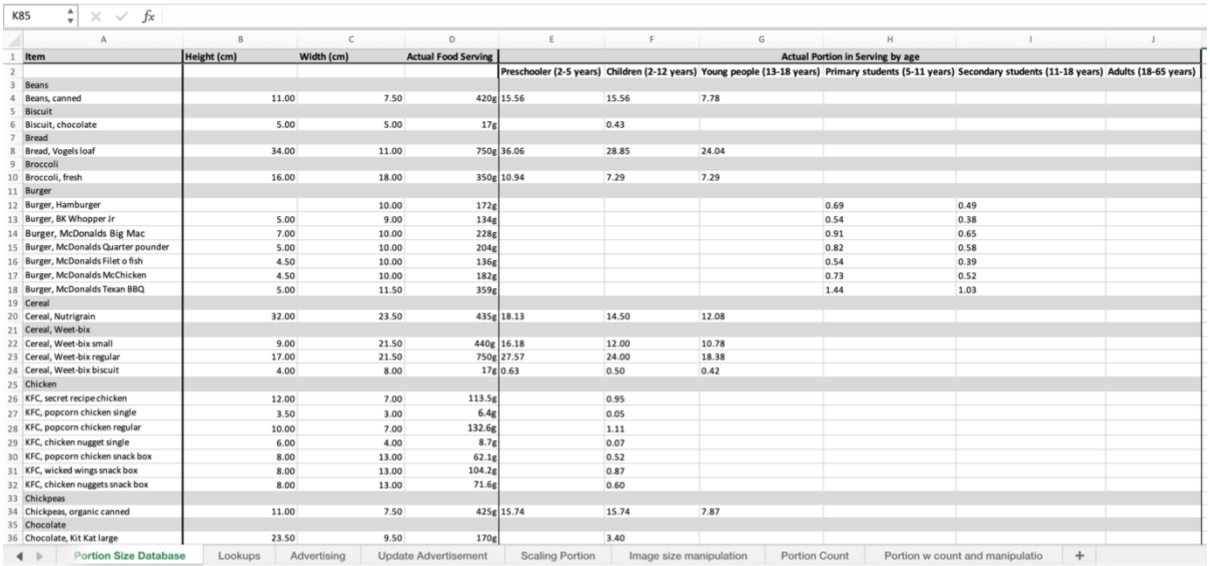
Figure 10. Setting Up The Fiducial Marker Database



Portion size database

Using the portion size database sheet, the user enters the name of a food or beverage, the dimensions (in centimetres) of the actual product and the number of children's guideline portions in the product serving (see figure 11). The number of portions in the product serving can be entered for a range of child age brackets. The first version of the PEAR Tool only required the height dimension of the food or beverage to be entered. Due to several images with smaller objects resulting in the arrowheads overlapping it was decided that both the height and width of the product would be incorporated so that the most appropriate direction of the arrow could be selected and scaled.

Figure 11. Setting Up The Portion Size Database



	Item	Height (cm)	Width (cm)	Actual Food Serving	Actual Portion in Serving by age					
2					Preschooler (2-5 years)	Children (2-12 years)	Young people (13-18 years)	Primary students (5-11 years)	Secondary students (11-18 years)	Adults (18-65 years)
3	Beans									
4	Beans, canned	11.00	7.50	420g	15.56	15.56	7.78			
5	Biscuit									
6	Biscuit, chocolate	5.00	5.00	17g		0.43				
7	Bread									
8	Bread, Vogels loaf	34.00	11.00	750g	36.06	28.85	24.04			
9	Broccoli									
10	Broccoli, fresh	16.00	18.00	350g	10.94	7.29	7.29			
11	Burger									
12	Burger, Hamburger		10.00	172g				0.69	0.49	
13	Burger, BK Whopper Jr	5.00	9.00	134g				0.54	0.38	
14	Burger, McDonalds Big Mac	7.00	10.00	228g				0.91	0.65	
15	Burger, McDonalds Quarter pounder	5.00	10.00	204g				0.82	0.58	
16	Burger, McDonalds Filet o fish	4.50	10.00	136g				0.54	0.39	
17	Burger, McDonalds McChicken	4.50	10.00	182g				0.73	0.52	
18	Burger, McDonalds Texan BBQ	5.00	11.50	359g				1.44	1.03	
19	Cereal									
20	Cereal, Nutrigrain	32.00	23.50	435g	18.13	14.50	12.08			
21	Cereal, Weet-bix									
22	Cereal, Weet-bix small	9.00	21.50	440g	16.18	12.00	10.78			
23	Cereal, Weet-bix regular	17.00	21.50	750g	27.57	24.00	18.38			
24	Cereal, Weet-bix biscuit	4.00	8.00	17g	0.63	0.50	0.42			
25	Chicken									
26	KFC, secret recipe chicken	12.00	7.00	113.5g		0.95				
27	KFC, popcorn chicken single	3.50	3.00	6.4g		0.05				
28	KFC, popcorn chicken regular	10.00	7.00	132.6g		1.11				
29	KFC, chicken nugget single	6.00	4.00	8.7g		0.07				
30	KFC, popcorn chicken snack box	8.00	13.00	62.1g		0.52				
31	KFC, wicked wings snack box	8.00	13.00	104.2g		0.87				
32	KFC, chicken nuggets snack box	8.00	13.00	71.6g		0.60				
33	Chickpeas									
34	Chickpeas, organic canned	11.00	7.50	425g	15.74	15.74	7.87			
35	Chocolate									
36	Chocolate, Kit Kat large	23.50	9.50	170g		3.40				

Lookups

The lookups sheet provides the user access to drop-down options that can be inserted into the various sheets (see figure 12). The user enters a list of the known products, fiducial markers, type of dimensions and age group of reference portion sizes (see figure 13).

Figure 12. List of Dropdown Lookup Options

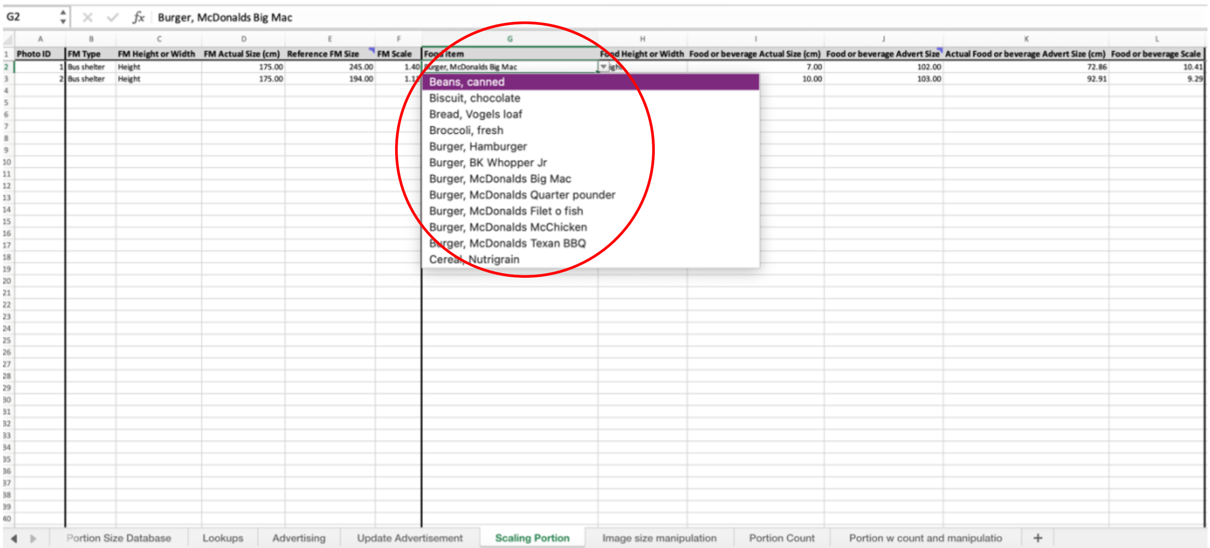
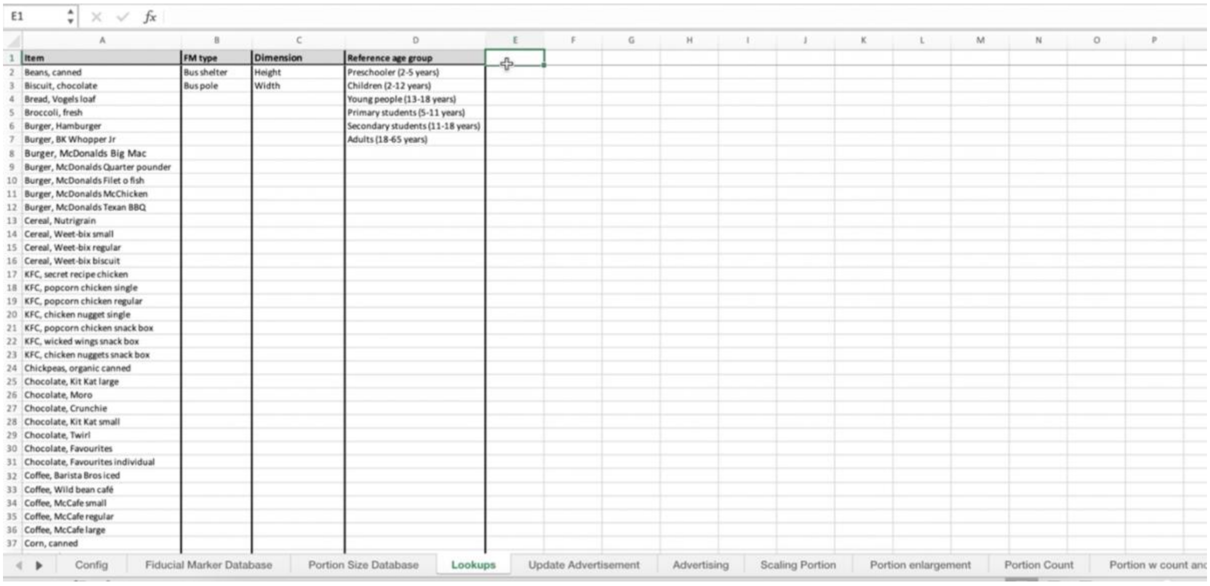


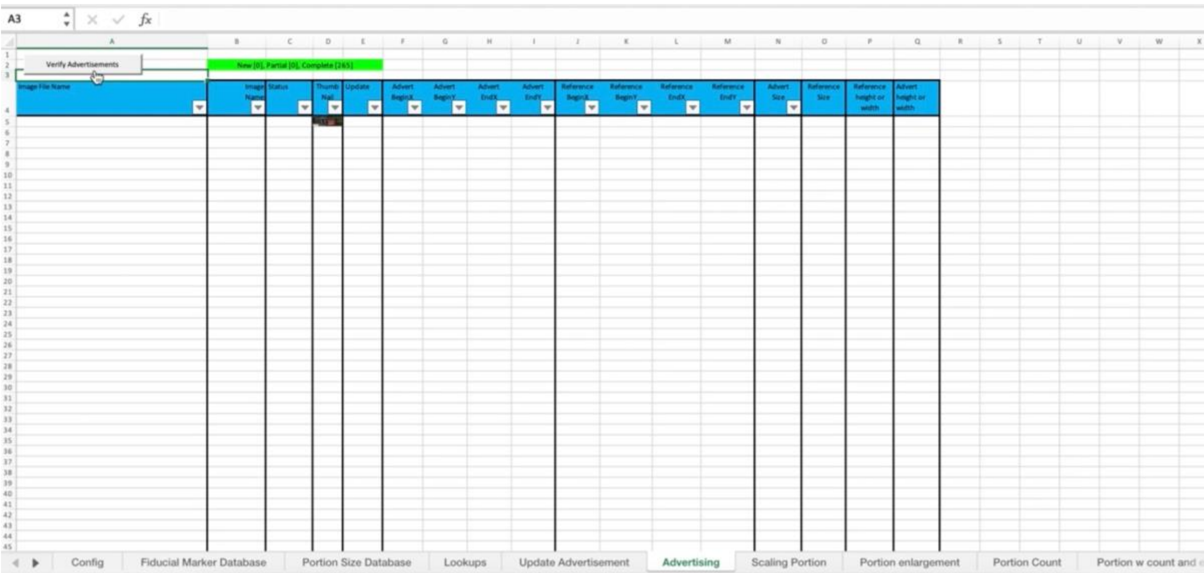
Figure 13. Creating Lookups



Uploading images

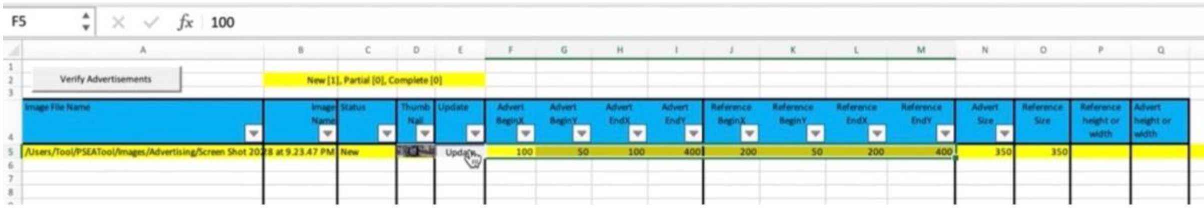
System users estimate the size of the product and fiducial marker by positioning markers over the image. To upload the required advertisement images from the disk directory, users select the 'verify advertisements' button in the Advertisements sheet (see figure 14).

Figure 14. Uploading Advertisement Images



Any new images will be created with an image file name, update button and the initial marker positions set (see figure 15). For each image, the user selects the ‘update’ button, which will display the image in the update advertisement sheet.

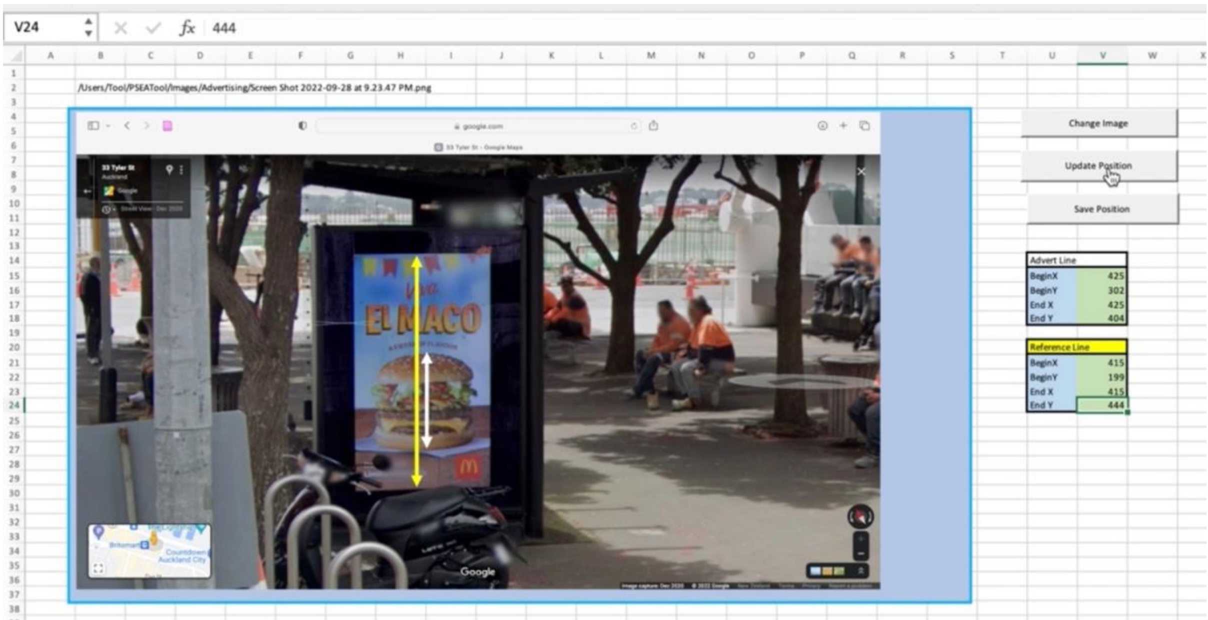
Figure 15. Setting Initial Marker Positions



Measure fiducial marker and product

The selected image will be displayed with two overlayed markers, one for the reference fiducial marker and another for the advertised food or beverage item. The user adjusts the numbers in the coordinate table, then selects ‘update position’ to view the new marker positionings (see figure 16). Due to the unstandardised distance and angle of GSV images, the “Markers” needs to be placed proximal to each other and the food or beverage.

Figure 16. Updating Marker Positions



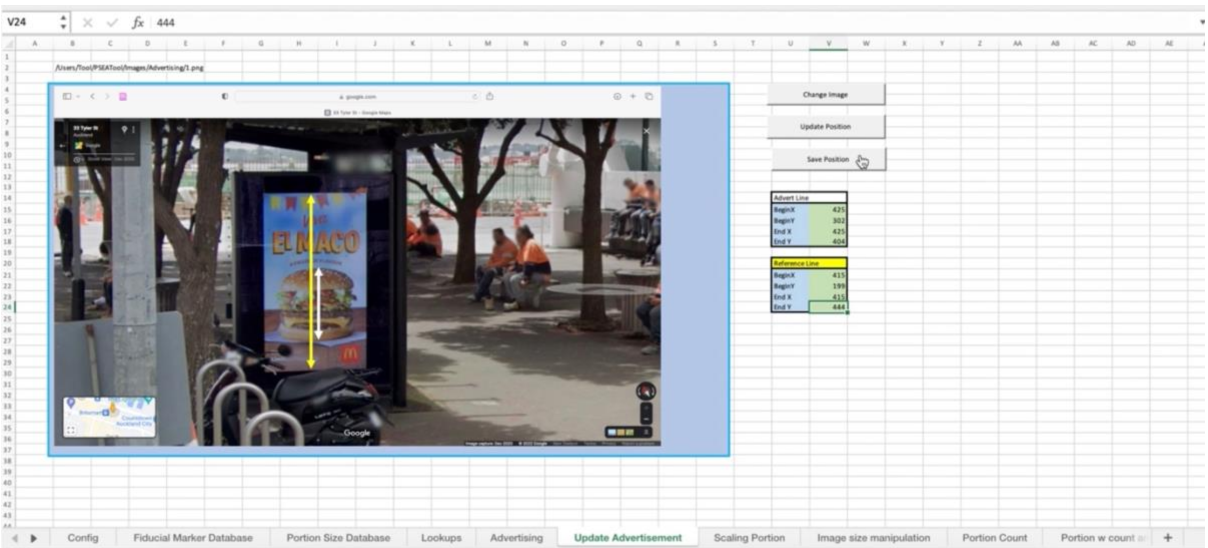
The arrows are positioned by entering X and Y coordinates for each end of the arrow. The coordinates are then used to calculate a rectangle around the arrow. By applying the Pythagorean Theorem with the arrow being the Hypotenuse and the X and Y lengths known from the coordinates we can calculate the length of the arrows (see figure 17).

Figure 17. Pythagorean Theorem to Calculate The length of The Arrows

$$c = \sqrt{a^2 + b^2}$$

Once the desired positions are set, the user selects the ‘save position’ button (see figure 18). The system is programmed to estimate and store the length of the arrows after a coded ‘save function’ is triggered, which will write the coordinates in the advertisement sheet. There is also an option to select ‘change image’ to return to the ‘advertising’ sheet. The user must note whether the arrows were placed to measure the height or width of the respective object.

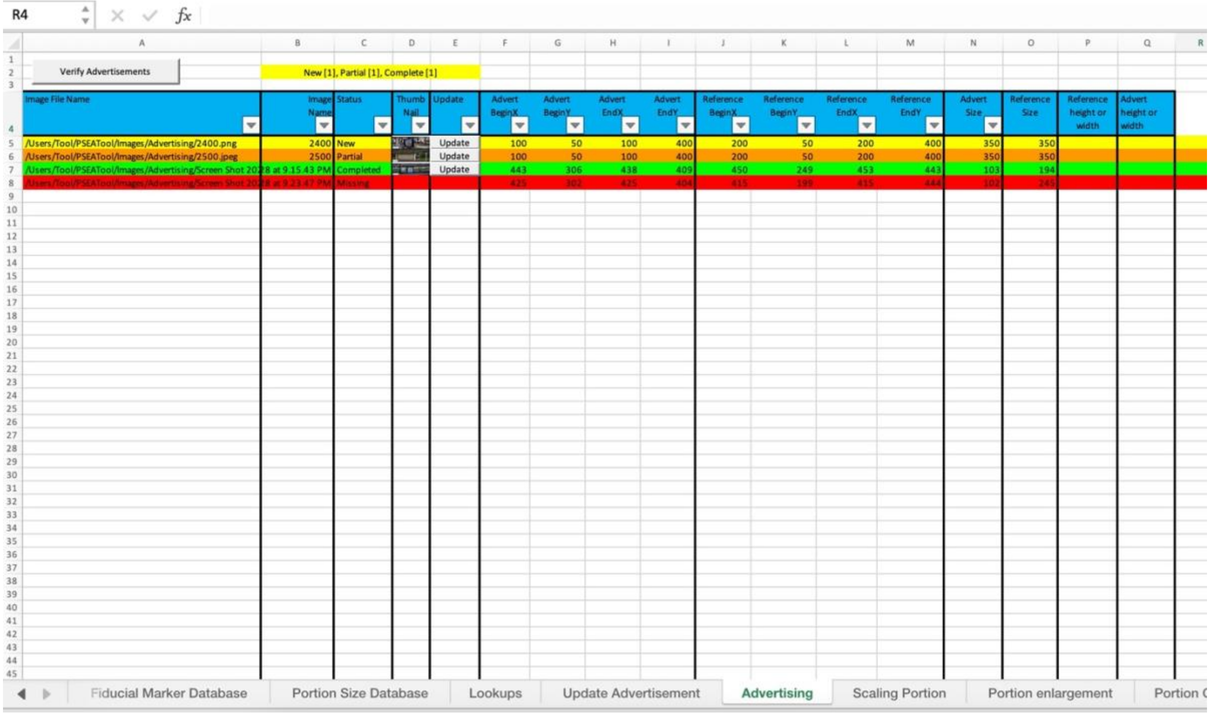
Figure 18. Saving Marker Positionings



Status message

A status will be set for each image in the advertisement sheet. A status will be displayed as yellow if a new image is added, orange if the markers are still set to the initial coordinates, green if the marker positioning is complete or red if the image is unable to be located (see figure 19). The number of statuses in each category will be displayed in the message bar.

Figure 19. Status Message Box



Scale portion

The user enters the photo ID. The system prompts the user with lookups to select the associated fiducial marker, height or width of the fiducial marker, food or beverage item, and height or width of food. Once these values have been selected, the system inserts the actual fiducial marker dimension, size of the reference marker, actual food or beverage size, and size of the advert marker. The system then estimates the actual size of the food or beverage advert (in centimetres) using coded formulas to calculate the scale of the depicted fiducial marker relative to the actual fiducial marker dimensions and then applies this calculated scale to the actual food or beverage dimensions. By applying the calculated scale to the actual food or beverage size, the actual advertised size of the food or beverage can be calculated (see figure 20). Therefore the tool is generic and can be used to provide a scale between any identifiable fiducial marker and food or beverage in an image.

Figure 20. Estimating The Actual Size of A Food or Beverage in an Advertisement

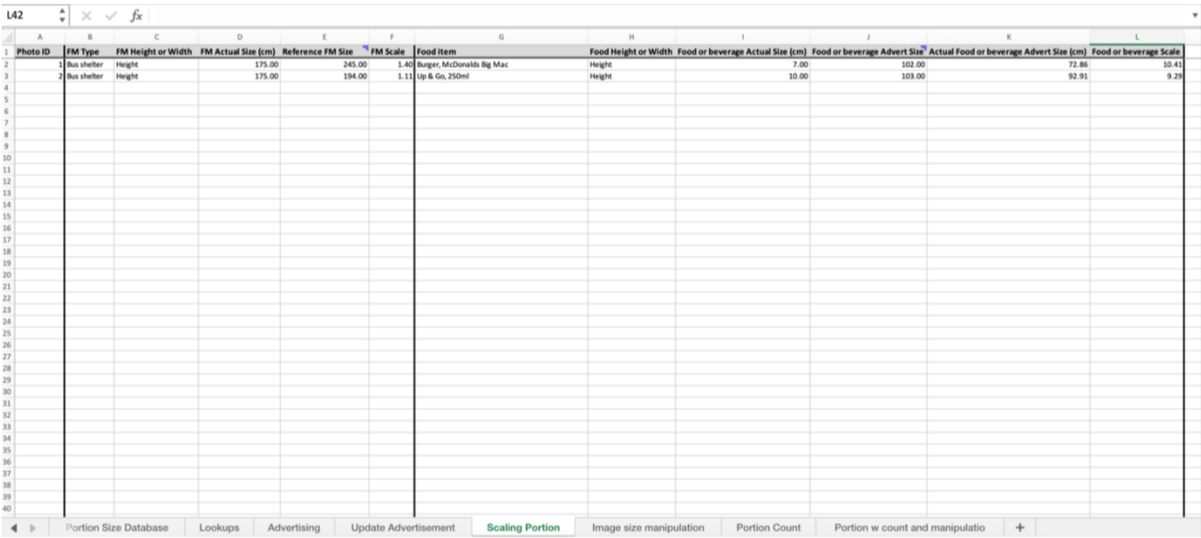
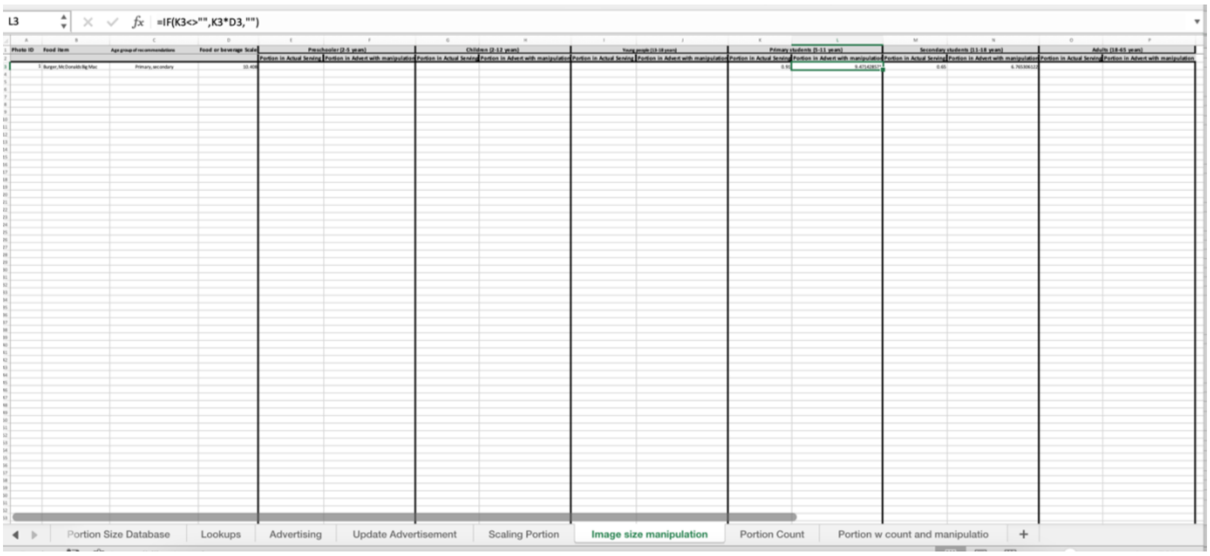


Image size manipulation

The user enters the photo ID. The item and scale are then inserted from the previous sheet using coded formulas. The age brackets of the relative nutrition guidelines for that food or beverage reference are entered. The system uses coded formulas to insert the number of recommended portions within the product serving. Allowing the system to then calculate the portions in the advert by multiplying the portion with the scale of the food or beverage item (see figure 21).

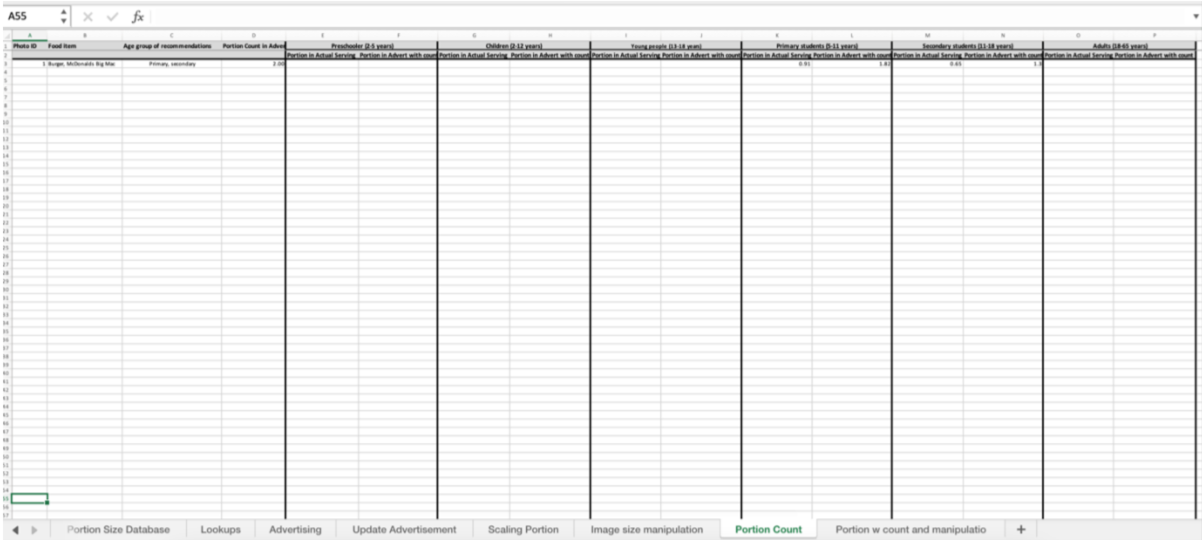
Figure 21. Calculating Number of Portions After Image Size Manipulation



Portion count

The photo IDs are entered by the user. The food item and age bracket for that food or beverage reference guideline is then inserted from the previous sheet using coded formulas. The item count, for the number of the same food or beverage items in the advert, is entered by the user, and portions inclusive of the count are calculated using coded formulas (see figure 22).

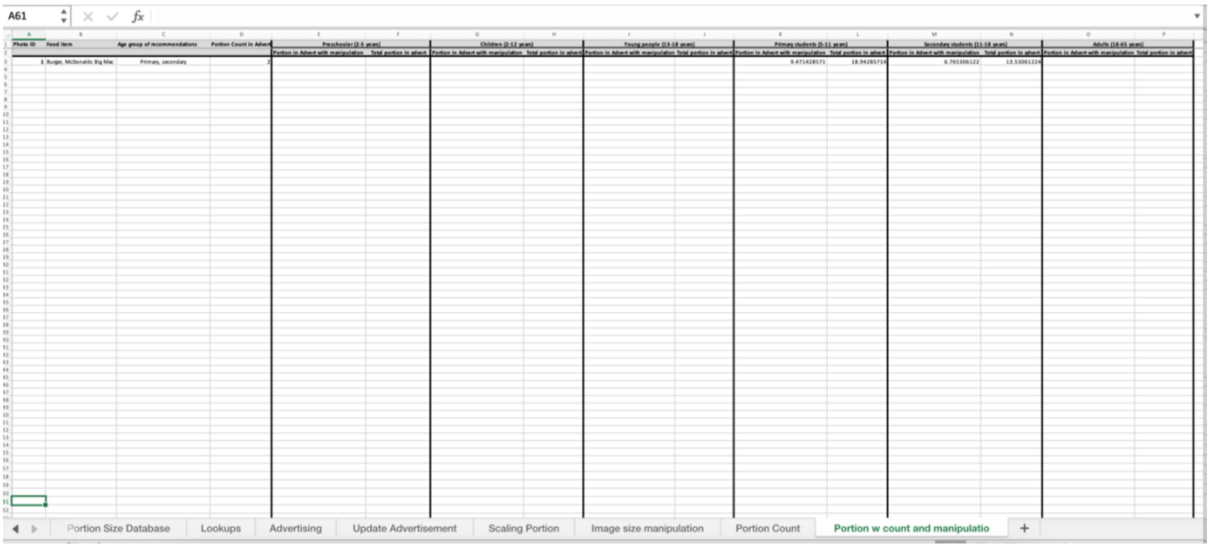
Figure 22. Calculating Number of Portions After Count



Total portion depicted

The user enters the photo ID. The food item, age bracket for that food or beverage reference guideline and portion count is then inserted from the previous sheet using coded formulas. Coded formulas are then used to look up the portion after image size manipulation and multiply this by the portion after count (see figure 23).

Figure 23. The Total Number of Portions After Count and Image Size Manipulation



Storage and access to the PEAR Tool

To ensure the security of the tool, the PEAR Tool spreadsheet application has been stored on a secure server at the University of Auckland. Researchers interested in using the PEAR Tool in their work should email v.egli@auckland.ac.nz to discuss this further.

5. GSV Study Estimating Portion Sizes in 'Bus Stops Near Schools Advertising Junk Food and Sugary Drinks' (Study C)

5.1. Methods of the GSV study

This chapter outlines and discusses the findings of the third research objective, "*To evaluate the portion sizes in advertising on bus shelters within a 500m road network boundary of schools around Auckland using images captured on GSV*". This chapter is organised as follows: section 1 provides an overview of the 'Bus Stops Near Schools Advertising Junk Food and Sugary Drinks' study. This is followed by a description of the methods of an ancillary study conducted to investigate portion sizes depicted on bus shelter advertisements captured using GSV. Section 2 then outlines the key findings of this ancillary study.

Study design overview

The current research is a sub-study of the larger 'Bus Stops Near Schools Advertising Junk Food and Sugary Drinks' project, a cross-sectional observational study of food and beverage advertisements on bus shelters within a 500m boundary of schools (n=190) from the Auckland region (Huang et al., 2020). The most recent GSV image captures of advertisements on each side of double-sided bus shelters were collected between August 2019 and January 2020. Screenshots of identified advertisements were saved by school type and decile with calculations made to measure the distance from school boundary, Walk Score® and Transit Score®. School decile was measured as a proxy for socio-economic disadvantage to indicate the socioeconomic status of the students neighbourhood (Ministry of Education, 2022). At the conclusion of the data collection period, all images were saved on a secure drive at the University of Auckland, Auckland. Each advertisement image for food and beverages was manually categorised and coded based on the WHO Regional Office for Europe Nutrient Profile Model (2015). In total, 25.5% of bus stop advertisements promoted food and/or beverages, of which 50.2% were for non-core foods. The aim of this study by Huang et al. (2020) was to quantify the nature and extent of children's exposure to food and beverage promotion marketed to children at bus stops within walking distance from all Auckland schools and inform NZ advertising policies. Further information on the 'Bus Stops Near Schools

Advertising Junk Food and Sugary Drinks' study design, sampling strategy and data collection is available elsewhere (Huang et al., 2020).

In total, 842 bus stop advertisements were identified. Of these, only images categorised as food and/or beverage were eligible for inclusion in this ancillary study. Images with data coded as unclear or no image were excluded. Advertisements for infant formula were removed, as recommended portions are tailored to meet the individual requirements of children up to 12 months of age. Further exclusions were applied to advertisements for discontinued products and advertisements that lacked a food or beverage product (see table 5), leaving 179 food and/or beverage advertisements in the analysis. Core and non-core food and beverages were included to gain a more comprehensive understanding of all portion sizes in advertised food and beverages in children's neighbourhoods.

Table 5. Food or Beverage Advertisements Lacking a Food or Beverage Item

Advertisement exclusion	Description	Examples
McDonalds	Monopoly game	
Nespresso coffee	Harvester picking coffee beans	

Coding and data analysis

Information from GSV image captures required for data entry included photo identification number, school decile, school type, distance from school boundary in metres, advertising categorisation, Walk Score® and Transit Score®. Images were coded using manual content analysis performed in Microsoft Excel by a single researcher over one week in August, 2022. Images were coded using a two-tiered framework for 1) advertisements containing two or more foods or beverages and 2) a count for multiples of the same food or beverage.

Advertisements containing two or more foods or beverages were subsequently copied, and separate data points were created. For example, an image depicting a bottle of juice, a glass of orange juice and fresh oranges was then copied and renamed to create three images (see table 6). Each image file was then categorised as ‘core’ or ‘non-core’ (see table 7), in accordance with the previous GSV research by Huang et al. (2020). Classification of food or beverage products was not possible for six images (i.e. puff pastry sheets, herbs and spices) since a suitable reference portion size could not be found for the specific food or beverage item; thus, were excluded from this study.

Table 6. Coding Advertisement Images With More Than One Food or Beverage Item

<table>
<tr><th>Food and beverage advertisement ID</th><th colspan="3">Food and beverage item in advertisement ID</th></tr>
<tr><td>1090
</td><td>1090a
</td><td>1090b
</td><td>1090c
</td></tr>
</table>

Table 7. Categorisation of Food and Beverages in Advertisements

Advertisement category	Examples
Food core	Yoghurt, bread, fruit and vegetables
Food noncore	Chocolate, burger, ice cream
Beverage core	Milk, reduced sugar juice
Beverage noncore	Flavoured milk, coffee, energy drinks, juice

A count was conducted by recording in Microsoft Excel how many of the same food or beverage item were depicted. For example, an image depicting two Whopper Jr. burgers is recorded as a portion count of 2 (see figure 24). Images where a food or beverage is partially depicted were coded for the proportion of the item inclusive of the advertisement. This was decided to minimise the number of entries in the database and allow the application of a single product across several advertisements with various product spatial arrangements. For example, half a bottle of Powerade on the bottom of the advertised image is coded as a portion count of 0.5 (see figure 25).

Figure 24. Coding Portion Count

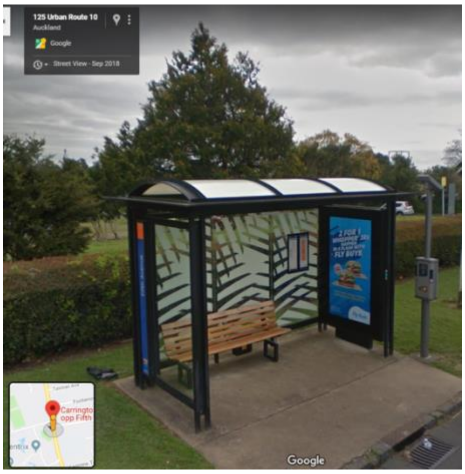
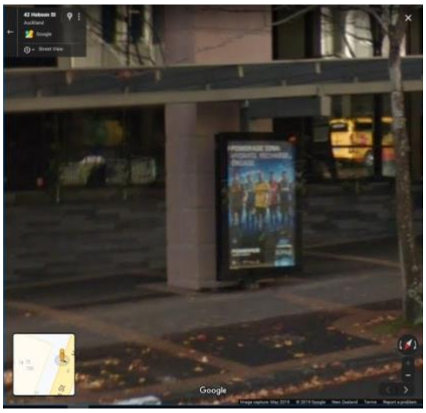


Figure 25. Coding Partial Portion Depictions

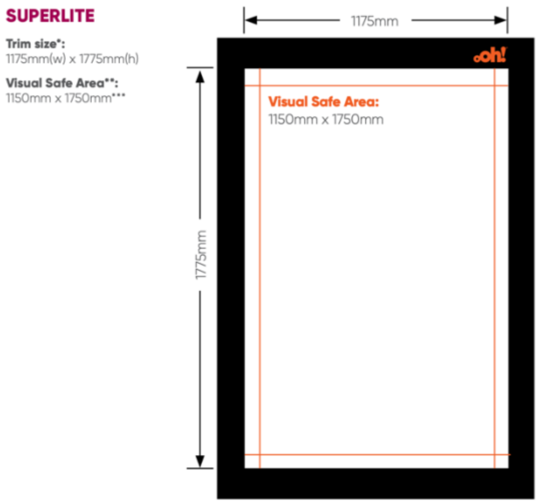


The eligible bus stop advertisement images were then imported into the PEAR Tool, using the methods described in Chapter 4, section 2, to determine the scale of portion sizes from image size manipulation and the portion count and how this compares to national dietary recommendations that are suitable for use in NZ children.

Fiducial marker database development

As bus shelters were a common object with standardised dimensions, it was decided this was the only marker to be entered into the current database. The object name and reference dimensions, measured in centimetres, were recorded in the 'Fiducial Marker database' sheet in the PEAR Tool spreadsheet. The researcher had initially planned to measure the dimensions of each of the five types of bus shelters depicted in the collected images. However, as the images were captured up to 7 years ago, the current bus shelters at each of the bus stop addresses visited had been replaced by one company, Ooh Media. The dimensions of the bus shelters were obtained through the Ooh Media advertising website, and related to the visual safe area as seen in figure 26 (Ooh Media, 2022).

Figure 26. Dimensions of Ooh Media Bus Shelter Advertising Space



Note. (Ooh Media, 2022)

Portion size database development

In a Microsoft Excel spreadsheet, the food or beverage item, reference portion size for relative age groups and the nutrition guidelines the reference was obtained from, food or beverage dimensions and portions in food or beverage serving were recorded. Included items were chosen based on the foods and beverages identified in advertisements by Huang et al. (2020). The researcher visited Countdown, Pak 'n' Save, Wild Bean Café, Burger King, McDonalds and Kentucky Fried Chicken outlets in August 2022, over a period of two weeks, to collect the dimensions and portions in each serving of the identified products. As the two supplement products were out of stock at several pharmacies visited, these were sourced online from TheMarket.com. Each item was measured using a single measuring tape to determine the height and width of the item. All dimensions were recorded in centimetres and measured using the highest and widest points. The servings of food and beverages were then recorded, using millilitres or grams. Food and beverage servings were also obtained from the McDonald's, Subway and BP's online nutritional information (McDonalds, 2022; Subway, 2022; Wild Bean Cafe, 2022). Where a variety of product unit sizes were available with no discernible features to determine which was utilised in the advertisement (see figure 27), it was decided that the largest unit size would be measured to demonstrate the degree of manipulation of even the largest unit size.

Figure 27. Products of varying unit size with indistinguishable features

Several foods and beverages were not found in predetermined amounts: including a bowl of yoghurt, sauce on hot chips, glass of orange juice, smoothie and a plate of rice. For these items, separate objects within the images were used to estimate the size of the depicted product. For example, a plate of rice was estimated by the dimensions of a pea (see figure 28). The dimensions of the pea were measured using a tape measure laid over the laptop screen. Using the same level of zoom, the tape measure was then positioned to measure the plate. An actual pea was subsequently measured and used to calculate the scale of the of the actual plate. A plate of similar shape and size was located. This plate was filled with rice to reflect the depicted portion which was then weighed using scales.

Figure 28. Measuring Food and Items Not In a Predetermined Size

The reference portions were based on several nutrition guidelines. A tier of these guidelines was drafted by the researcher, revised by the supervisors who are experts in Dietetics, Public Health, and Children's Health, and subsequently finalised (see figure 29). Where possible, reference guidelines designed for NZ children were used (Healthy Auckland Together, 2022; Ministry of Health, 2015, 2020b). Due to a paucity of recommended portion sizes for unhealthy foods and beverages, the criteria was expanded to include Australian nutrition guidelines due to the similar demographics of these populations (NSW Ministry of Health, 2020; Queensland Health, 2020). When missing both, NZ adult nutrition guidelines were referenced (National District Health Board Food and Drink Environments Network, 2019; The New Zealand Institute for Plant and Food Research & Ministry of Health, 2022). It was decided that if the advertised portion size is greater than that recommended for an adult, then it is likely the portion size will unequivocally match or surpass the portion sizes recommended for children.

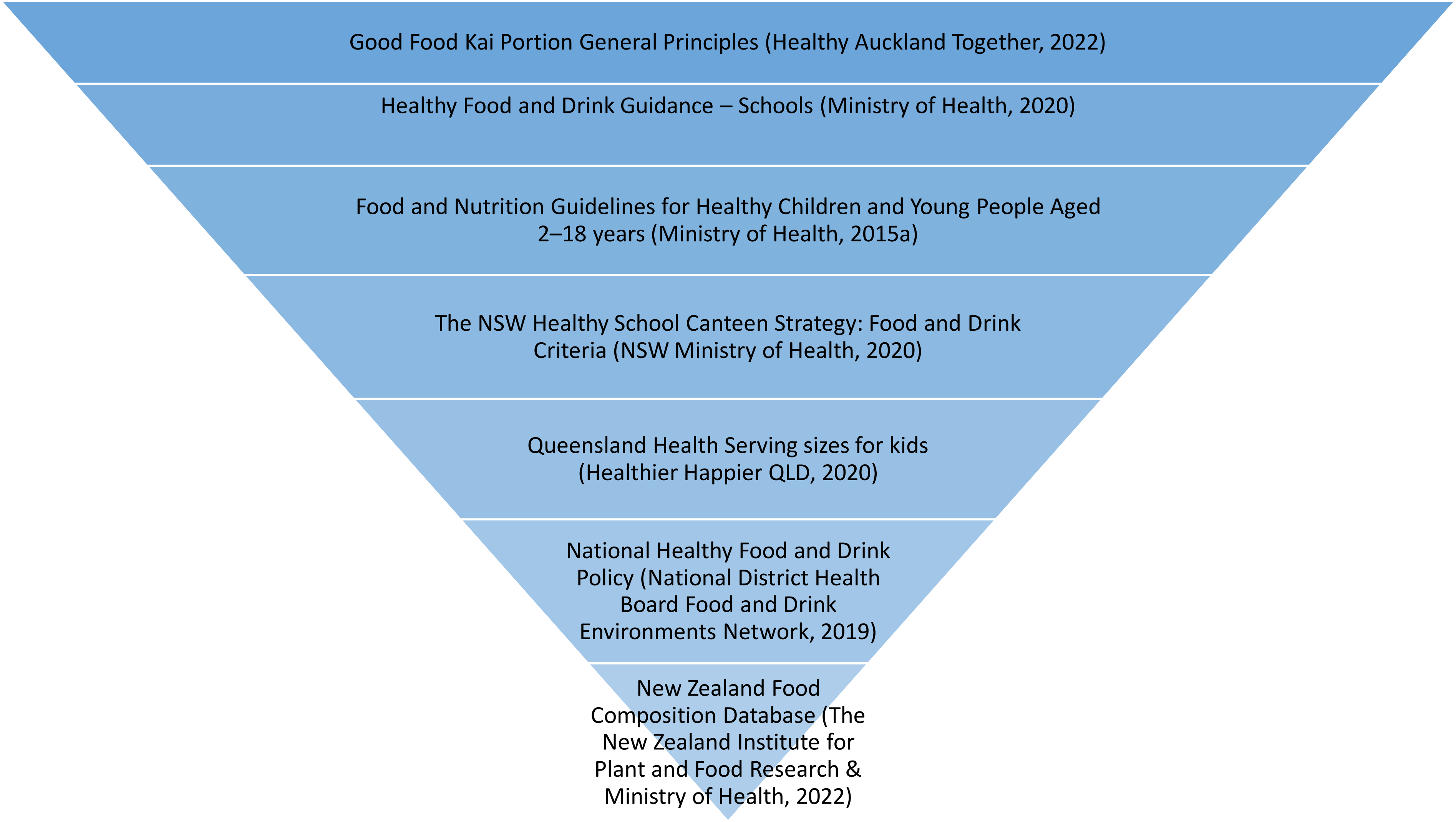
As nutrient requirements vary widely between different age brackets of children under 18 years-of-age (Ministry of Health, 2015), an effort was made to have an option to enter different portion sizes for different age groups. Under the MoH Nutrition Guidelines for children (2015), portion sizes are listed with age group variants determined by the number of servings in each food group per day. It was decided to multiply the portion size by the number of daily servings for that food group and divide the total by 5 to represent the consumption of five daily meals (three main meals and two snacks). The number of recommended portions in a serving was calculated by dividing the recommended portion size by the food or beverage serving.

Content write-up was drafted by the researcher, revised by a supervisor who is a NZ registered dietitian, and subsequently finalised. This database was then imported into the portion size database sheet of the PEAR Tool spreadsheet application. A full list of the elements included in the food and beverage portion size database can found be found in Appendix 2.

Statistical analysis

Data were analysed using IBM SPSS for Mac version 29. Descriptive statistics were used to assess the number and proportion of food and/or beverage advertisements. The number and proportion of food or beverage items within the advertisements were evaluated by food or

Figure 29. Reference Nutrition Guideline Tier



beverage categorisation, school decile, distance from school boundary, Walk Score® and Transit Score.

School decile was categorised into one of three categories; low (1-3), medium (4-7) or high (8-10). The distance of the bus shelter advertisement to the school entrance was separated into quintiles; with quintile 1 representing the least distance from the school entrance (≤100m), and quintile 5 representing the greatest distance (401-500m). Walk Score® and Transit Score® were categorised from 1, most car-dependent or least transport, to 5, least car-dependent or most transport.

Descriptive statistics were conducted to determine the mean and standard deviation of the portion size after adjusting for the manipulation to the image size, item count and total portion size depicted in advertisements across each food and beverage category. For this analysis, the portion size calculated across the six age groups, for each of the portion size variables, were averaged. This was due to the portion size for each food or beverage not being available for all age groups, subject to the available guideline recommendations. Independent- Samples Kruskal-Wallis Tests were performed to investigate how the portion size advertised differ by school decile, distance from school boundary, Walk Score® and Transit Score®. For all analyses, a P value of <0.05 was considered statistically significant.

5.2. Results of the GSV study

The capture date of street view images included in this study ranged from February 2012 to October 2019. Of the 842 bus shelter advertisements within a 500 m walking distance of schools in the Auckland region, 211 had advertisements for food and/or beverages that could be identified. Of those advertisements, 10 (4.74%) lacked a food or beverage item in the advertisement, 10 (4.74%) advertised infant formula and 13 (6.16%) identified discontinued products. 2.84% (n=6) of advertisements were coded as miscellaneous. Due to time constraints in finding a suitable reference portion, these images (n=6, 2.84%) were excluded from analysis.

Of the 172 advertisements remaining, 13 (7.6%) of advertisements were for core beverages, 22 (12.8%) were for non-core beverages, 77 (44.8%) for core food, 58 (33.7%) for non-core food and 2 (1.1%) for non-core food and beverages. The greatest proportion of schools with advertisements within a 500m boundary were contributing schools (n=65, 37.8%), followed by full primary schools (n=34, 19.8%), and then secondary schools for students aged 9-15 years (n=25, 14.5%). 41.3% (n=71) were located within a 500m boundary of the high decile schools, and 31.4% located around low decile schools (n=54). Table 8 presents descriptive results of the advertisements.

It was considered important to identify the proportion of foods and beverages within the advertisements, as multiple food or beverage items could be advertised within a single advert. A total of 265 foods or beverages were identified within the advertisements. 133 (50.2%) of all foods or beverages in advertisements were coded "non-core". However, the most frequent category of foods or beverages in advertisements were for "food core" (n=116, 43.8%). Table 9 presents descriptive results of the food and beverages within advertisements.

Table 8. Descriptive Table of Advertisement Results

		N (%)
Food or beverage category	Beverage core	13 (7.6)
	Beverage noncore	22 (12.8)
	Food and beverage noncore	2 (1.1)
	Food core	77 (44.8)
	Food noncore	58 (33.7)
School Type	Activity centre	2 (1.1)
	Composite	14 (8.1)
	Contributing	65 (37.8)
	Full Primary	34 (19.8)
	Intermediate	18 (10.5)
	Secondary (7-15)	7 (4.1)
	Secondary (9-15)	25 (14.5)
	Special School	7 (4.1)
Decile	N/A*	3 (1.7)
	Low (1-3)	54 (31.4)
	Medium (4-7)	44 (25.6)
	High (8-10)	71 (41.3)
Distance from school (m)	<100	18 (10.5)
	101-200	23 (13.4)
	201-300	20 (11.6)
	301-400	48 (27.9)
	401-500	63 (36.6)
Walk Score	1	3 (1.7)
	2	23 (13.4)
	3	53 (30.9)
	4	68 (39.5)
	5	25 (14.5)
Transit Score	N/A**	5 (2.4)
	1	0 (0.0)
	2	64 (37.5)
	3	71 (41.3)
	4	12 (7.2)
	5	20 (11.6)

** Private schools without a decile rating were coded 'N/A'*

*** Schools without a Transit Score® were coded 'N/A'*

Table 9. Descriptive Table of Food and Beverages in Advertisements Results

		N (%)
Food or beverage categorisation	Beverage core	16 (6.0)
	Beverage noncore	32 (12.1)
	Food core	116 (43.8)
	Food noncore	101 (38.1)
School Type	Activity Centre	2 (0.8)
	Composite	20 (7.5)
	Contributing	100 (37.7)
	Full Primary	56 (21.1)
	Intermediate	27 (10.2)
	Secondary (7-15)	12 (4.5)
	Secondary (9-15)	35 (13.3)
	Special School	13 (4.9)
Decile	N/A*	3 (1.1)
	Low (1-3)	86 (32.5)
	Medium (4-7)	60 (22.6)
	High (8-10)	116 (43.8)
Distance from School Boundary (m)	<100	26 (9.8)
	101-200	33 (12.5)
	201-300	32 (12.1)
	301-400	72 (27.2)
	401-500	102 (38.4)
Walk Score	1	6 (2.3)
	2	33 (12.5)
	3	85 (32.0)
	4	114 (43.0)
	5	27 (10.2)
Transit Score	N/A**	9 (3.4)
	1	0 (0.00)
	2	92 (34.7)
	3	126 (47.6)
	4	18 (6.8)
	5	20 (7.5)

** Private schools without a decile rating were coded 'N/A'*

*** Schools without a Transit Score® were coded 'N/A'*

As seen in Table 10, most core foods advertised were yoghurt (n=59, 22.3%) and breakfast cereals (n=30, 11.3%). While plain milk was the primary core beverage advertised (n=13, 4.9%). Examples of non-core foods advertised included condiments such as mayonnaise and tomato sauce (n=26, 9.8%), chocolate bars (n=25, 9.4%), and burgers (n=11, 4.2%). The most frequent non-core beverages were coffee (n=11, 4.2%); followed by flavoured milk (n=8, 3.0%), energy drinks (n=3, 1.1%) and soft drinks (n=3, 1.1%).

Table 10. Descriptive Table of Food and Beverage Items Being Advertised

	N (%)
Biscuit	1 (0.4)
Bread	2 (0.8)
Burger	11 (4.2)
Cereal	30 (11.3)
Chickpeas	4 (1.5)
Chocolate	25 (9.4)
Coffee	11 (4.2)
Condiment	26 (9.8)
Cream	2 (0.8)
Egg	3 (1.1)
Energy drink	3 (1.1)
Fizzy/soft drink	3 (1.1)
Flavoured milk	8 (3.0)
Fruit	2 (0.8)
Hot chips	11 (4.2)
Hot dog	1 (0.4)
Ice cream	3 (1.1)
Instant noodle	1 (0.4)
Juice	6 (2.3)
Milk	13 (4.9)
Potato chip	3 (1.1)
Processed chicken	17 (6.4)
Rice	3 (1.1)
Sandwich	4 (1.5)
Sports drink	2 (0.8)
Supplement	3 (1.1)
Vegetable	8 (3.0)
Yoghurt	59 (22.3)

Scale

The mean scale of all food and beverages in advertisements, relative to the actual item size, was 4.7 (SD=2.0). There was a statistically significant difference in the scale of non-core food and beverages (M=5.1, SD=2.2) compared with core food and beverages (M=4.3, SD=1.7), p=<0.001 (see table 11). The minimum scale applied to items in advertisements was 0.9 (n=1, 0.4%), while the maximum extended up to 11.7.

Table 11. Scale of Food and Beverages in Advertisements

Food or beverage categorisation	Scale of food or beverage in advertisements	
	Mean (SD)	P value
Beverage core	2.6 (0.5)	<0.001
Beverage noncore	3.9 (1.8)	
Food core	4.6 (1.6)	
Food noncore	5.5 (2.1)	
Total	4.7 (2.0)	

Count

77 (29.1%) of the images were coded with a count (table 12). For the count of same food and beverage items in an advertisement, there was a statistically significant difference in the mean of items of non-core food and beverages (M=1.3, SD=1.1), compared with core food and beverages (M=1.1, SD=0.5), p=0.005. As seen in table 13, 1.2 (SD=0.9) was the mean portion count of all foods and beverage items in advertisements.

Table 12. Proportion of Items in Advertisements Which Included a Count

	N (%)
Beverage core	1 (1.3)
Beverage noncore	9 (11.7)
Food core	41 (53.2)
Food noncore	26 (33.8)
Total	77 (29.1)*

**% of total advertisements with a count*

Table 13. Portion Count of Food and Beverages in Advertisements

	Portion count of food or beverage in advertisement	
Food or beverage categorisation	Mean (SD)	P value
Beverage core	1.1 (0.5)	0.010
Beverage noncore	1.4 (1.0)	
Food core	1.1 (0.5)	
Food noncore	1.3 (1.1)	
Total	1.2 (0.9)	

Portions by advertisement categories

The mean number of portion sizes for a food or beverage in advertisements, after adjusting for the manipulation of the image size and item count, was 28.4 (SD=47.8) times the recommendations. The mean total number of recommended portions depicted within non-core foods (M=31.8, SD=50.2) was double the mean total number of recommended portions depicted in core beverages (M=14.1, SD=11.1). Across each food or beverage categorisation, there was a statistically significant difference in the number of portion sizes above those recommended for a food or beverage after adjusting for the manipulation to image size (p=<0.001), item count (p=<0.001) and overall portions depicted in the advertisement (p=<0.001), as seen in table 14.

Table 14. Number of Recommended Portion Sizes in an Advertised Food or Beverage

Mean (SD)						
Food or beverage categorisation	Portion after image manipulation	P value	Portion after count	P value	Portion total	P value
Beverage core	11.8 (3.4)	<0.001	5.4 (3.3)	<0.001	14.1 (11.1)	<0.001
Beverage noncore	22.7 (84.0)		7.9 (24.2)		24.4 (83.7)	
Food core	35.5 (44.1)		8.6 (14.1)		28.5 (33.5)	
Food noncore	34.4 (59.2)		5.9 (8.9)		31.8 (50.2)	
Total	32.1 (55.2)		7.3 (13.7)		28.4 (47.8)	

Portions by food and beverage items

As seen in Table 15, the total portions of food and beverage items, as times by the recommended portions, were greatest for cream (M=284.1, SD=269.2), supplements (M=149.3, SD=123.5 and condiments (M=101.8, SD=54.9).

Table 15. Number of Recommended Portion Sizes of Advertised Food or Beverages by Item

	Mean (SD)		
	Portion after manipulation	Portion after count	Portion total
Biscuit	5.1 (0.0)	0.7 (0.0)	7.6 (0.0)
Bread	81.4 (0.5)	29.7 (0.0)	60.04 (0.3)
Burger	4.5 (3.4)	0.7 (0.2)	4.8 (3.4)
Cereal	55.5 (30.1)	11.4 (5.8)	39.4 (20.3)
Chickpeas	104.6 (1.6)	13.1 (0.0)	68.0 (1.0)
Chocolate	9.6 (6.7)	2.0 (2.2)	10.0 (6.5)
Coffee	4.5 (1.9)	1.7 (1.5)	7.4 (4.9)
Condiment	114.2 (70.3)	17.8 (9.7)	101.8 (54.9)
Cream	284.1 (269.2)	100.0 (0.0)	284.1 (269.2)
Egg	3.7 (0.4)	0.4 (0.0)	2.6 (0.2)
Energy drink	6.2 (0.1)	1.2 (0.2)	6.2 (0.1)
Fizzy	9.1 (7.5)	2.2 (0.3)	8.6 (4.7)
Flavoured milk	1.6 (0.7)	1.0 (0.7)	2.9 (4.3)
Fruit	11.3 (3.8)	4.7 (3.1)	17.2 (15.1)
Hot chips	3.7 (4.1)	0.8 (1.0)	4.7 (4.2)
Hot dog	8.2 (0.0)	1.2 (0.0)	5.7 (0.0)
Ice cream	15.5 (13.7)	3.1 (1.2)	18.0 (12.0)
Instant noodle	4.3 (0.0)	1.9 (0.0)	8.6 (0.0)
Juice	12.0 (5.6)	5.7 (5.7)	19.5 (17.7)
Milk	11.6 (1.4)	4.8 (0.9)	11.6 (1.4)
Potato chip	10.5 (8.8)	6.8 (7.4)	22.2 (23.9)
Processed chicken	2.4 (0.6)	0.7 (0.2)	2.4 (0.5)
Rice	9.1 (6.2)	2.6 (0.7)	11.1 (2.9)
Sandwich	3.4 (1.5)	0.7 (0.1)	3.4 (1.5)
Sports drink	8.1 (4.1)	3.0 (2.1)	9.5 (9.8)
Supplement	192.2 (153.3)	69.8 (57.3)	149.3 (123.5)
Vegetable	41.1 (25.2)	12.3 (8.8)	44.8 (32.5)
Yoghurt	15.7 (7.9)	4.0 (2.3)	14.7 (8.9)

Decile

Overall, advertising around medium decile (four to seven) schools contributed the lowest mean number of recommended portions sizes in the depicted portion size after adjusting for image size manipulation (M=25.3, SD=37.9), item count (M=5.6, SD=6.9) and overall portion size (M=23.7, SD=31.9), see table 16 below. While advertising for non-core food or beverages around high decile (eight to ten) schools contributed the greatest mean number of recommended portions sizes in the depicted portion size after adjusting for image size manipulation (M=51.4, SD=87.6), item count (M=8.6, SD=15.6) and overall portion size (M=46.9, SD=79.6). There were no trend differences between portions in each food or beverage categorisations and school decile.

Table 16. Mean Portion Size of Food and Beverage Advertisements by Decile

		Mean (SD)		
Food or beverage categorisation	Decile	Portion after manipulation	Portion after count	Portion total
Beverage core	Low (1-3)	12.8 (3.7)	7.3 (6.4)	21.8 (21.6)
	Medium (4-7)	10.8 (5.2)	4.1 (1.9)	10.8 (5.2)
	High (8-10)	12.2 (1.4)	5.3 (0.6)	12.2 (1.4)
Beverage noncore	Low (1-3)	15.6 (31.7)	14.9 (34.4)	20.5 (30.1)
	Medium (4-7)	5.5 (2.4)	1.6 (1.2)	7.0 (4.0)
	High (8-10)	34.9 (117.3)	7.6 (24.7)	35.2 (117.3)
Food core	Low (1-3)	50.2 (64.0)	13.1 (22.7)	38.0 (49.0)
	Medium (4-7)	32.9 (31.6)	8.1 (7.0)	30.3 (25.5)
	High (8-10)	27.0 (27.4)	5.9 (5.8)	21.5 (19.7)
Food noncore	Low (1-3)	13.4 (32.0)	3.3 (6.4)	14.5 (32.4)
	Medium (4-7)	26.2 (50.1)	4.6 (7.7)	24.4 (42.8)
	High (8-10)	57.9 (73.7)	9.0 (10.5)	51.5 (60.3)
Total	Low (1-3)	29.4 (50.8)	8.8 (19.0)	25.5 (40.9)
	Medium (4-7)	25.3 (37.9)	5.6 (6.9)	23.7 (31.9)
	High (8-10)	38.2 (65.3)	7.2 (11.6)	33.5 (58.6)

A greater proportion of food and beverage advertisements were found as school decile decreased (Table 17). Advertisements for noncore beverages, noncore foods and core foods followed the same pattern.

Table 17. Proportion of Advertisements by School Decile

		N (%)				
		Beverage core	Beverage noncore	Food core	Food noncore	Total
	N/A*	1 (6.3)	1 (3.1)	1 (0.9)	0 (0.0)	3 (1.1)
Decile	Low (1-3)	6 (37.5)	16 (50.0)	53 (45.7)	41 (40.6)	116 (43.8)
	Medium (4-7)	4 (25.0)	8 (250.0)	37 (31.9)	37 (36.6)	86 (32.5)
	High (8-10)	5 (31.3)	7 (21.9)	25 (21.6)	23 (22.8)	60 (22.6)
	Total	16 (100.0)	32 (100.0)	116 (100.0)	101 (100.0)	265 (100.0)

** Private schools without a decile rating were coded 'N/A'*

Distance from school boundary

The table below, Table 18, shows a comparison of the number of recommended portion sizes in the depicted item portion size as distance from the school boundary increases, for each of the food and beverage categorisations. The mean number of recommended portions sizes in the total portion size was greatest at a medium distance (301-400m) from the school boundary (M=38.8, SD=43.9); followed by a low distance (0-100m) from the school boundary (M=35.9, SD=38.2). There were no trend differences between portions in each food or beverage categorisations and distance from school boundary.

Table 18. Mean Portion Size of Food and Beverage Advertisements by Distance From School Boundary

Food or beverage categorisation	Distance from School Boundary (m)	Mean (SD)		
		Portion after manipulation	Portion after count	Portion total
Beverage core	<100	11.23 (0.00)	2.78 (0.00)	11.23 (0.00)
	101-200	11.44 (1.10)	4.87 (0.80)	11.44 (1.10)
	201-300	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	301-400	11.81 (1.54)	5.10 (0.72)	11.81 (1.54)
	401-500	12.19 (6.19)	6.57 (5.97)	19.40 (20.08)
Beverage noncore	<100	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	101-200	4.36 (2.61)	0.91 (0.26)	4.36 (2.61)
	201-300	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	301-400	5.45 (4.36)	1.91 (1.61)	7.53 (5.76)
	401-500	45.25 (125.82)	16.04 (35.59)	47.11 (125.24)
Food core	<100	32.97 (28.15)	8.51 (8.51)	26.19 (20.93)
	101-200	26.51 (23.70)	6.46 (5.55)	24.63 (23.10)
	201-300	41.47 (39.76)	8.63 (7.71)	24.63 (23.10)
	301-400	38.77 (66.66)	10.84 (24.06)	30.53 (51.38)
	401-500	34.81 (31.72)	7.39 (6.11)	27.45 (22.03)
Food noncore	<100	79.43 (63.73)	13.83 (10.22)	79.43 (63.73)
	101-200	52.23 (77.18)	7.41 (9.34)	45.06 (60.02)
	201-300	56.76 (78.31)	7.87 (9.85)	46.78 (58.71)
	301-400	24.69 (49.45)	4.81 (8.48)	24.28 (43.05)
	401-500	25.32 (51.39)	4.79 (8.42)	24.28 (45.55)
Total	<100	41.07 (40.43)	9.31 (8.84)	35.85 (38.23)
	101-200	27.56 (42.86)	5.65 (6.19)	24.91 (35.06)
	201-300	48.16 (59.14)	8.30 (8.57)	38.81 (43.93)
	301-400	26.59 (53.21)	7.07 (17.14)	23.08 (42.11)
	401-500	30.11 (61.40)	7.16 (15.03)	28.08 (57.62)

As the distance from the school increased, more total advertisements per 100 m were found (see Table 19 below). A greater proportion of advertisements were found 300-500m from the school boundary across food and beverage categories.

Table 19. Proportion of Advertisements by Distance From School Boundary

		N (%)				
		Beverage core	Beverage noncore	Food core	Food noncore	Total
Distance from School Boundary (m)	<100	1 (6.3)	0 (0.0)	20 (17.2)	5 (5.0)	26 (9.8)
	101-200	4 (25.0)	5 (15.6)	16 (13.8)	5 (5.0)	33 (12.5)
	201-300	0 (0.0)	0 (0.0)	18 (15.5)	8 (7.9)	32 (12.1)
	301-400	6 (37.5)	13 (40.6)	33 (28.4)	14 (13.9)	72 (27.2)
	401-500	5 (31.3)	14 (43.8)	29 (25.0)	54 (53.5)	102 (38.5)
	Total	16 (100.0)	32 (100.0)	116 (100.0)	101 (100.0)	265 (100.0)

Walk Score

Schools with a medium Walk Score® (3) made up the greatest mean number of recommended portion sizes in the depicted item portion size after adjusting for the manipulation to image size (M=38.2, SD=69.7), item count (M=8.4, SD=16.1) and overall portion size (M=35.9, SD=64.0). There were no trend differences between portions in each food or beverage categorisations and Walk Score®, see Table 20 below.

Table 20. Mean Portion Size of Food and Beverage Advertisements by Walk Score®

Food or beverage categorisation	Walk Score	Mean (SD)		
		Portion after manipulation	Portion after count	Portion total
Beverage core	1	18.0 (0.0)	16.7 (0.0)	54.1 (0.0)
	2	11.2 (0.0)	2.8 (0.0)	11.2 (0.0)
	3	11.9 (4.7)	4.8 (1.9)	11.9 (4.7)
	4	11.2 (3.4)	4.9 (0.8)	11.2 (1.6)
	5	10.4 (0.1)	4.2 (0.0)	10.4 (0.1)
Beverage noncore	1	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	2	4.4 (1.4)	3.0 (1.7)	11.6 (4.8)
	3	48.1 (130.5)	17.1 (36.8)	50.1 (129.9)
	4	5.0 (4.6)	1.3 (0.8)	5.6 (4.5)
	5	8.8 (5.1)	2.4 (0.9)	7.5 (7.0)
Food core	1	32.9 (48.9)	7.2 (9.3)	25.3 (32.4)
	2	28.3 (31.0)	6.4 (6.3)	21.9 (20.6)
	3	31.5 (27.9)	6.9 (5.7)	26.7 (22.7)
	4	36.2 (55.4)	10.4 (19.8)	30.6 (43.3)
	5	49.1 (35.5)	8.5 (5.7)	33.0 (22.7)
Food noncore	1	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	2	29.6 (42.4)	6.5 (7.7)	32.7 (42.2)
	3	44.0 (68.8)	7.1 (9.6)	39.5 (56.6)
	4	28.2 (54.7)	4.9 (8.7)	26.1 (47.8)
	5	28.9 (60.1)	3.9 (8.4)	23.0 (44.6)
Total	1	30.4 (44.2)	8.8 (9.1)	30.1 (31.2)
	2	26.1 (34.4)	6.0 (6.5)	24.9 (30.3)
	3	38.2 (69.7)	8.4 (16.1)	35.0 (64.0)
	4	28.1 (50.8)	7.0 (14.7)	24.9 (41.8)
	5	37.3 (43.3)	6.4 (6.6)	26.5 (29.8)

The greatest proportion of advertising across all categories was found in schools with a medium-high Walk Score® (4). Schools with the lowest Walk Score® (1) had the least advertisements. In terms of Walk Score®, there were no trend differences between core and non-core advertisements (Table 21).

Table 21. Proportion of Advertisements by Walk Score®

		N (%)				
		Beverage core	Beverage noncore	Food core	Food noncore	Total
Walk Score	1	1 (6.3)	0 (0.0)	5 (4.3)	0 (0.0)	6 (2.3)
	2	1 (6.3)	3 (9.4)	16 (13.8)	13 (12.9(	33 (12.5)
	3	6 (37.5)	13 (40.6)	28 (24.1)	38 (37.6)	85 (32.1)
	4	6 (37.5)	14 (43.8)	52 (44.8)	42 (41.6)	114 (43.0)
	5	2 (12.5)	2 (6.3)	15 (12.9)	8 (7.9)	27 (10.2)
	Total	16 (100.0)	32 (100.0)	116 (100.0)	101 (100.0)	265 (100.0)

Transit Score

Schools with a low-medium Transit Score® (2) made up the greatest mean number of recommended portion sizes in the depicted item portion size after adjusting for the manipulation of image size and item count (M=32.8, SD=59.4). There were no trend differences between food or beverage categorisations and Transit Score (see Table 22 below).

Table 22. Mean Portion Size of Food and Beverage Advertisements by Transit Score®

		Mean (SD)		
Food or beverage categorisation	Transit Score	Portion after manipulation	Portion after count	Portion total
Beverage core	1	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	2	13.0 (3.0)	7.0 (5.6)	20.2 (19.0)
	3	12.8 (0.4)	5.6 (0.0)	12.8 (0.4)
	4	9.4 (0.0)	4.2 (0.0)	9.4 (0.0)
	5	10.4 (0.1)	4.2 (0.0)	10.4 (0.1)
Beverage noncore	1	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	2	55.3 (141.6)	19.8 (39.7)	58.3 (140.5)
	3	4.5 (4.0)	1.6 (1.4)	5.8 (5.4)
	4	9.8 (6.2)	1.5 (0.3)	8.7 (4.2)
	5	5.1 (55.3)	1.5 (0.0)	2.6 (0.0)
Food core	1	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	2	40.6 (34.4)	9.1 (7.5)	32.0 (24.8)
	3	30.4 (52.5)	8.9 (19.1)	26.3 (41.7)
	4	33.6 (34.6)	6.5 (4.6)	24.5 (21.8)
	5	51.6 (35.8)	8.7 (5.6)	34.5 (23.0)
Food noncore	1	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	2	28.2 (55.5)	5.2 (8.4)	28.1 (48.2)
	3	44.4 (66.2)	7.3 (9.8)	39.1 (55.3)
	4	4.4 (5.4)	0.9 (0.3)	4.9 (5.1)
	5	8.6 (2.2)	0.9 (0.2)	8.6 (2.2)
Total	1	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	2	35.3 (64.1)	8.5 (15.7)	32.8 (59.4)
	3	31.8 (55.4)	7.2 (14.3)	28.1 (45.5)
	4	18.9 (26.3)	3.8 (4.0)	15.2 (17.2)
	5	36.6 (35.4)	6.4 (5.7)	25.3 (22.4)

The greatest proportion of advertising across all categories was found in schools with a medium Transit Score® (3). Schools with the lowest Transit Score® (1) had the least advertisements. In terms of Transit Score®, there were no trend differences between core and non-core advertisements (Table 23).

Table 23. Proportion of Advertisements by Transit Score®

		N (%)				
		Beverage core	Beverage noncore	Food core	Food noncore	Total
Transit Score	N/A*	2 (12.5)	1 (3.1)	4 (3.4)	2 (2.0)	9 (3.4)
	1	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	2	5 (31.3)	11 (34.4)	35 (30.2)	41 (40.6)	92 (34.7)
	3	5 (31.3)	16 (50.0)	56 (48.3)	49 (48.5)	126 (47.5)
	4	2 (12.5)	3 (9.4)	8 (6.9)	5 (5.0)	18 (6.8)
	5	2 (12.5)	1 (3.1)	13 (11.2)	4 (4.0)	20 (7.5)
	Total	16 (100.0)	32 (100.0)	116 (100.0)	101 (100.0)	265 (100.0)

** Schools without a Transit Score® were coded 'N/A'*

The Independent-Samples Kruskal-Wallis Test was used to examine the relationship between the variables of portion size after adjusting for the manipulation to image size and school decile (tertiles), distance from school boundary (quintiles), Walk Score® (quintiles) and Transit Score® (quintiles). Distance from school boundary was statistically significant (p=<0.001). School decile was not statistically significant (p=0.446); the Walk Score® was not statistically significant (p=0.275); and, Transit Score® was not statistically significant (p=0.345).

Using the same test, the relationship between the variables of portion size after adjusting for the item count and school decile (tertiles), distance from school boundary (quintiles), Walk Score® (quintiles) and Transit Score (quintiles) was examined. Distance from the school boundary was statistically significant (p=0.007). School decile was not statistically significant (p=0.990); the Walk Score® was not statistically significant (p=0.426), and Transit Score® was not statistically significant (p=0.764).

Finally, the Independent-Samples Kruskal-Wallis Test was used to examine the relationship between the variables of the overall portion size in the advertisement, and school decile (tertiles), distance from school boundary (quintiles), Walk Score® (quintiles) and Transit Score® (quintiles). Distance from the school boundary was statistically significant (p=0.004).

School decile was not statistically significant ($p=0.708$); the Walk Score® was not statistically significant ($p=0.321$); and Transit Score® was not statistically significant ($p=0.446$).

The descriptive statistics and Independent-Samples Kruskal-Wallis Test were used to test for statistical significance. Mixed model regression analysis will occur after the submission of this thesis when I and my supervisors develop the findings presented above into a manuscript for publication in a peer review journal.

6. Discussion and Conclusions

In this chapter, I will bring the key findings from Chapters 2, 3, 4 and 5 together. The extent of food advertising in NZ children's neighbourhoods is well-documented (Brien et al., 2022; Egli et al., 2018; Huang et al., 2020; Maher et al., 2005; Signal et al., 2017). However, there is an apparent paucity of research illustrating the nature of portion sizes in advertisements and their compliance to national and local advertising policies. Aided by the development of a novel PSEA tool that is designed to measure depicted portion sizes in advertising, this thesis is the first step toward understanding the portion sizes of food advertising in children's neighbourhood food environments. The key findings of this thesis are 1) the majority of core and non-core advertisements all showed an enlargement in depicted image size, 2) the mean number of recommended portions sizes in the total portion size of non-core food and beverages were double that of core, 3) while a greater proportion of advertisements were found near low decile schools, the number of recommended portions sizes in the depicted portion size were greater in advertisements near high decile schools, 4) the greatest proportion of advertisements across categories were found >300m from school boundaries, while the number of portions above recommendations for non-core food advertisements was greater at more proximate distances and 5) there were no significant trends regarding Walk Score® or Transit Score® across the advertisement categories. The key strengths and limitations of the study are identified. Finally, future recommendations for policy and research are presented before the thesis is concluded.

6.1 PSEA development and evaluation of advertised portion sizes on bus stops near schools

PEAR Tool development

There is currently limited literature on the relationship between portion sizes and food advertising surrounding schools. The aim of this study was to develop an understanding of portion sizes in food and beverage advertising to children in Auckland, NZ. The need to create a PSEA suitable for use in images of advertisements was identified in response to no literature illustrating the compliance of portion sizes in advertisements targeted at children to local and national advertising standards and that the current PSEAs were not suitable to measure this, for reasons outlined in section 3.2. Unlike previous PSEAs, which focused on developing reference portion sizes from national data on usual intake (Foster et al., 2014, 2017; Nelson et al., 1994), this research sought to develop a tool based on the recommended portion sizes for core and non-core food and beverage advertising. Thus, building upon current evidence on individuals eating behaviours to explore the influence of factors in the surrounding food environment, such as advertised portion sizes. Application of the PEAR Tool to a dataset with bus stops in every advertisement image allowed for an easily identifiable object with known dimensions to serve as a comparable scale within the image. Several previous PSEAs utilised a shape library to overcome the lack of standardised fiducial markers in captured images (Chae et al., 2011; Lee et al., 2012; Woo et al., 2010). However, it was decided that using two points with a known distance was adequate for estimating the scale of food or beverage items in images of advertisements. Thus, the PEAR Tool is innovative as it can also be applied to any advertisement image where a suitable fiducial marker of known dimensions can be identified and sized from the same image.

The lack of specialised software and pre-set programming of the PEAR Tool offers high potential for applying the PEAR Tool in future research evaluating portion sizes in food advertising by anyone with MS Excel basic skills. As such opening up opportunities for those in local public health organisations to gather and present quantifiable evidence on how advertised portion sizes compare to national recommendations when advocating for changes to improve the food environment of the community. A key feature that sets the PEAR Tool apart from previous PSEAs, is the use of specific branded food and beverage items. Printed food photography, food models and food drawings were designed with a limited range of broad foods items (Bradley et al., 2021; Foster et al., 2017; Nelson et al., 1994; Steyn et al., 2006; Yuhas et al., 1989). Incorporating precise values of items depicted in advertisements strengthens the PEAR Tool's ability to hold the industry accountable when identifying and claiming breaches of specific advertisements in accordance with the current advertising code, such as the portion sizes advertised.

This is the first tool to evaluate portion sizes in outdoor food and beverage advertisements. The development of the PEAR Tool has allowed an inexpensive evaluation of portion sizes beyond population dietary intakes, to include the nature of advertised portion sizes in the food environment of children's neighbourhoods. More specifically, how these portion sizes compare to national dietary recommendations for children. The tool has also provided a method to measure marketing techniques, such as the degree of augmentation, by estimating the scale of products in relation to their actual size, which has previously not been quantified. Overcoming the need for images to be captured with standardised features such as a uniform fiducial marker, allows the tool to perform retrospective analysis from a single image. Additionally, this is the first PSEA that has been developed for use in a NZ population. Another feature of the PEAR Tool that advances innovation in PSEAs is the dynamic ability for application in a range of child age groups as well as to an adult population. The initial application of the PEAR Tool to advertising on bus stops near schools showed the tool is able to be used to generate previously unknown information about portion size advertising to Auckland children in their neighbourhoods. This adds to our understanding of children's food environment, particularly our understanding of unhealthy food advertising. Therefore, the PEAR Tool should continue to be utilised in research regarding advertising and the food environment going forward.

Scale of advertisements

In this study, the scale of food and beverages was exaggerated in all but one advertisement. This scale may have been underestimated as the largest unit size for each item was selected when there were no distinguishable features among the available units to choose from to demonstrate that even when the largest unit size is selected, the degree of distortion is still high. Due to the paucity of research in this space, no supporting literature was found in relation to the degree of manipulation to image size of any advertised products across various mediums. Thus, this is the first study to quantify the degree of distortion children are exposed to in food advertising. Individuals are likely to regard an item as one portion, even when the size of a food item increases (Geier et al., 2006). Therefore, marketing messages whereby appropriate amounts of food products are larger than reality are passively accepted into an individual's beliefs (Gunter, 2016). Furthermore, the commercial exploitation of advertising encourages children to be consumers and impacts extend beyond physical health to include holistic health, behaviours, knowledge, and identities of children (Powell, 2020). Given only 50.2% of advertisements were for non-core advertising, these findings support calls for bans on all forms of advertising to children, not just unhealthy foods and beverages.

Portion sizes in advertisements

This study extends beyond where and what types of advertising are in children's neighbourhoods to provide quantifiable evidence on how portion sizes in advertisements compare with national dietary recommendations. Our findings demonstrated overall portion sizes were 28.4 (SD=47.8) times the recommendations. The results from this study may be subject to under and over-estimation when comparing distinct food and beverage items. For example, comparisons were made between items such as a jar of mayonnaise, where the recommendation is close to a teaspoon, to items that come in a predetermined amount, such as a burger or an orange. These results are much larger than the findings from a study conducted in America, where the average depicted serving size on cereal packaging was 65.26% greater than the average suggested serving size on the nutrition panel (Tal et al., 2017). This discrepancy may be accounted for by the depiction of a single food item and the product packaging as the primary advertising medium. The exaggeration of portion sizes in advertisements shows similarities to other variables in children's food environments, such as the 4.8% increase in serving size of food products in NZ restaurants between 2012 and 2016 (Eyles et al., 2018).

The ASA Children and Young People's Advertising Code states that advertised portion sizes should not exceed those deemed appropriate for the age of the person depicted by the national nutrition guidelines (Advertising Standards Authority, 2017). Non-compliance with the current advertising codes and ineffective reviewing of advertisements by the ASA may be in part due to the lack of quantifiable portion size recommendations for occasional food and beverages in the MoH Nutrition Guidelines for children and young people (2015). Portion sizes in this study for tomato sauce, mayonnaise, soft drinks, energy drinks and sports drinks were evaluated using guidelines for adults (National District Health Board Food and Drink Environments Network, 2019; The New Zealand Institute for Plant and Food Research & Ministry of Health, 2022). Thus, there is no ambiguity that the advertised portions of advertisements relative to the recommendations for adults would exceed the recommended portions for a child. Exposure to enlarged images on food packaging has been shown to have a positive association with children's purchasing and consumption of the advertised product (Huang et al., 2022; McGale et al., 2020; Neyens et al., 2015). Furthermore, the portion size effect can be counteracted when age-appropriate portion sizes for children are encouraged (Dixon et al., 2007; Hollands et al., 2015; Robinson & Kersbergen, 2018; Steenhuis & Vermeer, 2009; Vermeer et al., 2014).

School decile

As shown in Table 17 (see chapter 5.2, page 86), this study found a greater proportion of advertisements near schools of a low decile. Recent research investigating advertising on convenience stores in Auckland has demonstrated that twice as many advertisements were found on stores around low decile schools ($n = 1170$, 51.8%) compared to stores around medium ($n = 561$, 24.8%) or high decile schools ($n = 529$, 23.4%) (Brien et al., 2022). Similarly, the highest proportion of unhealthy food advertisements of at least A4 size was around schools with the highest deprivation (50.7% vs. 37.4%, $p < 0.001$) (Vandevijvere et al., 2018). These findings are further supported by global literature showing that people from more deprived backgrounds are disproportionately exposed to greater food advertising (Fagerberg et al., 2019; Settle et al., 2014; Thomas et al., 2019). However, other studies have found differences in the density of food and beverage advertising marketed to children by neighbourhood deprivation was not supported by statistical analysis (P>0.05) (Egli et al., 2018). While a pilot study conducted in the Wellington region found that the proportion of food advertisements was significantly greater in high SES neighbourhoods (p=0.01), advertisements in low SES neighbourhoods were significantly closer to the secondary schools (p<0.0001) (Maher et al., 2005). While there is some evidence to support a link between socio-economic deprivation and saturation in exposure to unhealthy food advertising further research is needed to confirm and study this relationship.

Given the implications of such a relationship on healthy equity, this study has extended beyond previous research to evaluate whether an association exists between socio-economic deprivation and the portions sizes depicted within food advertisements. The lack of association (p=0.708) observed between portion size and school decile may suggest that advertisement companies do not alter the content of advertisements based on school decile, but will instead attempt to saturate more deprived areas with advertisements for non-core food and beverages.

Distance from school boundary

There was a clear association between distance from the school boundary and frequency of advertisements, as seen in Table 19 (see chapter 5.2, page 88). This finding is consistent with previous work by Brien et al. (2022), who found the greater distance away from the school had a greater number of advertisements ($p < 0.021$). Contrary, advertisements surrounding Australian primary schools for non-core food products were twice as likely within 250m than 250-500m boundary of primary schools (Kelly et al., 2008). Similarly, Within a 500 m radius of primary and secondary schools in Perth, a significantly higher proportion of unhealthy food advertisements were found within a 250m boundary (Trapp et al., 2021). Additionally, a scoping review indicated that while it was unlikely for unhealthy products to be advertised within a 100m–800m boundary of schools there was an increased likelihood of ‘other’ products being advertised in the spaces around schools, particularly gambling (Finlay et al., 2022). The implementation of policies such as the Auckland Signs Bylaw may be why we see a greater presence of advertisements within the outer boundaries. However, it is important to remember that the bylaw is self-regulated, and the original ‘Bus Stops Near Schools Advertising Junk Food and Sugary Drinks’ study documented breaches in their enforcement to not permit advertisements for HFSS products within 300 metres of schools (Huang et al., 2020).

A new finding this study contributes to our knowledge of advertisements surrounding schools is that portion sizes, compared to recommendations, are greatest at a medium distance (301-400m) from the school boundary. Advertisers may be adapting the content of advertisements to incorporate more prominent products as near as possible to the target audience within the constraints of current advertising policies. Thus, it is not just the placement of advertisements but the nature of advertisements that must be considered in future policymaking. As schools are a central element of a child's neighbourhood building, a comprehensive understanding of portion sizes in relation to school measures, such as distance to school boundary, is important as these factors can be easily controlled by the Auckland Council by way of informing and influencing policy changes. The wording of ‘public safety’ in the Auckland Signs Bylaw and ‘supporting healthy lifestyle choices’ in the Auckland Transport Advertising Policy can be adapted to utilise these tools as a method to improve the food environments in children’s neighbourhoods by way of the advertised messages surrounding schools. Future research needs to be undertaken to confirm the relationship between advertised portion sizes and the distance from school boundary.

Walk Score® and Transit Score®

There was no significant association between portion size and Walk Score® or Transit Score®. Similarly, in the parent study, there were no significant trends regarding the proportion of core and non-core advertisements and Walk Score® ($p=0.403$) or Transit Score® ($p=0.534$) (Huang et al., 2020). This finding potentially indicates that not enough advertisements were included in the study to have sufficient statistical power to detect meaningful effects. Another NZ study by Brien et al. (2022) found a relationship between the target audience and Walk Score® ($p < 0.001$). Whether the influence of Walk Score® and Transit Score® extends beyond the positioning of advertisements, in regards to frequency and target audience, to include the content of advertisements is something that should be explored further in future research.

Discoveries

This study has provided previously unknown information about the nature of portion sizes in advertising. Previously, trends in portion sizes had only been examined in restaurant serving sizes. Quantifying the portion sizes in advertisements has allowed a comparison to be made against national dietary recommendations and identified breaches in current advertising policies. In particular, the environment is promoting portion sizes larger than those set out in dietary recommendations. This allows us to build upon current knowledge describing what types and where advertisements are found in children's neighbourhoods and begin to understand the nature of the content to which children are exposed. It shows insights into how advertisers may adapt the content of advertisements on the border of policy boundaries to retain exposure to the target market whilst adhering to current advertising policies. This research is important because misunderstanding the nature of advertising exposure by researchers could lead to ineffective policymaking. Demonstrating a breach in the compliance of NZ children's exposure to advertisements can be used to support policymakers to ensure depicted portion sizes better match the recommended portion sizes set out in national guidelines to positively influence nutrition behaviours and health in children.

6.2 Implications

6.2.1 Implications for policy

An effort has been made to improve the food environment within schools by regulating foods sold through canteen facilities, advertising on school grounds and contents of vending machines (Carter & Swinburn, 2004; Ministry of Health, 2020b). However, the surrounding nutrition environment has been left susceptible to ambiguous advertising policies that lack proper enforcement. This study is the first to analyse the nature of portion sizes in advertising near schools in NZ and has highlighted opportunities to strengthen policies to promote healthy food environments on travel routes by children travelling to and from school. The Advertising code states, "the quantity of the food in the advertisement should not exceed portion sizes that would be appropriate for consumption on one occasion by a person, or persons, of the age depicted (Advertising Standards Authority, 2017, pg 5)." However, many of the advertisements around schools promoted large portion sizes, as identified from my research. The screenshot function of GSV can provide evidentiary support to public health experts when advocating for policy changes in their neighbourhoods. While it can be argued that several of the food and beverage items were mainly targeted to adults (such as coffee and energy drinks) and are not frequently consumed by children, their presence within a 500m walkable distance in schools should be considered as marketing to children as exposure in areas frequented by children encourages consumption (Mackay et al., 2018). It is important to advocate for children, given their susceptibility to not understanding the pervasive intentions of advertisements (Sadeghirad et al., 2016; Signal et al., 2019; Story & French, 2004; Wilcox et al., 2004). While the ASA (2017) identifies schools as a place where children frequent and thus considered targeted to children, the findings from this thesis suggest the application of these guidelines be extended to include travel routes to and from school.

Despite the pilot nature of this study, it has provided some initial information about the relatively 'exaggerated' content of food advertising in school neighbourhoods. As evidenced by the use of several nutrition guidelines, as detailed in section 5.1 (see page 74), there is a need to update existing self-regulatory policies criteria on appropriate portion sizes for children in advertising policies to ensure policy definitions are transparent. Policies can be further strengthened by integrating clear and convincing consequences for policy breaches beyond removing inappropriate advertisements. South Korea has implemented a minimum $10,000 fine for displaying broadcast, radio or internet advertisements for unhealthy food and beverages (Kim et al., 2013). A lack of urgency to make policy changes may be related to resistance from the food industry. However, this ultimately compromises the best interests of children’s health.

According to a 2006 NZ enquiry into national policies, “government regulation would only be considered should industry self-regulation prove to be ineffective” (Jenkin et al., 2012). Current reporting of advertisements to the ASA is conducted through an online-based complaints system, which requires individuals to be aware of existing advertising criteria and proactive in protecting children from inappropriate content (Advertising Standards Authority, 2017). Combined with a self-regulated industry, this complaints system can inadvertently lessen the policy's effectiveness. Changing the policy environment to support the reduction of exposure and exaggeration of portion sizes in food advertising to children is warranted to hold the advertising industry accountable for the conflicts of interest identified in a report of industry self-regulatory reports on policy compliance (Sing et al., 2020). Thus, it may be worthwhile for independent research on the advertising industry in the food environment to be conducted for more effective monitoring.

Previous research conducted overseas has demonstrated that self-regulated advertising has done little to reduce children's exposure to food and beverage advertisements (Harris, Pomeranz, et al., 2009; Kent et al., 2011; Lumley et al., 2012). Government regulation has been deemed by the WHO to have the highest potential to decrease this exposure of food advertising to children (World Health Organization, 2012). Legal resolutions have been passed in several countries including Chile, Brazil and the Netherlands to restrict food advertising targeted towards children (Carpentier et al., 2020; Hoogenraad & Duivenvoorde, 2015; Soares, 2014). Removing unhealthy food and drink advertising targeted to children in public spaces provides an opportunity to use these spaces and occupy these spaces with more enriching elements. In the form of bus shelters, advertising could be replaced by artwork on public transport structures. If and when new policy is adopted or enforcement of policies is strengthened, the findings of this research can serve as a baseline for future research. Local governments can exert their existing power to implement stronger restrictions on government-owned transport and street furniture. For example, Auckland Council can update and deliver a clearer definition of public safety in its bylaw to include a greater focus on the public health implications for items depicted in food and beverage advertising. Furthermore, it is within their existing power to prevent food and beverage advertisement placements on government assets such as bus stops and buses.

6.2.2 Implications for research

The PEAR Tool has been shown to offer a feasible approach to evaluating the portion sizes in advertising captured using GSV, compared to national recommendations for children. After submitting this thesis, I will initiate discussions with my supervisor and a biostatistician to reanalyse this data using multivariable regression models. It is then planned that this study will be submitted for publication (Porter, J., Roy, R., van der Werf, B., Egli, V (in preparation) The PEAR Tool: Evaluating portion sizes of food and beverages in food advertising in children's neighbourhoods using GSV. Public Health Nutrition [IF 3.182]). The development process of the PEAR Tool design has created a PSEA tool that has the potential to be easily modified to facilitate research in other settings, locations and population age groups. This study was conducted in Auckland, the largest and most densely populated region in the country. Thus, the results may not be generalisable to other regions across NZ. There are future research opportunities to explore how portion sizes in advertising may differ across regions in NZ. Exploring the nature of advertising in more locations, such as parks and playgrounds, may aid in the overall aim to create healthier environments for children to live, learn and play. There is also a future research opportunity to apply the PEAR Tool to alternative advertising mediums such as billboards, posters or in-store adverts. Thus, it should be possible to build upon previous research data assessing the extent of advertising around primary and secondary schools conducted by Brien et al. (2022), Egli et al. (2018) and Signal et al. (2017). Exploring the nature of advertising across all mediums would be laborious; however, it would enhance our understanding of the role of advertising in the food environment.

The current study has described the nature of portion sizes in advertisements around schools as largely being exaggerated in size. However, we did not examine the direct effect of said advertising on diet. As shown in previous literature, advertising has the potential to encourage and normalise consumption (Pettigrew et al., 2013; Sadeghirad et al., 2016; Smith et al., 2019).

Thus, research concerning the direct effect of this environment on children's health and nutrition behaviours is imperative moving forward to fully understand the effects of advertising on individual and population health. Literature linking the consumption of discretionary foods and adverse health outcomes is well defined (Juul et al., 2021; Marmot & Wilkinson, 2005). When combined with literature linking portion distortion on food packaging to consumption this outcome suggests that exaggerated portion sizes in advertising may be conducive to developing nutrition-related diseases (McGale et al., 2020; Neyens et al., 2015; Tal et al., 2017). Research demonstrating a link between advertising, portion sizes and diet quality would aid in our understanding of the issue and play a significant role in informing effective policy to reduce children's exposure to unhealthy food advertising.

6.3 Strengths and limitations

The novelty of this study is the primary strength of this research; as this is the first step in evaluating the portion sizes of outdoor advertisements for food and beverages. The nature of a cross-sectional observational study design and ease of data collection (e.g. no participants) make the methods of this study highly replicable.

When evaluating the nature of advertising in the food environment with an analysis of neighbourhood characteristics, GSV has proved to be a useful time and cost-effective tool (Bader et al., 2017; Brien et al., 2022; Egli et al., 2018; Huang et al., 2020; Rzotkiewicz et al., 2018). In comparison to field audits, GSV offers reduced travel to collect data in large geographically dispersed samples, researcher safety and achieving of screenshots for review at later points in time (Rundle et al., 2011). This offers a logistically convenient method to enable multi-city and international comparisons. This would prove valuable to support the current study's findings and build upon the limited evidence base. A minimal contact approach is favourable during times of 'social distancing' due to the COVID-19 pandemic. Lastly, utilising freely available data without the need for costly software or equipment, such as wearable cameras, is a key strength of using GSV in future research.

Several limitations were present in this study and should be taken into consideration when interpreting the findings. As a pilot study, conclusions on the effectiveness of the PEAR Tool for evaluating portion sizes in advertising cannot be drawn. However, it is hoped that the data provided has offered a feasible approach to future research on larger samples and more diverse advertising mediums. The primary limitation of a cross-sectional study design is the ‘snapshot’ of one point in time. GSV images in our study date back to 2012, with less recent images generally found in more rural areas. Since these images were captured, one advertising company has replaced all advertising on bus shelters, resulting in the same dimensions being applied to all advertising images, despite identifying five variations in shelters. Furthermore, it is likely that the products advertised are subject to temporal patterns and vary seasonally. For example, adverts over easter could be expected to advertise more confectionary. Thus, there would likely be variations in finding if the study were to be repeated. This poses a barrier to evaluating change brought about by policy, especially in areas where GSV data are infrequently updated.

The researcher's involvement in both the development and evaluation of the PEAR Tool could be seen as having a possibility for bias. An unintentional influence for the intervention to perform well may have arisen from the ‘personal investment’ into the PEAR Tool design. Thus, it would have been favourable for separate researchers to conduct each sub-study of this thesis. Further, to assess the accuracy of arrow placement, item size estimation should be performed independently by another rater, and inter-rater reliability tested.

The exposure of children to food advertisements is likely to be underestimated following the exclusion of several products which have been discontinued or a lack of appropriate nutritional guidelines that were able to be identified to perform portion size comparisons. A challenge associated with the PEAR Tool is maintaining up-to-date fiducial marker and portion size databases, especially given the frequent introduction of new and reformulation of existing products. Thus, the PEAR Tool requires ongoing input.

Limitations are also associated with the GSV imagery. In particular, the image quality, size and presence of buses or people partially blocking advertisements (Rzotkiewicz et al., 2018). Thus, several images were excluded from the analysis. It is anticipated that the accuracy of the data derived from GSV will improve as technology advances and more image quality capabilities are added to the service. As outlined in the main study by Huang et al. (2020) the number of advertisements captured were not absolute given not all school entrances are mapped on Google, not all roads are captured in street view and some school boundaries experienced an overlap. In this study, bus stop advertisements were the only advertising medium included in the analysis, which is likely to underrepresent the frequency and nature of advertising children are actually exposed to. Due to time constraints, only advertisements on bus stops were included in this research. To deliver a comprehensive assessment of the entire food environment, it would be useful for future studies to assess portion sizes in other advertising mediums, such as billboards, posters, and on transport vehicles. A final limitation in the current study is a lack of participants. How many food and beverage advertisements were actually viewed by children cannot be concluded, as no exposure data was accessible using GSV images. Thus, there is potential for future research to examine children's actual exposure by comparing GSV images with data captured using wearable cameras.

6.4 Conclusions

The purpose of this thesis is to gain insight into the nature of advertised portion sizes of food and beverages in children's neighbourhoods compared to reference portion sizes set by national standards. It offers a comprehensive evaluation of advertisements on bus shelters near schools in Auckland to contribute to the evidence base on food environments surrounding schools in NZ. The literature was reviewed to understand the common characteristics of available PSEA tools. The PEAR Tool was developed to calculate the scale of advertised food and beverages using coded formulas and functions. The PEAR Tool is the first of its kind to estimate portion sizes in advertising. Thus, it is a unique tool, especially considering the lack of data on how advertised portion sizes align with children's dietary recommendations. The usability of the PEAR Tool was tested on advertisements on bus shelters within 500m of Auckland schools. The findings from this cross-sectional observational study demonstrate through descriptive analyses that food and beverage items are enlarged, and portions exceed those set out for children in national dietary guidelines. Other variables of interest, such as advertisements by school decile and distance from school boundary, were analysed. The findings of the proportion of advertisements in relation to these variables were consistent with other national studies. New insights presented in this research into the depicted portion sizes did not follow the same trends. The need for stricter enforcement and revised definitions in national and local advertising policies for children was highlighted. It is evident that further research is needed to support the findings of this thesis and demonstrate links between portion sizes advertised in children's neighbourhoods and health outcomes, including the direct effect on children's consumption of HFSS foods. Such research could then be used to strengthen existing and inform future policies to improve the food environments surrounding schools across NZ.

Appendices

Appendix 1. Portion Size Database

Item	**Reference Portion Size**	**Population designed for**		**Reference Guidelines**	**Actual Height (cm)**	**Actual Width (cm)**	**Actual Serving (g or ml)**	**Actual Portions in Serving**					
		Age	**Country**					**Pre-schooler (2-5 year)**	**Children (2-12 year)**	**Young people (13-18 year)**	**Primary students (5-11 year)**	**Secondary students (11-18 year)**	**Adults (18-65 year)**
Beans	135g (3/4 cup) *Pre-schoolers and children 1-2 serve* *Young people 2 serve*	Children	New Zealand	NZ Food & Nutrition Guidelines									
Beans, canned					11.00	7.50	420g	15.56	15.56	7.78			
Biscuit	<40g	Children	New Zealand	Healthy Auckland Together									
Biscuit, chocolate					5.00	5.00	17g		0.43				
Bread	26g (1 slice) *Pre-schoolers 4 serve* *Children 5 serve* *Young people 6 serve*	Children	New Zealand	NZ Food & Nutrition Guidelines									
Bread, Vogels loaf					34.00	11.00	750g	36.06	28.85	24.04			
Broccoli	80g (1/2 cup) *Pre-schoolers 2 serve* *Children and young people 3 serve*	Children	New Zealand	NZ Food & Nutrition Guidelines									
Broccoli, fresh					16.00	18.00	350g	10.94	7.29	7.29			
Burger	250g primary students 350g secondary students	Children	Australia	NSW Healthy School Canteen									
Burger, Hamburger						10.00	172g				0.69	0.49	

Item	**Reference Portion Size**	**Population designed for**	**Reference Guidelines**	**Actual Height (cm)**	**Actual Width (cm)**	**Actual Serving (g or ml)**	**Actual Portions in Serving**						
		Age	**Country**					**Pre-schooler (2-5 year)**	**Children (2-12 year)**	**Young people (13-18 year)**	**Primary students (5-11 year)**	**Secondary students (11-18 year)**	**Adults (18-65 year)**
Burger, BK Whopper Jr					5.00	9.00	134g				0.54	0.38	
Burger, McDonalds Big Mac					7.00	10.00	228g				0.91	0.65	
Burger, McDonalds Quarter pounder					5.00	10.00	204g				0.82	0.58	
Burger, McDonalds Filet o fish					4.50	10.00	136g				0.54	0.39	
Burger, McDonalds McChicken					4.50	10.00	182g				0.73	0.52	
Burger, McDonalds Texan BBQ					5.00	11.50	359g				1.44	1.03	
Cereal	30g (1 cup) *Pre-schoolers 4 serve* *Children 5 serve* *Young people 6 serve*	Children	New Zealand	NZ Food & Nutrition Guidelines									
Cereal, Nutrigrain					32.00	23.50	435g	18.13	14.50	12.08			
Cereal, Weet-bix	34g (2 biscuits) Pre-schoolers 4 serve Children 5 serve Young people 6 serve	Children	New Zealand	NZ Food & Nutrition Guidelines									
Cereal, Weet-bix small					9.00	21.50	440g	16.18	12.00	10.78			
Cereal, Weet-bix regular					17.00	21.50	750g	27.57	24.00	18.38			
Cereal, Weet-bix biscuit					4.00	8.00	17g	0.63	0.50	0.42			

Item	**Reference Portion Size**	**Population designed for**	**Reference Guidelines**	**Actual Height (cm)**	**Actual Width (cm)**	**Actual Serving (g or ml)**	**Actual Portions in Serving**						
		Age	**Country**					**Pre-schooler (2-5 year)**	**Children (2-12 year)**	**Young people (13-18 year)**	**Primary students (5-11 year)**	**Secondary students (11-18 year)**	**Adults (18-65 year)**
Chicken	<120g	Children		NZ Healthy Guidance for Schools									
KFC, secret recipe chicken					12.00	7.00	113.5g		0.95				
KFC, popcorn chicken single					3.50	3.00	6.4g		0.05				
KFC, popcorn chicken regular					10.00	7.00	132.6g		1.11				
KFC, chicken nugget single					6.00	4.00	8.7g		0.07				
KFC, popcorn chicken snack box					8.00	13.00	62.1g		0.52				
KFC, wicked wings snack box					8.00	13.00	104.2g		0.87				
KFC, chicken nuggets snack box					8.00	13.00	71.6g		0.60				
Chickpeas	135g (3/4 cup) *Pre-schoolers and children 1-2 serve Young people 2 serve*	Children	New Zealand	NZ Food & Nutrition Guidelines									
Chickpeas, organic canned					11.00	7.50	425g	15.74	15.74	7.87			
Chocolate	<50g (1 small bar)	Children	New Zealand	Healthy Auckland Together									
Chocolate, Kit Kat large					23.50	9.50	170g		3.40				

Item	Reference Portion Size	Population designed for	Reference Guidelines	Actual Height (cm)	Actual Width (cm)	Actual Serving (g or ml)	Actual Portions in Serving						
		Age	Country					Pre-schooler (2-5 year)	Children (2-12 year)	Young people (13-18 year)	Primary students (5-11 year)	Secondary students (11-18 year)	Adults (18-65 year)
Chocolate, Moro					3.50	15.00	60g		1.20				
Chocolate, Crunchie					3.50	20.00	50g		1.00				
Chocolate, Kit Kat small					6.50	13.00	45g		0.90				
Chocolate, Twirl					3.50	13.50	39g		0.78				
Chocolate, Favourites					25.00	12.00	570g		11.40				
Chocolate, Favourites individual					9.00	3.50	12.5g		0.31				
Coffee	500ml (2 cups) if >13 years	Children	New Zealand	NZ Food & Nutrition Guidelines									
Coffee, Barista Bros iced					18.50	7.00	500ml			1.00			
Coffee, Wild bean café					12.70	9.00	460ml			0.92			
Coffee, McCafe small					9.30	8.00	250ml			0.50			
Coffee, McCafe regular					11.00	8.50	350ml			0.70			
Coffee, McCafe large					13.00	8.50	460ml			0.92			
Corn	80g (1/2 cup) *Pre-schoolers 2 serve* *Children and young people 3 serve*	Children	New Zealand	NZ Food & Nutrition Guidelines									
Corn, canned					11.00	7.50	420g	13.13	8.75	8.75			
Corn, cob					17.00	5.50	80g	2.50	1.67	1.67			
Cream	20g (1tsp), whipped	Children	Australia	Healthier. Happier (QLD)									

Item	**Reference Portion Size**	**Population designed for**	**Reference Guidelines**	**Actual Height (cm)**	**Actual Width (cm)**	**Actual Serving (g or ml)**	**Actual Portions in Serving**						
		Age	**Country**					**Pre-schooler (2-5 year)**	**Children (2-12 year)**	**Young people (13-18 year)**	**Primary students (5-11 year)**	**Secondary students (11-18 year)**	**Adults (18-65 year)**
Cream, 2L					25.50	13.50	2000ml		100.00				
Eggs	50g (1 egg) Pre-schoolers and children 1-2 serve Young people 2 serve	Children	New Zealand	NZ Food & Nutrition Guidelines									
Egg					6.00	4.00	50g	0.40	0.40	0.40			
Energy drink	250ml	Adult	New Zealand	NZ Food Composition Tables									
Energy drink, 250ml can					13.50	5.00	250ml						1.00
Energy drink, V bottle					22.00	6.50	330ml						1.32
Fizzy drink	250ml	Adult	New Zealand	NZ Food Composition Tables									
Fizzy, 250ml can					13.50	5.00	250ml						1.00
Fizzy, takeaway regular					13.00	9.00	300ml						1.20
Fizzy, takeaway small					15.00	8.00	237ml						0.95
Fizzy, Coke bottle					24.00	7.00	600ml						2.40
Fizzy, wine glass					8.00	8.50	590ml						2.36
Flavoured milk	<360ml	Children	New Zealand	Healthy Auckland Together									
Up & Go, 250ml					10.00	6.50	250ml		0.69				
Smoothie, glass					13.50	8.50	250ml		0.69				

Item	Reference Portion Size	Population designed for	Reference Guidelines	Actual Height (cm)	Actual Width (cm)	Actual Serving (g or ml)	Actual Portions in Serving						
		Age	Country					Pre-schooler (2-5 year)	Children (2-12 year)	Young people (13-18 year)	Primary students (5-11 year)	Secondary students (11-18 year)	Adults (18-65 year)
Hot chips	<300g	Children	New Zealand	Healthy Auckland Together									
Hot chips, cup					9.50	9.00	280g		0.93				
McDonalds, hot chips single					9.00	0.50	1.5g		0.01				
McDonalds, hot chips med					11.00	10.00	104g		0.35				
McDonalds, hot chips small					11.50	10.00	76g		0.25				
KFC, hot chip single					12.00	1.50	1.5g		0.01				
KFC, regular chips					8.00	13.00	123.5g		0.41				
Hot dog													
Sausage	60g	Children	Australia	NSW Healthy School Canteen									
Bread	26g (1 slice) Pre-schoolers 4 serve Children 5 serve Young people 6 serve	Children	New Zealand	NZ Food & Nutrition Guidelines									
Hot dog, sausage					13.50		106g	1.31	1.23	1.16			
Ice cream	<120ml	Children	New Zealand	Healthy Auckland Together									
Ice cream, 4 pack					14.00	19.50	420ml		3.50				
Ice cream, single					16.00	5.50	105ml		0.88				
Ice cream, small tub					10.00	10.00	500ml		4.16				

Item	**Reference Portion Size**	**Population designed for**	**Reference Guidelines**	**Actual Height (cm)**	**Actual Width (cm)**	**Actual Serving (g or ml)**	**Actual Portions in Serving**						
		Age	**Country**					**Pre-schooler (2-5 year)**	**Children (2-12 year)**	**Young people (13-18 year)**	**Primary students (5-11 year)**	**Secondary students (11-18 year)**	**Adults (18-65 year)**
Instant noodles	75g (1 packet, dry)	Children	Australia	NSW Healthy School Canteen									
Instant noodle, cup					10.50	9.50	70g		0.93				
Juice	<360ml fresh pressed and reduced-sugar	Children	New Zealand	Healthy Auckland Together									
Juice, 1L					24.00	9.00	1000ml		2.78				
Juice, 2L					30.00	11.50	2000ml		5.56				
Juice, glass					13.50	8.50	315ml		0.88				
Mayonnaise	17g (<1 Tbsp)	Adult	New Zealand	NZ Healthy Food and Drink Policy									
Mayonnaise, Best Foods					12.50	7.50	405g						23.82
Mayonnaise, Praise					14.00	6.50	250ml						14.71
Mayonnaise, Heinz					14.50	8.00	470g						27.65
Milk	<360ml	Children	New Zealand	Healthy Auckland Together									
Milk, Puhoi					25.50	10.00	1500ml		4.17				
Milk, A2					25.50	13.50	2000ml		5.56				
Milk carton					19.00	9.00	1000ml		2.78				
Orange	130g (1) *2 servings*	Children	New Zealand	NZ Food & Nutrition Guidelines									
Orange, fresh					7.50	7.50	130g	2.50	2.50	2.50			
Potato chips	30g	Children	Australia	NSW Healthy School Canteen									
Chip, large packet					28.50	17.50	150g		5.00				
Chip, single					6.50	5.50	2.4g		0.08				

Item	**Reference Portion Size**	**Population designed for**	**Reference Guidelines**	**Actual Height (cm)**	**Actual Width (cm)**	**Actual Serving (g or ml)**	**Actual Portions in Serving**						
		Age	**Country**					**Pre-schooler (2-5 year)**	**Children (2-12 year)**	**Young people (13-18 year)**	**Primary students (5-11 year)**	**Secondary students (11-18 year)**	**Adults (18-65 year)**
Potato and gravy													
KFC gravy	65g (1/4c) KFC gravy	Adults	New Zealand	NZ Food Composition Tables									
Potato	135g (1 medium) potato Pre-schoolers 2 serve Children and young people 3 serve	Children	New Zealand	NZ Food & Nutrition Guidelines									
KFC, potato and gravy					5.50	7.50	131.6g	1.11	0.90	0.90			
Rice	250g primary 350g secondary	Children	Australia	NSW Healthy School Canteen									
Rice, instant packet					18.50	13.50	250g				1.00	0.71	
Rice, plate					3.60	17.60	625g				2.50	1.79	
Sandwich	250g primary students 350g secondary students	Children	Australia	NSW Healthy School Canteen									
Sandwich, Subway						15.2cm	240g				0.96	0.69	
Sandwich, toasted					15.50	10.00	174g				0.70	0.50	
Sports drinks	250ml	Adult	New Zealand	NZ Food Composition Tables									
Powerade					27.00	8.00	750ml						3.00

Item	Reference Portion Size	Population designed for	Reference Guidelines	Actual Height (cm)	Actual Width (cm)	Actual Serving (g or ml)	Actual Portions in Serving						
		Age	**Country**					**Pre-schooler (2-5 year)**	**Children (2-12 year)**	**Young people (13-18 year)**	**Primary students (5-11 year)**	**Secondary students (11-18 year)**	**Adults (18-65 year)**
Supplements		Children	New Zealand	Nutrient Reference Values for Australia and NZ									
Adequate Intake Vitamin D	5.0 µg/day												
Recommended Dietary Intake Calcium	700mg 4-8 years 1000mg 9-11 years 1300mg 12-18 years												
Supplement, Ostelin kids Vitamin D3 liquid					11.00	6.50	200µg (20ml - 0.5ml 5µg/day)	40.00	40.00	40.00			
Supplement, Ostelin kids Vitamin D and Calcium					13.00	6.00	679.5µg vitamin D (90 tabs - 7.55µg)	135.90	135.90	135.90			
							31,500mg calcium (90 tabs - 350mg)	45.00	31.50	24.23			
Tomato sauce	17g (<1 Tbsp)	Adult	New Zealand	NZ Healthy Food and Drink Policy									
Tomato sauce, bottle					19.00	8.50	560g						32.94
Tomato sauce, dollop on chips					4.0 (drip 4.5)	4.0 (drip 0.5)	28g						1.65
Tomato sauce, dollop on rice					4.5 (drip 3.5)	6.5 (drip 0.5)	56g						3.29
Tomatoes	80g (1 tomato) Pre-schoolers 2 serve Children and young people 3 serve	Children	New Zealand	NZ Food & Nutrition Guidelines									

Item	**Reference Portion Size**	**Population designed for**	**Reference Guidelines**	**Actual Height (cm)**	**Actual Width (cm)**	**Actual Serving (g or ml)**	**Actual Portions in Serving**						
		Age	**Country**					**Pre-schooler (2-5 year)**	**Children (2-12 year)**	**Young people (13-18 year)**	**Primary students (5-11 year)**	**Secondary students (11-18 year)**	**Adults (18-65 year)**
Tomatoes, canned					11.00	7.50	400g	12.50	8.33	8.33			
Tomatoes, punnet					12.50	11.00	180g	5.63	3.75	3.75			
Yoghurt	150g (1 pottle)	Children	New Zealand	NZ Healthy Guidance for Schools									
Yoghurt, 1kg					14.00	13.50	1kg		6.67				
Yoghurt, 4 pack					13.00	10.00	500g		3.33				
Yoghurt, bowl						17.6cm	380g		2.53				

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