Nutrient Profiling Interventions Targeting Obesity
Prevention: Role and Potential Impact

by
Gary Sacks

Submitted in fulfilment of the requirements for the degree of
Doctor of Philosophy

Deakin University
October, 2010
I certify that the thesis entitled

**Nutrient profiling interventions targeting obesity prevention: role and potential impact**

submitted for the degree of

**Doctor of Philosophy**

is the result of my own work and that where reference is made to the work of others, due acknowledgment is given. I also certify that any material in the thesis which has been accepted for a degree or diploma by any university or institution is identified in the text.

Full Name ........................................................................................................................................

Signed ............................................................................................................................................

Date ..................................................................................................................................................
Publications and conference abstracts arising from this thesis

Journal articles

1. **Sacks G** , Swinburn B, Lawrence M. A systematic policy approach to changing the food system and physical activity environments to prevent obesity. Aust New Zealand Health Policy 2008;5:13 (Refer to Chapter 3)

2. **Sacks G** , Swinburn B, Lawrence M. Obesity Policy Action framework and analysis grids for a comprehensive policy approach to reducing obesity. Obes Rev 2009;10(1):76-86 (Refer to Chapter 3)


5. Swinburn B, **Sacks G** , Ravussin E. Increased food energy supply is more than sufficient to explain the US epidemic of obesity. Am J Clin Nutr 2009;90(6):1453-6 (Refer to Chapter 5)

6. **Sacks G** , Rayner M, Swinburn B. Impact of front-of-pack 'traffic-light' nutrition labelling on consumer food purchases in the UK. Health Promot Int 2009;24(4):344-52 (Refer to Chapter 6)

7. **Sacks G** , Tikellis K, Millar L, Swinburn B. Impact of ‘traffic-light’ nutrition information on online food purchases in Australia. Aust N Z J Public Health 2011;ePub ahead of print March 8 (Refer to Chapter 7)

**Letter to the editor**

1. Swinburn B, **Sacks G**, Ravussin E. Reply to KD Hall and CC Chow. Am J Clin Nutr 2010;91(3):817-a (Refer to Chapter 5)

**Oral conference presentations**

1. **Sacks G**, Lawrence M, Swinburn B. A comprehensive framework to identify policies for obesity action. Australasian Society for the Study of Obesity (ASSO), 16th Annual Scientific Meeting, Canberra, Australia. 31 August – 2 September 2007


3. **Sacks G**, Swinburn B, Ravussin E. Combining biological, epidemiological and food supply data to demonstrate that increased energy intake alone virtually explains the obesity epidemic in the United States. 7th International Conference on Diet and Activity Methods (ICDAM 7), Washington DC, United States of America. 4 – 7 June 2009


**Other publications related to this thesis**

Acknowledgements

My PhD studies were enjoyable throughout, and I am grateful to a number of people for enabling such a positive experience.

Firstly, I would like to thank my supervisory team of Professor Boyd Swinburn, Associate Professor Mark Lawrence and Associate Professor Marj Moodie for the support and guidance they provided. It was Boyd’s passion and strategic vision that first attracted me to study with him, and he proved a continued source of inspiration and wisdom throughout my candidature. It has been a privilege to work as Boyd’s apprentice and colleague, and he has opened up opportunities for me beyond all expectations. I hope to continue my association with Boyd, Mark and Marj long into the future.

Secondly, I would like to thank all the researchers with whom I collaborated in completing this research. In particular, I would like to thank Dr Mike Rayner and the other members of the Department of Public Health at the University of Oxford who hosted me for five months as part of my studies. Mike’s enthusiasm and generosity ensured that my time in the UK was thoroughly stimulating. I am also indebted to Professor Steve Gortmaker at Harvard University who kindly hosted me for three months during this research. Thanks also to my fellow students and colleagues at Deakin University who offered their advice and assistance, and a special note of thanks to Dr Lucy Firth who first encouraged me to pursue a PhD.

Thirdly, I would like to acknowledge the staff at the supermarket chains in Australia and the UK who assisted me in gathering data for this research. It was a pleasure to work with both organisations.
Finally, I would like to thank my family and friends. My parents, Brian and Jenny, have always encouraged me to perform at my best and I owe a great deal of my achievements to them. My sister, Michelle, my brother, Darren, and their families have supported me in everything I have undertaken. Thanks also to Bronwen and Paul Lasky for serving as my PhD role models, and Kate Wengier and Lara Hurst for their friendship and encouragement.

In undertaking this research, I was supported financially by a Deakin University Postgraduate Research Scholarship.
Abstract

Governments in many countries around the world, including Australia, are actively seeking sustainable strategies to combat rising levels of obesity. However, there is little evidence of what preventative actions are likely to be successful. This thesis aimed to investigate the role and potential impact of obesity prevention policy options, and to provide evidence to support policymakers and researchers tackling this issue.

The research consisted of six studies that used a combination of different research methods to address the overall research aims and objectives. In Study A, a framework was developed for comprehensive and systematic identification of areas for obesity prevention policy action. The framework incorporated multiple approaches for addressing obesity, and organised areas for potential policy action by the level of governance responsible for their implementation and the sector or setting to which they apply.

Study B investigated the potential role of nutrient profiling (the science of categorising foods, for example, as ‘healthy’ or ‘unhealthy’, according to their nutritional composition) for obesity prevention. The study identified that there is substantial scope to use nutrient profiling as part of interventions aimed at influencing food environments and nutrition behaviour, and outlined a logic model for demonstrating the pathways by which these interventions can affect health outcomes. The study indicated that the adoption of a common nutrient profiling system to underpin the multiple potential applications was vital to ensure coherent policy implementation. The analysis showed that the development of such a system appeared feasible – although several technical factors and other implementation considerations would need to be taken into account.
In Study C, an equation to predict mean population body weight change in response to a given change in mean energy intake or expenditure was developed for adults. The equation was derived directly from the observed relation between total energy expenditure (measured using doubly-labelled water) and body weight in previously conducted cross-sectional studies. The equation forms an important part of models that aim to estimate the potential impact of policy interventions on health outcomes. As part of this study, the equation was also used to estimate the relative contributions of increased energy intake and reduced physical activity to the United States obesity epidemic. The results provided evidence that population approaches to preventing obesity should prioritise changes to food environments above efforts to increase physical activity.

Studies D and E collected empirical data on the impact of ‘traffic-light’ nutrition labelling (which shows the nutritional content of food products at a glance, using simple colours) on consumer food purchases. In Study D, sales data from a major supermarket chain in the United Kingdom were analysed to assess the impact of the introduction of front-of-pack traffic-light nutrition labelling on the healthiness of consumer purchases in selected food categories. Study E consisted of a 10-week trial of traffic-light nutrition labelling on selected products in an online grocery store of a major supermarket chain in Australia. Sales data were analysed to determine the effect of the trial on the healthiness of consumer purchases in the selected food categories, and customers were surveyed to understand their response to the trial. Both studies found that the introduction of traffic-light nutrition labelling on a small selection of supermarket ‘own-brand’ products did not impact on the relative healthiness of food purchases in the short-term.

The final study, Study F, modelled the likely cost and potential impact on obesity-related health outcomes of two promising population-wide interventions in the Australian context: the mandatory introduction of front-of-pack traffic-light nutrition labelling on all products in selected food categories (accompanied by an associated social marketing campaign); and a consumer-end tax on foods in a selection of unhealthy food categories. The scenarios modelled in Study F
showed that both interventions were likely to offer excellent ‘value for money’ from an obesity prevention perspective. However, other policy-relevant factors (such as the likely opposition to these interventions from private industry, and the financial impact of the tax on low-income groups) need to be taken into account in considering their implementation.

The frameworks and models developed as part of this research provide tools for various stakeholders (including local, state and national governments, non-government organisations, and private industry) to identify areas for obesity prevention action and to assess their impact. Furthermore, the empirical and modelled evidence produced as part of this research can be used to inform the decisions of policy makers in their obesity prevention efforts. Future research in this area should aim to: involve key stakeholders as part of the research process; consider the impact of interventions more broadly than just obesity (for example, on environmental outcomes and on diet-related chronic diseases more generally); understand the impact of multiple interventions implemented together as part of a policy portfolio; evaluate the differential effects of interventions on different socio-economic groups; and make greater use of supermarket sales data for public health purposes.

Keywords: obesity prevention, nutrient profiling, policy interventions, nutrition labelling, food-related taxes, cost-effectiveness
# Table of contents

Publications and conference abstracts arising from this thesis ................................................................. iii

Acknowledgements ........................................................................................................................................ vi

Abstract ................................................................................................................................................... viii

Glossary of key terms and abbreviations ................................................................................................. xv

Chapter 1: Introduction ............................................................................................................................ 1
  1.1 Chapter overview .................................................................................................................................... 1
  1.2 Research context .................................................................................................................................. 1
  1.3 The problem of obesity ....................................................................................................................... 2
  1.4 Aetiology of obesity ............................................................................................................................ 3
  1.5 Obesity prevention policy .................................................................................................................. 4
    1.5.1 Definition of ‘policy’ .................................................................................................................. 4
    1.5.2 Role of policy in obesity prevention ......................................................................................... 5
  1.6 Nutrient profiling .................................................................................................................................. 7
  1.7 Nutrition labelling ................................................................................................................................... 9
    1.7.1 Nutrition information panel ....................................................................................................... 9
    1.7.2 Impact of nutrition labelling on health .................................................................................... 10
    1.7.3 Front-of-pack nutrition labelling .............................................................................................. 10
  1.8 Food-related taxes and subsidies ........................................................................................................ 13
  1.9 Modelling the impact of obesity prevention interventions .............................................................. 14
    1.9.1 Previous obesity prevention intervention modelling studies .................................................. 14
    1.9.2 Logic pathway for modelling intervention effects ...................................................................... 15
    1.9.3 Estimating a change in body weight from a change in energy balance ..................................... 16
  1.10 Research aims and objectives ........................................................................................................... 18
  1.11 Significance of this research ............................................................................................................. 19
  1.12 Thesis structure ................................................................................................................................... 20

Chapter 2: Research design .................................................................................................................... 22
  2.1 Chapter overview ................................................................................................................................ 22
  2.2 Theoretical perspective ....................................................................................................................... 24
  2.3 Solution-oriented approach ............................................................................................................... 24
  2.4 Study A: Policy framework ................................................................................................................. 25
    2.4.1 Study objective ......................................................................................................................... 25
    2.4.2 Study design ............................................................................................................................. 25
    2.4.3 Scope of the study ....................................................................................................................... 26
  2.5 Study B: Nutrient profiling .................................................................................................................. 27
    2.5.1 Study objective ......................................................................................................................... 27
    2.5.2 Study design ............................................................................................................................. 27
    2.5.3 Scope of the study ....................................................................................................................... 28
Chapter 3: Framework for obesity prevention policies .................................................. 42

Chapter overview ........................................................................................................ 42

Manuscript 1 ................................................................. 43
Abstract ........................................................................ 46
Background ................................................................... 47
Methods ....................................................................... 48
Policy actions that influence the food system ................................................................. 51
Policy actions that influence physical activity environments ......................................... 53
Discussion .................................................................... 54
Conclusion ..................................................................... 56
References ..................................................................... 58

Manuscript 2 ................................................................. 65
Abstract ........................................................................ 68
Introduction .................................................................... 69
Methods ....................................................................... 70
Results .......................................................................... 71
Discussion .................................................................... 77
Conclusion ..................................................................... 79
References ..................................................................... 81

Chapter 4: Role and potential impact of nutrient profiling interventions ......................... 95

Chapter overview ........................................................................................................ 95

Manuscript 3 ................................................................. 96
Abstract ........................................................................ 99
Background ................................................................... 100
Framework for identifying and classifying potential applications of nutrient profiling .. 102
Logic pathway for evaluating the potential impact of interventions based on nutrient profiling .......................................................... 103
Feasibility of a core nutrient profiling system underpinning multiple applications ....... 105
Discussion .................................................................... 107
Conclusion ..................................................................... 109
References ..................................................................... 111
<table>
<thead>
<tr>
<th>Chapter 5: Relation between changes in energy balance and changes in body weight</th>
<th>125</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter overview</td>
<td>125</td>
</tr>
<tr>
<td>Manuscript 4</td>
<td>126</td>
</tr>
<tr>
<td>Abstract</td>
<td>130</td>
</tr>
<tr>
<td>Introduction</td>
<td>131</td>
</tr>
<tr>
<td>Participants and methods</td>
<td>132</td>
</tr>
<tr>
<td>Results</td>
<td>134</td>
</tr>
<tr>
<td>Discussion</td>
<td>136</td>
</tr>
<tr>
<td>References</td>
<td>140</td>
</tr>
<tr>
<td>Manuscript 5</td>
<td>151</td>
</tr>
<tr>
<td>Abstract</td>
<td>154</td>
</tr>
<tr>
<td>Introduction</td>
<td>155</td>
</tr>
<tr>
<td>Methods</td>
<td>156</td>
</tr>
<tr>
<td>Results</td>
<td>157</td>
</tr>
<tr>
<td>Discussion</td>
<td>157</td>
</tr>
<tr>
<td>References</td>
<td>160</td>
</tr>
<tr>
<td>Letter to the Editor</td>
<td>165</td>
</tr>
<tr>
<td>Chapter 6: Impact of traffic-light nutrition labelling on food purchases in the UK</td>
<td>175</td>
</tr>
<tr>
<td>Chapter overview</td>
<td>175</td>
</tr>
<tr>
<td>Manuscript 6</td>
<td>176</td>
</tr>
<tr>
<td>Abstract</td>
<td>179</td>
</tr>
<tr>
<td>Introduction</td>
<td>180</td>
</tr>
<tr>
<td>Methods</td>
<td>181</td>
</tr>
<tr>
<td>Results</td>
<td>183</td>
</tr>
<tr>
<td>Discussion</td>
<td>186</td>
</tr>
<tr>
<td>Conclusion</td>
<td>188</td>
</tr>
<tr>
<td>References</td>
<td>190</td>
</tr>
<tr>
<td>Chapter 7: Impact of traffic-light nutrition information on food purchases in Australia</td>
<td>200</td>
</tr>
<tr>
<td>Chapter overview</td>
<td>200</td>
</tr>
<tr>
<td>Manuscript 7</td>
<td>201</td>
</tr>
<tr>
<td>Abstract</td>
<td>204</td>
</tr>
<tr>
<td>Introduction</td>
<td>205</td>
</tr>
<tr>
<td>Methods</td>
<td>206</td>
</tr>
<tr>
<td>Results</td>
<td>208</td>
</tr>
<tr>
<td>Discussion</td>
<td>209</td>
</tr>
<tr>
<td>Conclusions</td>
<td>212</td>
</tr>
<tr>
<td>References</td>
<td>213</td>
</tr>
<tr>
<td>Customer survey</td>
<td>219</td>
</tr>
<tr>
<td>Introduction</td>
<td>219</td>
</tr>
<tr>
<td>Methods</td>
<td>219</td>
</tr>
<tr>
<td>Results</td>
<td>219</td>
</tr>
<tr>
<td>Discussion</td>
<td>220</td>
</tr>
<tr>
<td>Chapter 8: Cost-effectiveness modelling</td>
<td>222</td>
</tr>
<tr>
<td>Chapter overview</td>
<td>222</td>
</tr>
<tr>
<td>Manuscript 8</td>
<td>223</td>
</tr>
<tr>
<td>Abstract</td>
<td>226</td>
</tr>
<tr>
<td>Introduction</td>
<td>228</td>
</tr>
<tr>
<td>Methods</td>
<td>229</td>
</tr>
</tbody>
</table>
Chapter 9: Discussion .............................................................................................................. 255

9.1 Chapter overview ............................................................................................................. 255

9.2 Key findings and their public health implications ............................................................ 255
9.2.1 Policy framework ...................................................................................................... 255
9.2.2 Nutrient profiling .................................................................................................... 256
9.2.3 Energy balance equation for adults ......................................................................... 257
9.2.4 Empirical evidence of the impact of traffic-light nutrition labelling on food purchases ........................................................................................................... 258
9.2.5 Cost-effectiveness modelling .................................................................................... 260

9.3 Limitations of the research and directions for future research ..................................... 260
9.3.1 Stakeholder involvement ......................................................................................... 260
9.3.2 Narrow focus on obesity prevention ....................................................................... 261
9.3.3 Portfolio of interventions ......................................................................................... 262
9.3.4 Effects on different socio-economic groups ......................................................... 264
9.3.5 Range of nutrient profiling interventions ............................................................... 264

9.4 Conclusion .................................................................................................................. 265

References .................................................................................................................................. 267

Appendix ..................................................................................................................................... 278
### Glossary of key terms and abbreviations

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACE</td>
<td>Assessing Cost-Effectiveness</td>
</tr>
<tr>
<td>ACE-Obesity</td>
<td>Assessing the Cost-Effectiveness of Obesity</td>
</tr>
<tr>
<td>ACE-Prevention</td>
<td>Assessing Cost-Effectiveness in Prevention</td>
</tr>
<tr>
<td>Aetiology</td>
<td>The science that deals with the causes or origin of disease</td>
</tr>
<tr>
<td>AUD</td>
<td>Australian dollar</td>
</tr>
<tr>
<td>BMI</td>
<td>Body mass index, defined as body weight in kilograms divided by the square of height in metres (kg/m²)</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence interval</td>
</tr>
<tr>
<td>Common / core nutrient profiling system</td>
<td>A nutrient profiling model or system that is used for multiple applications, with some (but not necessarily all) design elements (e.g., scoring system, food categories) and structures (e.g., points system) used consistently across all applications</td>
</tr>
<tr>
<td>DALY</td>
<td>Disability adjusted life year, a measure of mortality and morbidity burden</td>
</tr>
<tr>
<td>Dominant</td>
<td>Effective and cost-saving (regarding the cost-effectiveness of interventions)</td>
</tr>
<tr>
<td>Doubly-labelled water</td>
<td>A method of indirectly estimating energy expenditure, considered to be the ‘gold-standard’ technique</td>
</tr>
<tr>
<td>DPAS</td>
<td>Global strategy on diet, physical activity and health</td>
</tr>
<tr>
<td>DRCD</td>
<td>Diet-related chronic disease</td>
</tr>
<tr>
<td>Energy flux</td>
<td>The amount of daily TEE and TEI while the subject is in energy balance</td>
</tr>
<tr>
<td>EnFlux</td>
<td>Energy flux</td>
</tr>
<tr>
<td>EUR</td>
<td>Euro</td>
</tr>
<tr>
<td>FFM</td>
<td>Fat-free mass</td>
</tr>
<tr>
<td>FM</td>
<td>Fat mass</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>FSA</td>
<td>Food Standards Agency (UK)</td>
</tr>
<tr>
<td>FSANZ</td>
<td>Food Standards Australia New Zealand</td>
</tr>
<tr>
<td>OPA</td>
<td>Obesity Policy Action</td>
</tr>
<tr>
<td>NCD</td>
<td>Non-communicable disease</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-government organisation</td>
</tr>
<tr>
<td>NHANES</td>
<td>National Health and Nutrition Examination Surveys (US)</td>
</tr>
<tr>
<td>NIP</td>
<td>Nutrition information panel</td>
</tr>
<tr>
<td>NNS</td>
<td>National nutrition survey (Australia)</td>
</tr>
<tr>
<td>Nutrient profiling</td>
<td>The science of categorising foods according to their nutritional composition, for example, as ‘healthy’ or ‘unhealthy’</td>
</tr>
<tr>
<td>Nutrient profiling intervention</td>
<td>A policy intervention that makes use of nutrient profiling</td>
</tr>
<tr>
<td>Nutrient profiling model</td>
<td>A model or system used to categorise foods according to their nutritional composition, for example, as ‘healthy’ or ‘unhealthy’</td>
</tr>
<tr>
<td>Obese</td>
<td>BMI greater than or equal to 30</td>
</tr>
<tr>
<td>Obesity</td>
<td>For simplicity, and unless otherwise stated, the term ‘obesity’ is used in this thesis to refer to a BMI greater than or equal to 25 (that is, including both overweight and obese)</td>
</tr>
<tr>
<td>Obesity prevention policy</td>
<td>System of laws, regulatory measures, courses of action, and funding priorities for the prevention of obesity</td>
</tr>
<tr>
<td>Obesogenic</td>
<td>Tending to encourage excessive weight gain</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td>Overweight</td>
<td>BMI greater than or equal to 25</td>
</tr>
<tr>
<td>PA</td>
<td>Physical activity</td>
</tr>
<tr>
<td>Policy area</td>
<td>A content area, such as ‘nutrition labelling’ or ‘products sold in schools’, that is amenable to policy intervention</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Policy intervention</td>
<td>A specific action implemented in order to achieve policy objectives</td>
</tr>
<tr>
<td>RMR</td>
<td>Resting metabolic rate</td>
</tr>
<tr>
<td>TEE</td>
<td>Total energy expenditure</td>
</tr>
<tr>
<td>TEI</td>
<td>Total energy intake</td>
</tr>
<tr>
<td>TLL</td>
<td>Traffic-light nutrition labelling</td>
</tr>
<tr>
<td>TLNI</td>
<td>Traffic-light nutrition information</td>
</tr>
<tr>
<td>Traffic-light labelling</td>
<td>Any format of nutrition labelling that makes use of colours to indicate</td>
</tr>
<tr>
<td></td>
<td>the relative levels of nutrients with red, amber, and green corresponding</td>
</tr>
<tr>
<td></td>
<td>to ‘high’, ‘medium’, or ‘low’ levels respectively</td>
</tr>
<tr>
<td>UI</td>
<td>Uncertainty interval</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Unhealthy</td>
<td>Less healthy, as commonly agreed or as defined by a nutrient profiling</td>
</tr>
<tr>
<td></td>
<td>model</td>
</tr>
<tr>
<td>US / USA</td>
<td>United States of America</td>
</tr>
<tr>
<td>USDA</td>
<td>United States Department of Agriculture</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>Wicked problem</td>
<td>A highly complex problem characterised by disagreement about the specific</td>
</tr>
<tr>
<td></td>
<td>causes and uncertainty about the best way to tackle the problem</td>
</tr>
</tbody>
</table>
Chapter 1: Introduction

1.1 Chapter overview

Governments in many countries around the world, including Australia, are actively seeking sustainable strategies to combat rising levels of obesity. However, there is little evidence of what preventative actions are likely to be successful. This thesis investigated the role and potential impact of obesity prevention policy options, and provides evidence of interventions that are likely to offer excellent ‘value for money’ for governments.

This chapter introduces the research by providing an overview of the topic, defining key terms and reviewing relevant research previously conducted in the area. The chapter also sets out the aims and objectives of the thesis, explains the significance of the research and outlines the thesis structure.

1.2 Research context

The research incorporated in this thesis was conducted predominantly in Australia. Accordingly, the focus of the thesis is on obesity prevention in Australia, with most of the examples and scenarios analysed in the Australian context. In addition, some of the primary data collection was conducted in the United Kingdom (UK), and, as such, these results are presented in the UK context. The research findings are intended to be applicable internationally, with a focus on high-income countries.

All of the research incorporated in this thesis was conducted between 2007 and 2010.
1.3 The problem of obesity

Overweight and obesity are defined by the World Health Organization (WHO) as "abnormal or excessive fat accumulation that presents a risk to health".\textsuperscript{1} For adults, overweight and obesity are most commonly measured by Body Mass Index (BMI): body weight in kilograms divided by the square of height in metres (kg/m\textsuperscript{2}). A BMI over 25 is considered overweight and a BMI over 30 is considered obese.\textsuperscript{2}

Over the last three decades the prevalence of overweight and obesity has increased substantially.\textsuperscript{1} Globally, approximately 1.6 billion adults are overweight and at least 400 million adults are obese.\textsuperscript{3} Furthermore, an estimated 170 million children (aged < 18 years) are estimated to be overweight,\textsuperscript{4} and in many countries, such as the United States of America (US), the number of overweight children has trebled since 1980.\textsuperscript{3} The prevalence of overweight and obesity continues to increase, with the WHO projecting that by 2015 approximately 2.3 billion adults will be overweight and more than 700 million will be obese.\textsuperscript{3} In Australia and in the UK, more than 60% of the adult population\textsuperscript{5-6} and approximately 25% of children are either overweight or obese.\textsuperscript{5,7} For simplicity, and unless otherwise stated, the term ‘obesity’ is used throughout the remainder of the thesis to refer to both overweight and obesity.

The high prevalence of obesity has serious health consequences. Raised BMI is a major risk factor for diseases such as cardiovascular disease, type 2 diabetes and many cancers (including, for example, colorectal cancer, kidney cancer and oesophageal cancer).\textsuperscript{8-10} These diseases, often referred to as non-communicable diseases (NCDs) or diet-related chronic diseases (DRCDs), not only cause premature mortality but also long-term morbidity. In Australia, DRCDs are the leading causes of overall disease burden,\textsuperscript{11} and obesity has recently overtaken tobacco as the largest preventable cause of disease burden in at least one State.\textsuperscript{12} The costs of DRCDs were estimated to be AUD2.25 billion per year in 2000,\textsuperscript{11} but more recent estimates indicate that the cost of obesity alone is over AUD58
billion per year.\textsuperscript{13} This mirrors the situation in several other high-income countries where obesity accounts for between 2 and 6\% of total health care costs.\textsuperscript{14}

As a result of the dramatic increase in prevalence, obesity is commonly considered one of the most serious health challenges of the early 21st century.\textsuperscript{1,15} In Australia, obesity is recognised as a public health crisis\textsuperscript{16} and the Australian National Health and Medical Research Council has identified obesity as a priority health issue.\textsuperscript{17}

\section{1.4 Aetiology of obesity}

Obesity is a multifaceted condition with genetic, metabolic, behavioural and environmental factors all contributing to its development.\textsuperscript{3,18} There have been several efforts to identify and map out all the determinants of obesity and their relations. Commonly cited examples include the ‘web of causation’ developed by Kumanyika et al.\textsuperscript{19} and the ‘Obesity System Influence Diagram’ developed as part of the Foresight Tackling Obesities project in the UK.\textsuperscript{15} These models serve primarily to illustrate the enormous complexity of the problem and the multitude of influences in operation. Indeed, the complexity of the problem has led to obesity being referred to as a ‘wicked’ problem,\textsuperscript{20} characterised by disagreement about the specific causes and uncertainty about the best way to tackle the problem.\textsuperscript{21}

Nevertheless, there is growing consensus that the dramatic increase in the prevalence of obesity in the past few decades can only be due to significant changes in nutrition and physical activity behaviours at the population level.\textsuperscript{3,18,22} Socio-ecological approaches have been widely used to explain the determinants of these behaviours.\textsuperscript{23-24} These approaches recognise that individual behaviour is determined to a large extent by the economic, socio-cultural and physical environments in which people live. In particular, changes to the global food
environment have been widely identified as a key driver of behavioural change that has led to shifts in dietary patterns.\textsuperscript{2,22} These changes to the food environment include, for example, the increased marketing and availability of energy-dense foods that have led to their increased consumption.\textsuperscript{24} This has been accompanied by a shift to more sedentary lifestyles, with increased urbanisation, the growth of tertiary industry, and greater use of cars.\textsuperscript{2,22} The environmental factors that have served to promote obesity are commonly referred to as ‘obesogenic’.\textsuperscript{25}

1.5 **Obesity prevention policy**

1.5.1 **Definition of ‘policy’**

There is a diversity of definitions of the term ‘policy’. At perhaps its simplest, policy is what governments choose to do or not to do.\textsuperscript{26} While this definition is consistent with those that consider policies to be only within the domain of government,\textsuperscript{27} many broad definitions of policy also include the role of private industry and non-government organisations (NGOs).\textsuperscript{28-29} To assist with this distinction, the term ‘public policy’ is often used to refer to only those policies implemented by government.\textsuperscript{30} Some definitions of policy focus only on actions that are mandatory or legislated;\textsuperscript{31} however, the majority of definitions also include non-legislated courses of action.\textsuperscript{27,32} Furthermore, the term ‘policy’ is also commonly used to include policy statements (for example, by governments and peak bodies) indicating overall directions or priority areas, rather than specific actions.\textsuperscript{30}

In considering policies related to obesity prevention, it is also relevant to briefly discuss the terms ‘health policy’ and ‘food policy’. Health policy can be defined as “an action plan that steers the direction of a social, professional and governmental response to a health-related issue”.\textsuperscript{28} Food policy can be defined as “the collective efforts of governments to influence the decision-making
environment of food producers, food consumers, and food marketing agents in order to further social objectives”. While seemingly broad, these definitions do not explicitly include the incidental effects of broader economic and social policies on health or diets. Increasingly however, in line with the ‘new nutrition sciences’, food policy definitions are being broadened in scope, incorporating environmental, social and economic influences on the food system.

In this thesis, ‘obesity prevention policy’ is used to mean the system of laws, regulatory measures, courses of action, and funding priorities for the prevention of obesity. A broad perspective is taken, considering policies that affect the set of institutions, organisations, services, and funding arrangements of the health care system, as well as policies that influence actions by public, private and voluntary organisations that have an impact on health. Accordingly, this definition covers action on the environmental and socio-economic determinants of health as well as population behaviours and health care provision. The term ‘policy intervention’ is used throughout the thesis to refer to a specific action implemented in order to achieve policy objectives. These interventions make use of policy instruments such as laws and regulations, spending and taxing, service and program delivery, and advocacy. ‘Policy area’ is used to mean a content area, such as ‘nutrition labelling’ or ‘products sold in schools’, that is amenable to policy intervention.

### 1.5.2 Role of policy in obesity prevention

As with other ‘wicked’ problems, such as climate change, there is recognition that the solution to the obesity epidemic will involve changing the behaviour of large population groups. It is widely-held that a portfolio of responses across multiple sectors will be needed to achieve substantial changes and that successful interventions will require coordinated efforts from multiple levels of government, NGOs, private industry and individuals.
Policy interventions are likely to form key components of an obesity prevention portfolio. The use of policy interventions to support improvements in health is well-recognised in the health promotion domain. The seminal ‘Ottawa Charter for Health Promotion’ prioritised the role of policy interventions, and the more recent ‘Bangkok Charter for Health Promotion in a Globalized World’ stated that action is needed across sectors and settings to “regulate and legislate to ensure a high level of protection from harm and enable equal opportunity for health and well-being for all people”.

Around the world, the majority of obesity-related interventions implemented to date have been education-based and focused on the treatment of obesity. These education and treatment strategies are necessary but are unlikely to be sufficiently effective or sustainable to stem the obesity epidemic, and there is widespread agreement that major changes to the current obesogenic environments will also be needed. Such environmental changes, for example, increasing the opportunities for active transport (physical environment), making healthy food choices more affordable (economic environment) and changing attitudes about food marketing to children (socio-cultural environment) are unlikely to happen without the backing of supportive policy. Furthermore, policy interventions that target obesogenic environments are often most appropriate for reaching multiple sectors of the community, including socio-economically disadvantaged populations where obesity levels are disproportionately high. These reasons, along with the need for potent, sustainable and cost-effective strategies to reduce obesity prevalence all point towards the importance of policy interventions. Nevertheless, it is recognised that some policy interventions have unintended consequences. For example, a policy to tax products high in saturated fat may result in consumers switching their consumption to products high in sodium, leading to increased strokes and, as a consequence, the policy intervention may cause more deaths than it averts. This highlights the need for potential policy interventions to be thoroughly analysed prior to their adoption and evaluated once implemented.
In recognition of the importance of policy, many authors have discussed potential policy interventions available to government to prevent obesity. Typically, these authors list potential environmental strategies and policy recommendations for reducing the prevalence of obesity. While the lists generated by these authors are useful in showing the wide range of policy interventions available, they do not necessarily reflect a comprehensive approach. Brownson et al. propose a conceptual model for understanding the prevention of chronic diseases through environmental and policy approaches, but their framework does not extend to sufficient detail to systematically identify the full range of obesity prevention policy interventions. As governments around the world move towards a strategic policy approach to tackling obesity, it will be increasingly important to consider the various policy intervention options in a comprehensive and systematic way.

1.6 Nutrient profiling

Nutrient profiling is commonly defined as “the science of categorising foods according to their nutritional composition”. Nutrient profiling is typically used to categorise foods (using words, graphics or numbers) according to either the nutrient levels in the food (for example, ‘high fat’, ‘low fat’, ‘source of fibre’, ‘energy dense, nutrient poor’) or with respect to the effects of consuming the food on a person’s health (for example, ‘healthy’, ‘healthier option’, ‘less healthy’, ‘good for your heart’). These categorisations can form an important part of policies aimed at preventing obesity and improving public health nutrition more generally.

Nutrient profiling is currently being used as part of a number of food policy interventions around the world. The most common of these ‘nutrient profiling interventions’ are food labelling schemes aimed at assisting consumers to make healthier food choices. Such schemes have been devised by governments (e.g., the Swedish National Food Administration’s ‘Keyhole’ scheme), non-
governmental organisations (e.g., the National Heart Foundation of Australia’s ‘Pick-the-Tick’ scheme) and multi-stakeholder groups (e.g., the US ‘Smart Choices’ programme). Many governments around the world (e.g., Australia and New Zealand and the European Union) have also used, or propose to use, nutrient profiling in the regulation of nutrition and health claims. Furthermore, the UK Office of Communications base their restrictions on television advertising of food and drink products to children on the nutrient profiling model developed by the UK Food Standards Agency (FSA), and products available for sale in schools often rely on a nutrient profiling model to determine foods eligible for sale (e.g., the Australian Healthy School Canteens Guidelines).

The number of different nutrient profiling models has increased rapidly in recent years. A 2008 review identified 39 different nutrient profiling models. The review found a wide variation in the model components, such as the choice of nutrients, the food categories used, and their relative weightings. Consequently, the way in which foods are classified differs according to each model. While there is a growing literature on methods for validating nutrient profiling models, there is currently no consensus on an ‘ideal’ nutrient profiling model that can be used across multiple applications.

As more applications of nutrient profiling emerge, the number of different nutrient profiling models is likely to increase. In turn, this is likely to increase discrepancies between models, and create unnecessary duplication and confusion for regulators, manufacturers and consumers. For example, without due care, the nutrient profiling model developed for one application may contradict the nutrient profiling model developed for another application. As governments seek to develop comprehensive, multi-pronged strategies for the prevention of DRCD and obesity in particular, it will be increasingly important that policy interventions are complementary in both their design and impact. As such, it will be important to consider all the potential applications of nutrient profiling and the feasibility of a common nutrient profiling model to underpin the multiple potential nutrient profiling interventions.
The next sections consider two potential applications of nutrient profiling: front-of-pack nutrition labelling (section 1.7) and food-related taxes (section 1.8). Both of these applications have been widely cited as promising interventions for improving public health nutrition.\textsuperscript{49,61}

1.7 Nutrition labelling

1.7.1 Nutrition information panel

Nutrition labelling is commonly identified as a potential tool to help consumers make healthy food choices.\textsuperscript{62} In Australia, as in many countries around the world, it is mandatory to display nutrition information, in the form of a standardised nutrition information panel (NIP), on the back of packaged food products.

A systematic review of consumer understanding and use of nutrition labelling (in formats such as the NIP) identified that consumers’ reported use of nutrition labels is high but more objective measures suggest that their actual use when purchasing food may be much lower.\textsuperscript{63} In addition, the review reported that consumers find the standard NIP difficult to understand and confusing.\textsuperscript{63}

Several countries are currently reviewing their food labelling regulations. For example, in the European Union new legislation has recently been proposed regarding mandatory nutrition information.\textsuperscript{64} In Australia, there is a major review of food labelling currently underway within the food regulatory system.\textsuperscript{65} This review is considering, amongst other things, the continued use of NIPs and standards related to front-of-pack labelling.\textsuperscript{65}
1.7.2 Impact of nutrition labelling on health

There is limited evidence of the impact of nutrition labelling on health outcomes. A review of the impact of nutrition interventions found that changes to nutrition information at the point-of-purchase can be expected to have, at best, only modest effects on the healthiness of consumer food choices in supermarkets.66 This finding is perhaps unsurprising when one considers the complex drivers of consumer purchasing behaviour and the number of factors, such as price, taste and advertising, that play a role in determining consumer food choices.67 When viewed in the context of a conceptual framework of shopping behaviour,68 nutrition considerations make up only one small aspect of the motivations and behaviour of the individual. Moreover, these individual considerations are influenced by the socio-cultural context of shopping and the broader shopping environment of which nutrition labelling is only a small part.69

Nevertheless, evidence indicates that improvements in nutrition labelling, such as the addition of interpretational aids and descriptors, help consumers in making comparisons between products and in putting products into a total diet context.63,70 Accordingly, format changes could make a small but important contribution towards making the shopping environment more conducive to the selection of healthier choices.71 Furthermore, many commentators have identified the importance of transparency and clarity in providing nutrition information to consumers.71-73 In this context, improvements to food labelling could be justified based on supporting consumers’ right to information even if they only have a small impact on health.

1.7.3 Front-of-pack nutrition labelling

In recent years there has been a move towards front-of-pack nutrition labelling schemes. The most established schemes are health-related endorsement programs, such as Sweden’s ‘Keyhole’ scheme 52 and Australia and New Zealand’s ‘Pick-
the Tick\textsuperscript{53}, that mark out individual food products as healthy or healthier choices. More comprehensive nutrient signposting schemes that highlight the content of particular nutrients on the front of the product packaging have also recently been introduced in various formats. One of the most commonly proposed nutrient signposting schemes is a ‘traffic-light’ labelling system that highlights the total fat, saturated fat, sugar and sodium content, with each nutrient colour-coded as red, amber, or green corresponding to high, medium, or low levels of that nutrient (Figure 1.1).\textsuperscript{74} In the UK in 2006, the FSA recommended the use of this format of traffic-light nutrition labelling in selected food categories, and documented the scientific basis for the setting of the various cut-off values.\textsuperscript{74} Some UK supermarket chains adopted traffic-light nutrition labelling as per the FSA guidelines. In contrast, several supermarket chains (for example, Tesco in the UK) and food industry bodies have developed and implemented their own schemes – each with different formats and using different criteria for classifying the ‘healthiness’ of products. In Australia, the food industry, led by the Australian Food and Grocery Council, is increasingly using a system of ‘Percentage Daily Intake’ front-of-pack nutrition labelling. This system highlights the percentage contribution of various nutrients to recommended intake levels, based on an ‘average’ adult consuming an 8700 kJ diet, but does not make use of colours.\textsuperscript{75}

![Figure 1.1](image)

**Figure 1.1**  Example format of front-of-pack traffic-light nutrition label
The preferred format for front-of-pack nutrition labelling has been vigorously debated\(^{72-73,76-78}\) and there have been numerous studies investigating consumer perceptions of front-of-pack nutrition labelling internationally\(^{69,77,79-81}\) and in Australia\(^{75,78,82}\). While the evidence is mixed, the majority of this research indicates that consumers find the use of colour-coding to indicate nutrient levels to be the most helpful labelling approach. The area is highly political, with the food industry generally opposed to traffic-light nutrition labels\(^{73,83}\) whilst many public health organisations advocate for their mandatory adoption\(^{84-85}\). Recent reports indicate that the food industry spent a staggering EUR1 billion successfully lobbying against the introduction of traffic-light nutrition labelling in the European Union\(^{86}\). In the US, the Institute of Medicine is currently undertaking a review of front-of-pack nutrition labelling\(^{87}\). A similar review is currently underway in Australia\(^{65}\) and a recent report by the National Preventative Health Taskforce recommended the implementation of a standardised front-of-pack nutrition labelling system\(^{88}\).

Front-of-pack nutrition labelling is widely identified as a potential tool for improving the nutrition of the population\(^{61,63,89}\). Advocates of various schemes argue that they not only help consumers make healthier food choices but also have an impact on product development: encouraging food manufacturers to alter the nutritional composition of their foods in beneficial ways. Despite some studies supporting these arguments (for example, an investigation into the impact of the ‘Pick the Tick’ program on the salt content of food\(^{90}\) and a recent study into product reformulation in response to the ‘Choices’ nutrition logo\(^{91}\)), there is little published evidence on the impact that labelling schemes have had on population health. Furthermore, a 2007 review found that there is very little evidence of consumer use of front-of-pack nutrition information in a ‘real world’ setting and the effect of labels on food purchases\(^{89}\). Moreover, the cost-effectiveness of nutrition labelling interventions has not been widely researched\(^{70}\).

As governments, industry groups and organisations consider various policy options for addressing DRCD and obesity in particular, evidence of the impact
and consumer response to front-of-pack nutrition labelling is likely to be highly valuable in informing their decisions.

1.8 Food-related taxes and subsidies

There is strong evidence that food purchases are influenced by the price of food. This is in addition to factors such as taste, mood, convenience, habitual behaviour, and pleasure that are known to influence food purchases. Furthermore, there is growing evidence that higher prices of less healthy foods and beverages (relative to healthier ones) are associated with increases in BMI and the prevalence of obesity.

In recognition of the importance of price in food purchase decisions, the potential to use fiscal policy measures, such as taxes and subsidies, as tools to alter the diet of the population has been widely identified. Indeed, there is a strong precedent of using economic instruments to influence health. In Australia, for example, a tax on tobacco has been in place for a number of years and this has led to a sustained reduction in tobacco consumption. Internationally, there is a wide variety of taxes levied on food, but the intention of these taxes is normally to raise revenue rather than to change diet and improve health. However, the potential for food taxes and subsidies to improve nutrition has gained increasing attention in recent years, and countries such as Finland and Denmark are currently considering the modification of food taxes as part of their efforts to combat obesity. Initiatives such as these are likely to use nutrient profiling as part of decisions about the foods to which taxes or subsidies should apply.

This is an emerging research area and there is currently only limited evidence indicating the effect that altering the relative prices of healthy and unhealthy foods is likely to have on food-purchasing patterns. Laboratory-based studies indicate that increasing the prices of unhealthy foods can decrease the purchases of those foods and lead to reduced overall energy intake. In addition, there
is some evidence to indicate that monetary incentives that encourage the purchase of healthier items may be effective in improving the nutritional value of food purchases.\textsuperscript{107} This research has been conducted primarily in controlled situations and there is very little research on the effects of food taxes and subsidies on behaviour and health in ‘real world’ environments.\textsuperscript{93,104} While favourable effects have been seen for the purchase of discounted low-fat snacks from vending machines\textsuperscript{108} and fruit and vegetables in response to discount coupons\textsuperscript{109}, a recent randomised control trial (the ‘SHOP’ trial) conducted in a supermarket environment in New Zealand found that price discounts did not have a significant effect on nutrients purchased.\textsuperscript{110} However, recent evidence from modelling studies in the UK indicates that targeted food taxes and subsidies could produce modest but meaningful changes in food consumption and substantial reductions in DRCD.\textsuperscript{43,111} There does not appear to be any published evidence of the likely impact of a tax on unhealthy food in the Australian context.

1.9 Modelling the impact of obesity prevention interventions

1.9.1 Previous obesity prevention intervention modelling studies

There is an increasing recognition of the need for preventative health investments to be informed by the best-available evidence of effectiveness and cost-effectiveness.\textsuperscript{112-113} However, there is limited empirical evidence of the effectiveness and cost-effectiveness of obesity prevention policy interventions.\textsuperscript{114-115} In the absence of empirical effectiveness data, modelled estimates of the impact of policy interventions are increasingly important to assess the potential impact of these interventions and to guide resource allocation decisions.\textsuperscript{116-117}

In recent years, a limited number of modelling studies have investigated the cost-effectiveness of various potential obesity prevention interventions. The Assessing the Cost-Effectiveness of Obesity (ACE-Obesity) study\textsuperscript{115} evaluated 13 interventions targeted at children and adolescents in Australia. In this study, the
one regulation-based intervention (‘reduction of television advertising of high fat and/or high sugar foods and drinks to children’) emerged as the intervention likely to offer the greatest health benefit and was also likely to save costs from a societal perspective.\textsuperscript{115} The Assessing Cost-Effectiveness in Prevention (ACE-Prevention) project,\textsuperscript{118} of which aspects of this research form a part, assessed the cost-effectiveness of 123 preventative interventions for addressing the NCD burden in Australia. Generally speaking, the results of this project showed that policy interventions that apply to whole populations tend to be more effective and cost-effective than targeted interventions that aim to convince individuals to change their behaviour.\textsuperscript{118} Studies by the Organisation for Economic Co-operation and Development (OECD) into the cost-effectiveness of a broad range of interventions for the prevention of chronic disease\textsuperscript{119} and obesity in particular\textsuperscript{120} also found that the majority of policy interventions targeting large population groups were likely to be cost-effective, with fiscal measures estimated as cost saving.

\subsection*{1.9.2 Logic pathway for modelling intervention effects}

The evidence-base informing the modelling of policy interventions is typically less strong than for clinical interventions. This is partly due to the fact that conducting randomised controlled trials is often not feasible for many policy interventions.\textsuperscript{113} Furthermore, population intervention studies typically only report outcomes of changes in key behaviours, such as energy intake or physical activity levels, rather than anthropometric outcomes, such as body weight or BMI changes.\textsuperscript{121} In addition, studies are usually of too short a duration to reliably estimate health outcomes that may take years to manifest.\textsuperscript{121} Accordingly, modelled estimates of the potential impact of policy interventions on health outcomes are typically based on logic pathways that outline the steps by which an intervention may be expected to lead to changes in behaviour and, ultimately, changes in health outcomes. Overall intervention effects are estimated based on
the relations between input and outcome variables at each step of the logic pathway, using the best-available evidence at each step.\textsuperscript{115}

An example of a logic pathway, developed by Swinburn et al.\textsuperscript{122}, that has been used to assess the impact of obesity prevention interventions\textsuperscript{115} is depicted in Figure 1.2. Unlike other logic pathways that have been developed to model the impact of single interventions, for example food-related taxes\textsuperscript{111} or restrictions on food advertising\textsuperscript{123}, the pathway shown in Figure 1.2 can be applied to multiple types of obesity prevention interventions. However, it does not facilitate modelling of the steps by which a change in policy leads to changes in diet and behaviour. Furthermore, it does not take into account impacts of policy and dietary changes beyond obesity, such as impacts on DRCDs more broadly.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{logic_pathway.png}
\caption{A logic pathway for modelling changes in eating and physical activity patterns to changes in body weight, BMI and prevalence of obesity}
\end{figure}

\subsection*{1.9.3 Estimating a change in body weight from a change in energy balance}

In the absence of empirical evidence indicating the impact of an intervention on body weight, one of the key steps in a logic pathway used to measure the impact
of an intervention is estimating the relation between a change in total energy intake (TEI) or total energy expenditure (TEE) (or, more simply, a change in energy balance, assuming that TEI and TEE are in dynamic equilibrium)\textsuperscript{23,122} and a change in body weight. Modelling the effects of changes in energy balance on individual body weight changes is highly complex,\textsuperscript{124-127} and simpler methods are needed to estimate this relation for interventions operating at the population level.\textsuperscript{122}

In order to estimate this relation, Hill et al.\textsuperscript{128} took the approach of back-extrapolating a change in energy balance from observed changes in mean population body weight assuming that the body converts excess energy into storage (that is, extra body weight) with an efficiency of 50%. Using this method, they derived a value for the progressive, daily energy imbalance needed to explain population body weight gain in adults over time – a concept they called the ‘energy gap’.\textsuperscript{122} However, there is substantial disagreement about the magnitude and even the definition of this energy gap.\textsuperscript{122,129-132} Another approach to estimating the relation between energy balance and body weight is to use reliably measured data of TEE to quantify the relation between TEE and body weight. Using a large sample of data collected using doubly-labelled water – the ‘gold-standard’ for measuring TEE\textsuperscript{133} – Swinburn et al.\textsuperscript{122} derived a simple equation for predicting the mean change in population body weight in response to a change in energy balance for children (aged 4 – 18 years). This equation was subsequently used as a component of the modelling within the ACE-Obesity study.\textsuperscript{115} Similar equations have been proposed for adults (aged \geq 18 years) using mathematical models of human energy expenditure by Hall et al.\textsuperscript{127,134} and other, less reliable, means of estimating changes in energy balance (such as food frequency questionnaires\textsuperscript{135}). However, prior to research conducted as part of this thesis, doubly-labelled water data had not been used to derive a similar equation for adults.

In summary, there is clearly an urgent need to fill the gap in the evidence base for understanding the potential impact of policy interventions for obesity.
At the same time, there is a need to further develop modelling techniques in an effort to increase the reliability of modelled estimates.

1.10 Research aims and objectives

In light of the previous research discussed above, the aims of this research were to make a substantial contribution to existing knowledge of the role and potential impact of policy interventions targeting obesity prevention, and to provide evidence to support policy makers and researchers tackling this issue. More specifically, the objectives of this research were to:

1. Develop a framework for comprehensive and systematic identification of areas for obesity prevention policy action.
2. Identify the potential role of nutrient profiling for obesity prevention, and construct a logic model to demonstrate the pathways by which nutrient profiling interventions can affect health outcomes.
3. Derive an equation to predict body weight change in response to a given change in energy balance for adults, to be used to model the potential impact of nutrient profiling interventions at a population level.
5. Model the cost-effectiveness of selected promising nutrient profiling interventions (front-of-pack traffic-light nutrition labelling and selected food-related taxes) from an obesity prevention perspective in Australia.

In addressing these aims and objectives, the thesis sought to answer the following research question:

“What is the role of nutrient profiling interventions in obesity prevention and what are the potential health impacts of selected promising nutrient profiling interventions in Australia?”
The primary hypothesis tested was that selected population-wide nutrient profiling interventions were cost-effective options for preventing obesity.

1.11 Significance of this research

The significance of this research can be summarised in the following points:

- Obesity is a significant public health issue. It has been identified as one of the most serious health challenges globally,\(^1\) and, in Australia, is designated as a national health priority.\(^{17}\) This research addressed this significant public health issue by examining the role and potential impact of policy interventions targeted at obesity prevention.

- The frameworks and models developed as part of this research provide tools for various stakeholders (including local, state and national governments, NGOs and private industry) to identify areas for obesity prevention action and to assess their impact. This can assist these stakeholders in developing comprehensive and coherent strategies.

- The empirical and modelled evidence produced as part of this research regarding the cost-effectiveness of different policy options can be used to inform the decisions of policy makers in their obesity prevention efforts.

- The frameworks, models and evidence produced as part of this research can be applied to problems beyond obesity, such as DRCD more generally.

These points will be expanded upon throughout the thesis with examples and scenarios provided.
1.12 Thesis structure

This thesis is presented as a series of manuscripts, each designed to stand on their own. However, when taken together, the manuscripts serve to address the research aims and objectives, and answer the research question posed above.

This chapter has provided an introduction to the research, reviewed the relevant literature, and set out the research aims and objectives. Chapter 2 presents the research design, outlining the theoretical perspective adopted, the studies making up the thesis, and an overview of the methods used in each of the studies.

The manuscripts making up the bulk of the thesis are presented in Chapters 3 through to 8, with some manuscripts grouped together in forming these chapters. Each of the manuscripts is written in the conventional publication style for their target journals and they are presented as such. Because each manuscript is designed to stand alone, there is an inevitable degree of repetition when they are read together, particularly in the literature presented in their ‘Background’ sections. The references for each manuscript are incorporated as part of the manuscripts. References cited in parts of the thesis that are not part of a manuscript are provided at the end of the thesis. The manuscripts were all written in conjunction with other researchers, and the relative contributions of each of the manuscripts’ authors are provided before each manuscript is presented.

Chapter 3 consists of two manuscripts that outline a framework for obesity prevention policies. Chapter 4 consists of a manuscript that identifies the role and potential impact of nutrient profiling interventions on DRCD, including a logic pathway that can be used to model intervention effects. Chapter 5 consists of two manuscripts and a related letter to the editor of the journal in which the manuscripts were published. The first manuscript estimates the relation between changes in energy balance and changes in body weight for adults – an important component of the logic pathway for modelling intervention effects. The second manuscript illustrates the way in which the relation can be applied by examining
the relative contributions of increased energy intake and decreased physical activity to the obesity epidemic in the US.

Chapter 6 consists of a manuscript that reports the results of a study that investigated the impact of traffic-light nutrition labelling on food purchases in the UK. The manuscript in Chapter 7 reports the results of a study that investigated the impact of traffic-light nutrition labelling on food purchases in Australia. The chapter also includes results from a survey of consumers conducted as part of the same study. Chapter 8 consists of a manuscript that reports modelled estimates of the cost-effectiveness of traffic-light nutrition labelling and a tax on unhealthy foods in Australia.

The final chapter (Chapter 9) provides a synthesis of the research findings, discusses their implications and limitations, and highlights directions for future research.
Chapter 2: Research design

2.1 Chapter overview

This chapter describes the way in which the research was designed to address the research aims and objectives. A combination of different research methods was used, with each method selected based on its appropriateness for addressing the particular research objective in a practical, reliable and rigorous way, given the time and resource constraints of the overall research project. The different methods used in addressing each of the research objectives are summarised in Table 2.1.

This chapter is structured as follows. Firstly, the theoretical perspective that underpinned the research approach is specified. This is followed by an overview of the research methods used in each of the six studies making up the thesis. The discussion of methods in this chapter is at a high-level only, with greater detail provided in the ‘Methods’ section of each of the manuscripts presented in subsequent chapters.
Table 2.1  Research objectives and corresponding research methods used

<table>
<thead>
<tr>
<th>Research objective</th>
<th>Study</th>
<th>Research methods</th>
</tr>
</thead>
</table>
| 1. Develop a framework for comprehensive and systematic identification of areas for obesity prevention policy action | A     | • Literature review  
• Input from panel of experts                                                    |
| 2. Identify the potential role of nutrient profiling for obesity prevention, and construct a logic model to demonstrate the pathways by which nutrient profiling interventions can affect health outcomes | B     | • Literature review                                    |
| 3. Derive an equation to predict body weight change in response to a given change in energy balance for adults, to be used to model the potential impact of nutrient profiling interventions at a population level | C     | • Statistical analysis of previously collected primary data |
| 4. Collect empirical evidence on the impact of front-of-pack traffic-light nutrition labelling on consumer food purchases | D     | • Quasi-experimental study in the UK                   |
|                                                                                   | E     | • Quasi-experimental study in Australia  
• Survey                                                                          |
| 5. Model the cost-effectiveness of selected promising nutrient profiling interventions (front-of-pack traffic-light nutrition labelling and selected food-related taxes) from an obesity prevention perspective in Australia | F     | • Epidemiological modelling  
• Economic evaluation                                                               |
2.2 Theoretical perspective

In undertaking this research, a positivist theoretical perspective was adopted. Neuman explains that positivism sees social science as “an organised method for combining deductive logic with precise empirical observations of individual behaviour in order to discover and confirm a set of probabilistic causal laws that can be used to predict general patterns of human activity”. This perspective can be contrasted with other theoretical approaches, such as interpretivism and structuralism.

The key ontological and epistemological assumptions underlying positivism can be summarised as follows:

- there is an objective external (‘real’) world that is independent of those who observe it;
- observed facts and events are independent of the value system, state of knowledge and experience of the observer;
- the relationships between objects in the real world are discoverable by observation of facts and events, and generalisation from them; and,
- causal and predictive theories can be built to explain the real world.

2.3 Solution-oriented approach

A solution-oriented research paradigm was adopted in line with the approach to obesity research recommended by Robinson and Sirard. Under this approach, the primary focus is on what can be done to solve the problem rather than what is to blame. This approach was adopted with a view to undertaking research with immediate relevance to health that can directly inform public policy action. This paradigm can be contrasted with the complementary problem-oriented
research paradigm that places greater emphasis on identifying causes and correlates of diseases and risk factors.

2.4 Study A: Policy framework

2.4.1 Study objective

The objective of this study was to develop a framework for comprehensive and systematic identification of areas for obesity prevention policy action. The study aimed to address the research question: “What are the potential areas for policy intervention for obesity prevention?”

2.4.2 Study design

This study addressed the stated objective by developing a multi-layered framework for obesity prevention policy action, utilising core concepts from the public health and health promotion literature.

The first step in developing the framework was to review the literature of previously recognised obesity prevention policy actions and previously proposed frameworks. From this literature review, the WHO framework for the implementation of the Global Strategy on Diet, Physical Activity and Health (DPAS)\(^3\) was selected to form the foundation of the framework developed in this study. The WHO framework was then modified to incorporate core concepts from the ‘new nutrition sciences’ literature,\(^33\) as well as three different public health approaches to addressing obesity prevention: the socio-ecological or ‘upstream’ approach, the behavioural or ‘midstream’ approach, and the health services or ‘downstream’ approach.\(^139\)
The modified WHO framework was then extended to include a series of analysis grids for each of the three public health approaches. These analysis grids classify policy areas by the sector to which they apply and the level of governance responsible for their administration. A series of workshops was then conducted with public health policy researchers and experienced public health practitioners in Melbourne, Australia to discuss the policy areas identified in the literature review. I convened these workshops, set the agendas and co-facilitated the main sessions. The workshops served to identify additional policy areas and clarify the scope of each policy area in an Australian context. Finally, the analysis grids were populated with a selection of policy areas to illustrate the way in which the overall framework can be applied in the Australian context.

Further details of the methods used in this study are presented in Chapter 3.

2.4.3 Scope of the study

The framework and the examples used to populate each of the analysis grids relate to the Australian environment. These examples may be relevant to other countries with similar social, economic, cultural and political contexts for policy making (for example, some other OECD countries) but are likely to need modification for use in other countries.

The organisation of policy approaches into different analysis grids provides a means to highlight policy targets, identify who is responsible for policy actions, and define places of intervention. However, the framework is not designed to indicate priority areas for action. Moreover, the inclusion of particular policy areas as part of the framework is not meant to indicate that there is evidence supporting the effectiveness of policy interventions in that area. In using the framework as part of the process of developing and implementing an overall obesity prevention strategy, specific policy interventions within each policy area would need to be defined. A systematic process of bringing about policy change
is likely to require working with relevant stakeholders to prioritise policy areas, analysing the influences and constraints operating in each of the potential policy areas, and estimating the likely impacts of specific interventions. These aspects are not included as part of the framework.

2.5 Study B: Nutrient profiling

2.5.1 Study objective

The objectives of this study were to identify the potential role of nutrient profiling for obesity prevention, and to construct a logic model to demonstrate the pathways by which nutrient profiling interventions can affect health outcomes. Furthermore, the study aimed to consider the feasibility of using a common nutrient profiling system to underpin the multiple potential applications. The study sought to address the research question: “What are the potential applications of nutrient profiling and how do they impact on obesity?”

2.5.2 Study design

The literature was searched to identify previously described applications of nutrient profiling and the components used in developing nutrient profiling models. In addition, the literature was reviewed to identify potential impacts of food policy interventions, and logic pathways previously used to model the impact of food policy and obesity-related interventions.

The applications of nutrient profiling identified in the literature were categorised using the classic “Four ‘P’s of Marketing” (Product, Promotion, Place and Price) framework in an effort to classify the multiple potential applications in a comprehensive and systematic way. The logic pathway developed by Swinburn et al. was used as a foundation for developing a logic pathway for modelling the
potential impact of nutrient profiling interventions. The Swinburn et al. logic pathway was expanded to include the steps by which changes in policy lead to changes in behaviour. Furthermore, the impacts of food policy changes on DRCD outcomes – beyond just obesity – were also incorporated. In addition, the economic, social and environmental impacts of policy changes were included in the logic pathway. The feasibility of a common nutrient profiling system was assessed by examining the implications of different model design decisions and their suitability to different purposes.

Further details of the methods used in this study are presented in Chapter 4.

2.5.3 Scope of the study

This study proposed a framework for identifying and classifying potential applications of nutrient profiling, presented a logic pathway that can be used to model the potential impact of nutrient profiling interventions, and examined the feasibility of a common nutrient profiling system to underpin multiple potential applications. While the focus of the overall research was on obesity prevention, this study also considered the impact of nutrient profiling interventions on DRCD more generally.

The study did not consider the process for developing a common nutrient profiling system and the related critical success factors. The study only addressed the technical aspects of developing a nutrient profiling model at a high-level, and did not consider the process of validating nutrient profiling models.
2.6 Study C: Energy balance equation for adults

2.6.1 Study objective

The objective of this study was to derive an equation to predict mean population body weight change in response to a given change in mean energy balance in a population of adults. This equation could then be used to model the potential impact of nutrient profiling and other policy interventions on obesity at a population level. The study aimed to address the research question: “How much does mean population body weight change in response to a given change in energy balance in a population of adults?”

2.6.2 Study design

This study replicated the design used to develop an equation for predicting the mean change in population body weight in response to a change in energy balance for children (aged 4 – 18 years). In this case, data from studies that had previously measured TEE using standard doubly-labelled water techniques in adults (aged ≥ 18 years) were collected from eight centres internationally. In total, cross-sectional data for 1,399 adults were collected, and data for body weight, TEE, height, sex, and age were included in the analysis. The key assumptions used in the previous analysis for children were applied: firstly, that the TEE measured by doubly-labelled water is equivalent to TEI (that is, TEE = TEI = energy flux), and secondly, that energy flux and body weight are interdependent and can be considered to be in a dynamic balance. Regression models were applied to the data to estimate the relation between TEE and body weight, adjusted for height, sex, and age. The findings were compared with the dataset used for the previous study of 963 children. In addition, some methodological changes to the regression models were made in response to a ‘Letter to the Editor’ regarding the original published version of the equation.
These changes ensured consistency with other mathematical models previously developed.

Further analysis was conducted in order to demonstrate one of the ways in which the equation developed as part of this study can be applied. Using food energy supply data for the US as a proxy for TEI, the equations for children and adults were used to estimate the change in mean population body weights in the US between the 1970s and 2000s. The predicted changes in mean population body weights from the equations were then compared to body weight increases measured in representative US surveys over the same period. By comparing the predicted to the measured results, it was possible to make observations regarding the relative contributions of increased energy intake and reduced physical activity to the US obesity epidemic.

Further details of the methods used in this study are presented in Chapter 5.

2.6.3 Scope of the study

This study developed an equation to relate changes in energy balance to changes in body weight for adults at the population level. The equation could be used to model the effect of population-wide obesity prevention interventions on mean population body weight, but caution is needed in applying the equation to individuals.

It can be expected that the relation between energy balance and body weight developed in this study can be applied across populations in high-income countries. However, it is uncertain whether the same relation exists for other populations, for example, where there is substantial under-nutrition.
2.7 Study D: Traffic-light nutrition labelling in the UK

2.7.1 Study objective

A key objective of this research was to collect empirical evidence on the impact of front-of-pack traffic-light nutrition information on consumer food purchases. The specific objective of this study was to analyse sales data from a UK supermarket that had implemented front-of-pack traffic-light nutrition labelling on selected products. The study aimed to address the research question: “Did the introduction of front-of-pack traffic-light nutrition labelling influence the relative healthiness of consumer food purchases in the UK?”

2.7.2 Study design

The study was conducted in conjunction with a major UK retailer (the UK Retailer). The UK Retailer operates a chain of over 1,000 supermarket stores across the UK. The UK Retailer progressively introduced front-of-pack traffic-light nutrition labelling, in the format recommended by the UK FSA, onto a selection of their ‘own-brand’ products across various food categories in 2007. Prior to the introduction of the traffic-light labels, all products in these categories had a table of nutrition information on the back-of-pack. Traffic-light labels were only introduced on the UK Retailer’s ‘own-brand’ products, and not onto other products in the UK Retailer’s stores. At the time that the traffic-light labels were introduced, the UK Retailer did not evaluate their impact on consumer purchases. In October 2007, I approached the UK Retailer and proposed to work with them to evaluate the impact of the introduction of traffic-light labels on sales. They agreed to provide relevant point-of-sales data in order to address the research question posed above.

By using the sales data from the UK Retailer to conduct a post-hoc analysis of the impact of the introduction of traffic-light labels, a quasi-experimental design was
adopted. Quasi-experimental studies are studies where the investigator does not have full control over the assignment or timing of the intervention but where the study is still conducted as if it were an experiment. In this case, this design was selected primarily for opportunistic reasons to take advantage of the sales data that the UK Retailer agreed to provide. However, the decision to adopt this method also reflected the belief that conducting a randomised control trial to achieve the study objective was not practical or feasible in this case. This research method was preferred to pure experimental methods (for example, observing consumer behaviour in a simulated and controlled shopping environment) as it was considered desirable to investigate consumer behaviour in a ‘real-world’ setting. Similarly, this method was preferred over surveys or focus groups examining consumer intentions as the research focus was on the actual purchasing behaviour of consumers rather than their intended behaviour. Furthermore, sales data are relatively free from the recall bias or misreporting commonly encountered in traditional dietary surveys. Indeed, a recent review identified that the use of supermarket sales data has great potential to be used as a tool to monitor population food purchases and can be successfully used to evaluate the effectiveness of intervention programs.

The analysis method was to examine the sales data to assess the initial impact of the introduction of traffic-light labels in selected food categories. For the selected products, sales data before and after the introduction of traffic-light labels were compared. Changes in sales were then analysed according to the relative healthiness of the products (measured in various ways). The quasi-experimental design in a supermarket environment meant that the external validity of the study was likely to be strong. However, the lack of a suitable control had the potential to substantially weaken the internal validity of the study, and the extent to which any observed changes in sales could be attributed to the introduction of traffic-light labels was uncertain. For this reason, and given the highly dynamic nature of the supermarket environment, it was important to select analysis methods that aimed to minimise the potential impact of factors beyond the introduction of traffic-light labels. Accordingly, only the short-term (4-week) impact of traffic-
light labels was considered – this was deemed long enough to observe any changes in sales whilst minimising the opportunity for other factors (such as changes in prices and store design) to play a role. Furthermore, analysis methods were selected to take into account the impact of seasonality, product promotions and product-life cycle.

Further details of the methods used in this study are presented in Chapter 6.

2.7.3 Scope of the study

The study investigated the short-term change in sales of products in which traffic-light labels were introduced. The study did not consider changes in sales of products that did not have traffic-light labels introduced. Furthermore, the study did not assess longer-term impacts of the traffic-light labels beyond their initial introduction. Importantly, only a limited number of the factors known to influence supermarket sales were taken into account in analysing the results.

The study did not assess consumer perceptions of traffic-light labels nor did it take into account the way in which consumers used the labels as part of their purchasing decisions. In addition, the study only investigated changes in consumer purchases and did not specifically consider changes in food consumption – although it is reasonable to assume that food purchases reflect food consumption patterns.

The study also did not consider other impacts of the introduction of traffic-light labels, such as their impact on the nutrition knowledge of consumers or the degree to which the labels affected product formulation and re-formulation.
2.7.4 Role of the UK Retailer

The UK Retailer provided product point-of-sales data for all of the food categories in which traffic-light labels were introduced, across all of their stores. In addition, sales data and associated customer demographic information were provided from their customer loyalty card scheme. This loyalty card data represented a subset of the overall sales data (not all customers made use of a loyalty card when making purchases).

Staff from the UK Retailer assisted in extracting data for analysis from the corporate information systems. They also provided contextual information regarding the timing and circumstances under which traffic-light labels were introduced and the prevailing retail and organisational conditions.

I signed a contract with the UK Retailer regarding the terms and conditions of the research. They agreed to allow me to report the results of the research in this thesis and in academic and industry publications, provided that no confidential information was disclosed without their consent. In addition, the agreement allowed the UK Retailer to review and comment on any proposed publication prior to submission for publication with the express stipulation that they had no editorial rights over the content of the academic work. The UK Retailer reimbursed me for my travel within the UK in connection with this study but I did not receive any other financial consideration from the UK Retailer, nor did any of my research collaborators.

2.8 Study E: Traffic-light nutrition labelling in Australia

2.8.1 Study objective

As per Study D, this study addressed the research objective of collecting empirical evidence on the impact of traffic-light nutrition labelling on consumer
This study aimed to assess the impact of traffic-light nutrition labelling on supermarket food purchases in Australia, and to answer the research question: “Did the introduction of traffic-light nutrition labelling influence the relative healthiness of consumer food purchases in Australia?”

### 2.8.2 Study design

The study was conducted in conjunction with a major national supermarket chain in Australia (the Australian Retailer). In April 2007, I approached the Australian Retailer and proposed to work with them to conduct a trial of traffic-light nutrition labelling. After a series of meetings discussing the feasibility of various study designs, it was agreed to conduct a trial using their online grocery store. This was preferred to a trial in the physical supermarket environment primarily because it overcame the need to physically place labels on individual products – which would have proved impractical. The online grocery store also represented a more controlled and more stable environment than a physical supermarket.

At the time of the study, the Australian Retailer operated two online supermarkets that sold the same set of products at the same prices but with differing website addresses, corporate branding and user interfaces. This quasi-experimental study was conducted as a 10-week trial on one of the online supermarkets (the ‘intervention’ store). Prior to the trial, neither the intervention store nor the other online store (the ‘comparison’ store) provided product-level nutrition information for any of the products sold. For the duration of the trial, traffic-light nutrition information in the form of four colour-coded indicators representing a product’s relative levels of fat, saturated fat, sugar and sodium content, was displayed on the product listing page of a selection of the Australian Retailer’s ‘own-brand’ products on the intervention store. No nutrition information was provided on products in the comparison store during the trial period. The nutrition criteria for the traffic-light indicators were based on the criteria recommended by the UK FSA. The changes in sales before and after the introduction of traffic-light
nutrition information were examined both within the intervention store and in the comparison store. Changes in sales were analysed according to the relative healthiness of the products (measured in various ways).

In order to gain insight into customers’ awareness of the traffic-light nutrition information and its perceived utility, customers were also surveyed as part of the study. During the trial, all visitors to the intervention store were invited to anonymously complete a self-report questionnaire. This use of this survey was approved by the Ethics Committee of Deakin University (EC 237-2007), and all survey participants provided informed consent online.

While the use of the comparison store in this study did not reflect a randomised control design, the internal validity of the study was nevertheless relatively strong. Prices on the online stores did not change throughout the study period, and none of the products that received traffic-light nutrition information were on promotion during this time. The stability of the environment and the use of the comparison store provided confidence that any observed changes in sales could reasonably be attributed to the introduction of traffic-light nutrition information. However, due to the differences between the online and physical shopping environment, the extent to which the results of the study can be generalised to the broader supermarket environment is uncertain.

Further details of the methods used in this study are presented in Chapter 7.

2.8.3 Scope of the study

For the products for which traffic-light nutrition information was introduced, sales on the intervention store during the trial period were compared to a corresponding period before the trial, and to sales on the comparison store. As with the UK study (Study D), the study did not consider changes in sales of products that did not have traffic-light nutrition information introduced. In
addition, the study did not specifically consider changes in food consumption – although, once again, it is reasonable to assume that food purchases reflect food consumption patterns. The study only assessed changes in sales during the trial period and not subsequently.

Through the use of the online survey, the study assessed customer awareness of the traffic-light nutrition information and its perceived utility. However, the study did not take into account the way in which consumers used the nutrition information as part of their purchasing decisions nor its impact on nutrition knowledge.

### 2.8.4 Role of the Australian Retailer

I worked directly with staff at the Australian Retailer to design and implement the study. After the trial, the Australian Retailer provided product level sales data for all of the relevant food categories in both the intervention and comparison stores for the relevant period. The Australian Retailer was not involved in the analysis of the results.

I signed a contract with the Australian Retailer regarding the terms and conditions of the research. They agreed to allow me to report the results of the research in this thesis and in academic and industry publications, provided that no confidential information was disclosed without their consent. In addition, the agreement allowed the Australian Retailer to review and comment on any proposed publication prior to submission for publication with the express stipulation that they had no editorial rights over the content of the academic work. I did not receive any financial consideration from the Australian Retailer in connection with this study, nor did any of my research collaborators.
2.9 Study F: Cost-effectiveness modelling

2.9.1 Study objective

This study directly tested the primary hypothesis of this research: that selected population-wide nutrient profiling interventions were cost-effective options for preventing obesity. The objective of this study was to model the likely cost and potential impact of front-of-pack traffic-light nutrition labelling and a food-related tax from an obesity prevention perspective in Australia. The study aimed to address the following research questions:

1. “What is the potential cost-effectiveness of modelled behaviour change in response to front-of-pack traffic-light nutrition labelling in Australia?”
2. “What is the potential cost-effectiveness of modelled behaviour change in response to a tax on selected unhealthy foods in Australia?”

2.9.2 Study design

This study formed part of the ACE-Prevention project, which aimed to provide a comprehensive analysis of the comparative cost-effectiveness of 123 preventative interventions for addressing the NCD burden in Australia.\textsuperscript{118} All analyses undertaken in ACE-Prevention adhered to a detailed economic protocol specifically designed for the project.\textsuperscript{117-118} However, unlike many of the other interventions modelled using the Assessing Cost-Effectiveness (ACE) methodology,\textsuperscript{117} this study did not include stakeholders in the process of selecting and specifying the intervention, providing expert input and interpreting the results.

The nutrition labelling intervention was specified as the mandatory inclusion of front-of-pack traffic-light nutrition labelling on products sold in selected food categories in Australia, coupled with a one-year national social marketing
campaign to educate and inform the population on how to interpret the labels. The tax intervention was specified as the imposition of a tax on foods in selected unhealthy food categories that would have the effect of raising the consumer-end prices of products in these categories by 10%.

In the absence of direct evidence of the effect of the selected interventions on BMI and health outcomes, a logic pathway – based on the logic pathway developed in Study B – was used to identify the steps in estimating the impact of each intervention from an obesity perspective. At each stage of the logic pathway, the best available evidence, in some cases supplemented with reasoned assumptions, was used to estimate the likely effect of the interventions on body weight and BMI. A previously developed epidemiological model was then used to estimate the changes in health outcomes, measured in disability adjusted life years (DALYs) averted, resulting from the estimated changes in body weight and BMI. Associated resource use was measured and costed using pathway analysis, based on a limited societal perspective. The cost-effectiveness of each intervention was modelled for the 2003 Australian adult population (aged ≥ 20 years) in accordance with the ACE-Prevention economic protocol, and uncertainty estimates for the results were provided. The results of the cost-effectiveness modelling were supplemented by a qualitative analysis of other factors (such as the strength of evidence, equity, feasibility and sustainability of the interventions) that were likely to be important to policy makers when making resource allocation decisions.

Further details of the methods used in this study are presented in Chapter 8.

2.9.3 Scope of the study

The study examined the potential cost-effectiveness of front-of-pack traffic-light nutrition labelling and a food-related tax from an obesity perspective in Australia. The study only examined the potential impact of the interventions on adults and
did not consider their potential impact on children – this was because the epidemiological model used to estimate changes in health outcomes based on changes in BMI was developed only for adults.

For the front-of-pack traffic-light nutrition labelling intervention, only the effects of the intervention on consumer supermarket purchases in selected food categories were taken into account. The potential impact of the intervention on product formulation and re-formulation was not considered, nor were the potential benefits of better informed consumers quantified. Changes to restaurant menu labelling were not considered. For the tax intervention, only an excise tax on selected food categories was examined. Other potential fiscal measures, such as a tax on restaurant meals or subsidies on healthy foods, were not considered. The specific mechanism by which the tax would be implemented and administered was also not considered in detail. The potential impacts of the interventions on different socio-economic groups were not examined.

In performing the cost-effectiveness analysis, a health sector perspective was adopted, with some costs to the industry also included. Accordingly, broader societal impacts of the interventions (such as their effect on employment and productivity) were not taken into account. In terms of the logic pathway developed in Study B, only a subset of the potential impacts of the interventions was considered. With regard to health outcomes, only diseases related to obesity were taken into account in the modelling, and the impact on DRCD more generally was not considered.

The results of the study are likely to be similar if the analysis was applied to other high-income countries; however, country-specific factors (such as nutrition behaviours, disease burdens, and economic and socio-cultural environments) are likely to impact on the results.
2.10 Summary

This chapter has described the overall approach to this research and described the six studies making up the thesis. While each study addressed a specific research objective and related research question, when taken collectively they served to address the overall research aims and the over-arching research question posed in Chapter 1.

It is noted that the primary hypothesis tested as part of this research was only directly examined in Study F. In this sense, Study F brought the research together, with many aspects of the other studies incorporated as part of Study F:

- the logic model developed in Study B informed the pathway by which the intervention effects were modelled;
- the equation developed in Study C was used to calculate how estimated changes in energy intake resulting from each intervention would result in changes in mean population body weight; and
- the empirical evidence collected in Studies D and E was used to inform the estimate of the impact of the nutrition labelling intervention on population energy intake, taking into account that the scenario modelled (mandatory implementation of traffic-light nutrition labelling on all products in selected food categories, accompanied by an education campaign) was different to the scenarios investigated in Studies D and E.

Furthermore, the framework developed in Study A was useful in understanding the overall context within which individual policy interventions, such as those modelled in Study F, were likely to fit into an overall obesity prevention strategy.
Chapter 3: Framework for obesity prevention policies

Chapter overview

This chapter reports on Study A of this research, and consists of two related manuscripts. The first manuscript sets out a structure for systematic identification of areas for obesity prevention policy action across the food system and full range of physical activity environments. The second manuscript places the analysis grids from the first manuscript within a broader framework for comprehensive identification of obesity prevention policy areas.
Manuscript 1

Sacks G, Swinburn B, Lawrence M. A systematic policy approach to changing the food system and physical activity environments to prevent obesity. Aust New Zealand Health Policy 2008;5:13

DEAKIN UNIVERSITY

STATEMENT OF CONTRIBUTION OF CO-AUTHORS

Declaration by candidate

In the case of the manuscript named above, the nature and extent of my contribution to the work was the following:

<table>
<thead>
<tr>
<th>Nature of contribution</th>
<th>Extent of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jointly developed the major concepts, drafted the manuscript, collated comments from other authors and responded to reviewers, approved the final manuscript, corresponding author</td>
<td>80%</td>
</tr>
</tbody>
</table>

The following co-authors contributed to the work:

<table>
<thead>
<tr>
<th>Name</th>
<th>Nature of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boyd Swinburn</td>
<td>Jointly developed the major concepts, provided comments on drafts of the manuscript, read and approved the final manuscript</td>
</tr>
<tr>
<td>Mark Lawrence</td>
<td>Jointly developed the major concepts, provided comments on drafts of the manuscript, read and approved the final manuscript</td>
</tr>
</tbody>
</table>

Gary Sacks
25 October 2010

Candidate’s Name          Signature          Date
Declaration by co-authors

The authors listed above have certified that:

1. The above declaration correctly reflects the nature and extent of the candidate’s contribution to this work, and the nature of the contribution of each of the co-authors.
2. They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise.
3. They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication.
4. There are no other authors of the publication according to these criteria.
5. Potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit.
6. They agree to the use of the publication in the student’s thesis and its publication on the Australasian Digital Thesis database consistent with any limitations set by publisher requirements.

Principal supervisor confirmation

I have sighted email or other correspondence from all co-authors confirming the above-mentioned certifications.

Boyd Swinburn

________________
Supervisor’s Name

________________
Signature

25 October 2010

________________
Date
Title: A systematic policy approach to changing the food system and physical activity environments to prevent obesity

Authors: Gary Sacks ¹*, Boyd Swinburn ¹, Mark Lawrence ¹

¹ School of Exercise and Nutrition Sciences, Deakin University, Melbourne, Australia

* All correspondence to Gary Sacks, WHO Collaborating Centre for Obesity Prevention, Deakin University, 221 Burwood Highway, Melbourne VIC 3125, Australia. Tel +61(0) 3 9244 6036. Fax +61(0) 3 9244 6640. Email: gary.sacks@deakin.edu.au

Competing interests: The authors declare that they have no competing interests.

Journal: Australia and New Zealand Health Policy. Received: 22 October 2007. Accepted for publication: 5 June 2008.
Abstract

As obesity prevention becomes an increasing health priority in many countries, including Australia and New Zealand, the challenge that governments are now facing is how to adopt a systematic policy approach to increase healthy eating and regular physical activity. This article sets out a structure for systematically identifying areas for obesity prevention policy action across the food system and full range of physical activity environments. Areas amenable to policy intervention can be systematically identified by considering policy opportunities for each level of governance (local, state, national, international and organisational) in each sector of the food system (primary production, food processing, distribution, marketing, retail, catering and food service) and each sector that influences physical activity environments (infrastructure and planning, education, employment, transport, sport and recreation). Analysis grids are used to illustrate, in a structured fashion, the broad array of areas amenable to legal and regulatory intervention across all levels of governance and all relevant sectors. In the Australian context, potential regulatory policy intervention areas are widespread throughout the food system, e.g., land-use zoning (primary production within local government), food safety (food processing within state government), food labelling (retail within national government). Policy areas for influencing physical activity are predominantly local and state government responsibilities including, for example, walking and cycling environments (infrastructure and planning sector) and physical activity education in schools (education sector). The analysis structure presented in this article provides a tool to systematically identify policy gaps, barriers and opportunities for obesity prevention, as part of the process of developing and implementing a comprehensive obesity prevention strategy. It also serves to highlight the need for a coordinated approach to policy development and implementation across all levels of government in order to ensure complementary policy action.
**Background**

The prevalence of obesity has increased to such an extent in recent decades that it has been recognised as a public health crisis in many countries, including Australia and New Zealand [1, 2]. The Australian National Health and Medical Research Council (NHMRC) has identified obesity as a priority health issue for the current triennium [3] and the New Zealand government has identified the reduction of obesity as one of its population health objectives [4].

Reliance on education and treatment strategies alone is unlikely to be sufficiently effective or sustainable to stem the obesity epidemic, and there is widespread agreement that major changes to the current obesogenic environments will also be necessary [5]. Such environmental changes often need to be driven by policy, for example, increasing the opportunities for active transport (physical environment), making healthy food choices more affordable (economic environment) and changing attitudes about food marketing to children (socio-cultural environment) are unlikely to be successful without the backing of supportive policy [6]. Policy approaches are also highly appropriate for reaching multiple sectors of the community, including socio-economically disadvantaged populations where obesity levels are disproportionately high [7, 8]. These reasons, along with the need for potent, sustainable and cost-effective strategies to reduce obesity prevalence all point towards the importance of policy approaches [9].

In recent years, many authors have discussed policy options available to government to prevent obesity. For example, French, Story and Jeffery [10] and Nestle and Jacobson [11] list potential environmental strategies and policy recommendations for reducing the prevalence of obesity, and Hayne, Moran and Ford [12] suggest regulatory levers worthy of consideration. While the lists generated by these authors are useful in showing the wide range of policy options available, they do not necessarily reflect a systematic approach. In order to ensure that obesity prevention policies are logical and coherent and that no major policy gaps or barriers are overlooked, we argue that it is valuable to start with a...
systematic scan of opportunities for intervention. A systematic approach will also ensure that synergies among policy actions can be identified and isolated policy actions that might be inconsistent with overall policy objectives can be avoided.

This article sets out a structure for systematically identifying areas for obesity prevention policy action across the food system and full range of physical activity environments, and across all levels of government. Within this structure, the article then categorises a selection of obesity prevention policy areas identified in the literature as they apply to the Australian context. In so doing, this article illustrates and classifies the broad array of legal and regulatory interventions that can be used to alter the food system and physical environments to help prevent obesity.

**Methods**

A literature search was conducted to gain perspective on the previously recognised obesity prevention policy actions that focus on changes to the food system and physical activity environments. The search aimed to locate a range of articles referring to obesity prevention policies in medical, economics, policy and law journals as well as in the ‘grey’ literature (government and non-government organisation reports). A combination of ‘Overweight’, ‘Obesity’ and ‘Social Control, Formal’ were used as MeSH (Medical Subject Headings) search terms in the ‘Medline’ database, while a combination of ‘Obesity’ and ‘Policy’ were used as search terms in the ‘EconLIT’ and ‘Business Source Premier’ databases. The authors were referred to other scientific literature and relevant grey literature by their contacts in the fields of obesity prevention, public health law and public health nutrition.

In reviewing the policy action examples from the literature, we confined our analysis to laws and regulations, including formal written codes and decisions that bear legal authority. In so doing, we aim to highlight the wide array of legal
intervention areas available, supporting the views of authors such as Nestle [13] and Gostin [14] who believe that legal and regulatory approaches have thus far been under-utilised in obesity prevention efforts. In our definition of laws and regulations, we included, for example, government policies or individual school policies on the types of food which may be sold in schools because these are codified and enforceable but we did not include non-enforceable guidelines or health promotion programs on school food. Also, we included rule-based economic interventions, such as taxes and subsidies, but not funding allocations for health promotion programs. Our scope included institutional policies within government agencies, non-governmental organisations and the private sector because these were considered rules with a degree of enforceability, and could be considered to complement the policy interventions at a government level. While we note the importance of other policy instruments (such as service delivery, programs and advocacy) available to governments and other specific interventions that are not enforceable, such as guidelines, professional practice and social norms [15], we have not focused on these specific options.

The discussions, issues and examples sourced from the relevant literature were categorised into policy areas. In this context, we define a ‘policy area’ as a content area in which enforceable rules could reasonably be implemented as specific policy interventions. In identifying these policy areas we recognise that specific policy interventions (e.g., legislation, regulations, other enforceable rules or policies) which could be applied in each policy area would still need to be defined further, taking into account the constraints and peculiarities of the particular policy environment. We classified policy areas under particular jurisdictions or levels of government based on the jurisdiction that typically has responsibility for administering policies in that area.

In areas where policies are enacted and administered at one level but enforced at a lower level of government, such as aspects of food safety in Australia where local governments typically enforce laws made at state level, the policy area was classified under the level of government at which the policy is administered.
Classifying the policy areas across two dimensions

Once we had identified the set of policy areas for preventing obesity through changes to the food system and physical activity environments, we classified the policy areas across two dimensions: the level of governance that is primarily responsible for administering the policy action, and the sector to which the policy action applies most directly. Adoption of these two dimensions facilitates a practical and systematic approach to analysing the policy environment and mapping potential policy intervention areas, and is similar to the approach taken by Schmid et al. [15] in outlining a conceptual framework for public policy related to physical activity and Lawrence [16] in outlining public policy opportunities in relation to nutrition.

Multiple levels of governance

The first dimension of analysis recognises that multiple levels of governance are responsible for developing and implementing policy interventions. The levels of governance will vary from country to country so, for example, in Australia they include local government, state government, national government, as well as international governance (acknowledging that the policies of international organisations, such as the World Trade Organisation [17], can have significant bearing on the affairs of nation states). This dimension also incorporates the policies of organisations, such as government agencies, non-governmental organisations and the private sector, that may be used as tools for (or serve as barriers to) obesity prevention.

Inter-sectoral analysis

The second dimension of analysis recognises that the health sector has only limited influence over environmental determinants and individual behaviours that contribute to obesity. Instead, the health sector’s role and responsibility is
confined principally to obesity care and treatment and certain promotion and education activities. It is only by analysing the policy actions of other (non-health) sectors in government and society more broadly that a comprehensive approach to obesity prevention can be developed. This approach draws on the ‘healthy public policy’ strategy proposed by the World Health Organization [18], and places responsibility on policy-makers in all government sectors to be accountable for the obesity impact of their policy decisions.

We considered the particular sectors to include in the analyses of the food system and physical activity environments to be quite distinct from each other. Accordingly, a separate sectoral analysis was required for each of the food system and physical activity environments and these are discussed in the sections below.

**Policy actions that influence the food system**

In order to systematically analyse the policy actions that influence the food system, it is necessary to consider all sub-components of the food system, including primary production (e.g., agriculture and fishing) and the inputs to primary production (e.g., fertilisers, pesticides); food processing (e.g., dairies, abattoirs, canners, brewers); distribution (e.g., logistics, importers, exporters); marketing; retail (e.g., supermarkets, marketplaces); and catering and food service (e.g., restaurants, schools, hospitals) (adapted from [19]). As depicted in **Table 1**, these sectors comprise one dimension with which to analyse policies to influence the food system, with the level of governance on the other dimension. In this way, Table 1 can be used to consider the influence that the policy actions of each level of governance have on each component of the food system (e.g., the influence of national government policy with respect to primary production). The intention of obesity prevention policy change in these areas is typically to alter the food environment such that healthier choices are the easier choices for individuals.
The examples shown in Table 1 represent a selection of obesity prevention policy areas related to the food system in Australia, as identified in the literature [10 – 12, 17, 20 – 25], for which laws and regulations are potential policy instruments. In this context, the policy areas represent potential regulatory intervention points for shaping the food system to prevent obesity. It should be noted that the items in Table 1 are intended to be illustrative only and do not represent a complete set of potential policy areas in this domain. While the policy areas we have identified are drawn from the literature, we did not make a judgement or take into account the level of evidence supporting the likely effectiveness of interventions in these areas. This sort of evaluation of the policy options identified here, using methodologies such as that used in a previous study evaluating the cost-effectiveness of various interventions [26], would be a logical next step in the process of developing a comprehensive obesity strategy.

In populating the table it was noted that some issues, such as restricting marketing of foods to children, can be influenced by the policies of multiple levels of government as well as the policies of corporate organisations and industry bodies. In these cases, the policy area was placed within multiple cells in the table to reflect the multiple areas for potential policy action.

In reviewing the populated tables for a particular country or community, it is worth considering the implications of parts of the analysis grid that are ‘empty’. Typically, boxes are ‘empty’ because a particular level of government does not have jurisdiction to influence a particular sector, e.g., local government typically has no influence on broadcast food marketing, with the ‘empty’ box indicating there are no potential policy interventions in that sector for that level of government. However, the advantage of using these analysis grids as a systematic scanning tool to identify policy options is that presence of ‘empty’ boxes may prompt policy analysts to identify previously unrecognised policy opportunities. For example, perhaps local governments have a role to play in restricting marketing of unhealthy food through restrictions on the placement of billboards in the community.
Policy actions that influence physical activity environments

Obesity prevention policies targeting physical activity environments will seek to alter the environment to make increased levels of physical activity and decreased levels of sedentariness the easy choices for the population. In order to have an influence, policies will need to target the sectors that control the environments within which physical activity predominantly occurs. Physical activity settings are well-documented [27, 28] and can be readily translated into sectors to which policy can be targeted, including infrastructure and planning, education, employment, transport and sport and recreation (refer to Table 2). By examining these sectors on one dimension, with the level of governance on the other dimension, Table 2 can be used to consider how the policies of each level of governance can be used to influence the environment to increase the level of physical activity and decrease sedentary behaviour of the population.

The examples shown in Table 2 represent a selection of obesity prevention policy areas, as identified in the literature [10 – 12, 20 – 21, 23, 24], that can be used to influence physical activity environments in the Australian context. The policy areas in the table represent potential regulatory intervention points for shaping the physical activity environment to prevent obesity. Once again, it should be noted that the items in Table 2 are intended to be illustrative only and do not represent a complete set of potential obesity prevention policy areas in this domain, nor are they meant to indicate the potential effectiveness of interventions in the area.

It is notable in Table 2 that, in the Australian context, the majority of policy areas influencing physical activity environments fall under the responsibility of local and state governments. There appears to be less of a role for the national government and international policy actions in this area, which contrasts with the analysis of the food environment (Table 1) that shows a number of policy areas which would be amenable to national and international policy actions. It is also
noted that we did not identify policy areas related to sedentary behaviour (e.g., television viewing and online gaming) that would be amenable to the application of enforceable rules.

**Discussion**

The analysis grids presented in this article provide a tool for systematically scanning for policy opportunities to change the food system and physical activity environments to prevent obesity. The use of this tool as part of developing a comprehensive obesity strategy may help reduce the risks of the ad hoc approaches often adopted in addressing this issue by ensuring that all major policy gaps and opportunities are identified for subsequent evaluation. This type of analysis can be applied at the level of individual local, state and/or national governments, and can be used by a wide array of groups including policy developers and analysts, advocacy groups and researchers.

In examining illustrative examples of potential legal and regulatory intervention areas in the Australian context, the policy areas identified include areas in which there may be existing laws and regulations that:

- are obesogenic (i.e., create an environment that contributes to obesity), e.g., land-use laws that allow for a large concentration of fast-food outlets selling energy-dense foods, and agricultural subsidies that result in an over-supply of sugar;
- serve as barriers to efforts to prevent obesity, e.g., public liability laws as a barrier to opening school grounds after hours, and food safety laws that encourage packaged and not fresh food in pre-schools; and
- serve as facilitators to obesity prevention, e.g., mandatory physical education in schools, car-free areas of cities.
The policy areas may also include areas in which there are regulatory gaps or weaknesses which, if addressed, would enhance obesity prevention efforts, for example, restricting food marketing to children, implementing front of pack nutrition signposting systems. Gaps and weaknesses may manifest themselves in the manner in which policy is implemented and interpreted in practice. The area of urban planning is a good illustrative example here. While in some cases urban planning legislation mandates that health be considered in planning decisions, this can potentially be overruled in practice by more specific legislation pertaining to other aspects of design and planning. Furthermore, the lack of enforceable guidelines on how to include health requirements in planning decisions may lead to the requirements being overlooked in some cases.

The structure of the tables highlights that multiple sectors and multiple levels of government have a role to play in efforts to prevent obesity, and may be useful in providing additional clarity as to the areas in which sectors beyond the health sector can play a role. While this article has only considered policy options of a regulatory nature, the same structure could be used to systematically identify opportunities for use of other policy instruments, such as programs and funding allocations. It is envisaged that the structure presented in this article can be easily adapted to apply to most countries around the world. As the tables are used in different policy contexts, the robustness of the structure will be tested, and there will be opportunity for the structure to be incrementally refined. Furthermore, the use of the two-dimensional analysis grids could be extended to identify obesity prevention policy opportunities beyond those targeting the food system and physical activity environments, such as those influencing other determinants of health and those supporting health services and clinical interventions. This may be valuable in considering a more holistic approach to obesity prevention.
Conclusion

This article is intended to facilitate a systematic approach to identifying obesity prevention policies targeting the food system and physical activity environments. The analysis grids could provide a valuable tool for all levels and sectors of governments to use in developing and implementing their obesity prevention policy and actions. The broad array of potential regulatory policy interventions indicates the need to collect and evaluate evidence of the likely effectiveness of a range of interventions in order to inform an evidence-based prioritisation process.

The article highlights that a coordinated approach to policy development and implementation across all levels of government is necessary to deliver complementary policy action. Similarly, a collaborative ‘whole of government’ approach, spanning multiple-sectors, is required to avoid fragmented, overlapping or contradictory policies.

Where the structure presented in this article is used to map the policy environment and identify potential policy areas for intervention, this represents only an initial step in the overall process of bringing about policy change and subsequent implementation. The next steps as part of a systematic process are likely to be:

1. Working with relevant stakeholders to prioritise policy areas at each level of government to devise a prioritised short-list of potential intervention areas.
2. Analysing each of these potential intervention areas to understand the policy area in detail, including historical influences and constraints on policy change.
3. Defining specific interventions, and modelling their likely health and economic impacts, using the best available evidence to evaluate their effectiveness and cost-effectiveness.
Acknowledgements

The authors would like to thank Bebe Loff, Anna Peeters and Brad Crammond from Monash University for their contribution to the major concepts.
References


Table 1  ‘Policy areas’ that influence the food system (related to Australian context)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Local Government</th>
<th>State Government</th>
<th>National Government</th>
<th>International</th>
<th>Organisational</th>
</tr>
</thead>
</table>
| Primary production | • Land-use management  
<pre><code>              | • Community gardens                                   | • Primary production subsidies and taxes            | • Primary production subsidies and taxes     | • Primary production subsidies and taxes |                          |
</code></pre>
<p>|                  | • Primary production subsidies and taxes              | • Product composition standards                       |                                                   |                                          |                          |
| Food processing  | • Food safety                                         | • Food transport                                      | • Importation restrictions, subsidies and taxes   | • Trade arrangements                      |                          |
|                  |                                                       |                                                       | • Quarantine                                      |                                          |                          |
| Distribution     | • Food transport                                      | • Importation restrictions, subsidies and taxes       | • Trade arrangements                              |                                          |                          |
|                  |                                                       |                                                       | • Quarantine                                      |                                          |                          |
| Marketing        | • Marketing to children                              | • Marketing to children                               | • Marketing to children                           | • Marketing to children                   |                          |
|                  | • Marketing practices in schools                      | • Nutrient content disclosures in marketing material  |                                                   |                                          |                          |
|                  |                                                       | • Consumer protection (e.g., misleading advertising)  |                                                   |                                          |                          |</p>
<table>
<thead>
<tr>
<th>Retail</th>
<th>Catering / Food service</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Land-use management</td>
<td>- Nutrition information in restaurants</td>
</tr>
<tr>
<td>- Density of local</td>
<td>- Nutrition information in restaurants</td>
</tr>
<tr>
<td>fresh food retailers</td>
<td>- Nutrition information in restaurants</td>
</tr>
<tr>
<td>- Density of fast food</td>
<td>- Food safety</td>
</tr>
<tr>
<td>outlets</td>
<td>- Food safety</td>
</tr>
<tr>
<td>- Products sold in schools</td>
<td>- Nutrition labelling</td>
</tr>
<tr>
<td>- Nutrition labelling</td>
<td>- School food policies</td>
</tr>
<tr>
<td>- Health claims on food</td>
<td>- Standards for food served in workplaces</td>
</tr>
<tr>
<td>products</td>
<td>- Food procurement policies</td>
</tr>
<tr>
<td>- Incentive system for</td>
<td></td>
</tr>
<tr>
<td>welfare recipients to</td>
<td></td>
</tr>
<tr>
<td>buy healthy food</td>
<td></td>
</tr>
<tr>
<td>- Food taxes / subsidies</td>
<td></td>
</tr>
<tr>
<td>- Nutrition labelling</td>
<td></td>
</tr>
<tr>
<td>- Health claims on food</td>
<td></td>
</tr>
<tr>
<td>products</td>
<td></td>
</tr>
<tr>
<td>Sector</td>
<td>Local Government</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Infrastructure and planning</td>
<td>• Land use</td>
</tr>
<tr>
<td></td>
<td>management</td>
</tr>
<tr>
<td></td>
<td>(zoning)</td>
</tr>
<tr>
<td></td>
<td>• Walking</td>
</tr>
<tr>
<td></td>
<td>environment</td>
</tr>
<tr>
<td></td>
<td>• Cycling</td>
</tr>
<tr>
<td></td>
<td>environment</td>
</tr>
<tr>
<td>Education</td>
<td>• Physical education in schools</td>
</tr>
<tr>
<td></td>
<td>• Facilities for physical activity in schools</td>
</tr>
<tr>
<td>Employment</td>
<td>• Building design standards</td>
</tr>
<tr>
<td></td>
<td>• Public transport</td>
</tr>
<tr>
<td></td>
<td>• Traffic control</td>
</tr>
<tr>
<td></td>
<td>• Taxation incentives for using public transport</td>
</tr>
<tr>
<td>Transport</td>
<td>• Public transport</td>
</tr>
<tr>
<td></td>
<td>• Traffic control</td>
</tr>
<tr>
<td>Sport and recreation</td>
<td>Facilities for physical activity – built structures</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Facilities for physical activity – open spaces</td>
</tr>
<tr>
<td></td>
<td>Public liability</td>
</tr>
<tr>
<td></td>
<td>Public liability</td>
</tr>
<tr>
<td></td>
<td>Access of general community to school sport facilities</td>
</tr>
</tbody>
</table>
**Manuscript 2**


---

**DEAKIN UNIVERSITY**

**STATEMENT OF CONTRIBUTION OF CO-AUTHORS**

**Declaration by candidate**

In the case of the manuscript named above, the nature and extent of my contribution to the work was the following:

<table>
<thead>
<tr>
<th>Nature of contribution</th>
<th>Extent of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jointly developed the major concepts, drafted the manuscript, collated comments from other authors and responded to reviewers, approved the final manuscript, corresponding author</td>
<td>80%</td>
</tr>
</tbody>
</table>

The following co-authors contributed to the work:

<table>
<thead>
<tr>
<th>Name</th>
<th>Nature of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boyd Swinburn</td>
<td>Jointly developed the major concepts, provided comments on drafts of the manuscript, read and approved the final manuscript</td>
</tr>
<tr>
<td>Mark Lawrence</td>
<td>Jointly developed the major concepts, provided comments on drafts of the manuscript, read and approved the final manuscript</td>
</tr>
</tbody>
</table>

Gary Sacks

Candidate’s Name: ___________________ Signature: ___________________ Date: 25 October 2010
Declaration by co-authors

The authors listed above have certified that:

1. The above declaration correctly reflects the nature and extent of the candidate’s contribution to this work, and the nature of the contribution of each of the co-authors.
2. They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise.
3. They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication.
4. There are no other authors of the publication according to these criteria.
5. Potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit.
6. They agree to the use of the publication in the student’s thesis and its publication on the Australasian Digital Thesis database consistent with any limitations set by publisher requirements.

Principal supervisor confirmation

I have sighted email or other correspondence from all co-authors confirming the above-mentioned certifications.

Boyd Swinburn

25 October 2010

Supervisor’s Name  Signature  Date
Title: Obesity Policy Action framework and analysis grids for a comprehensive policy approach to reducing obesity

Authors: Gary Sacks 1*, Boyd Swinburn 1, Mark Lawrence 1

1 School of Exercise and Nutrition Sciences, Deakin University, Melbourne, Australia

* All correspondence to Gary Sacks, WHO Collaborating Centre for Obesity Prevention, Deakin University, 221 Burwood Highway, Melbourne VIC 3125, Australia. Tel +61(0) 3 9244 6036. Fax +61(0) 3 9244 6640. Email: gary.sacks@deakin.edu.au

Conflict of interest: The authors declare no conflict of interest.

Abstract

A comprehensive policy approach is needed to control the growing obesity epidemic. This paper proposes the Obesity Policy Action (OPA) framework, modified from the World Health Organization (WHO) framework for implementation of the Global Strategy on Diet, Physical Activity and Health, to provide specific guidance for governments to systematically identify areas for obesity policy action. The proposed framework incorporates three different public health approaches to addressing obesity: ‘upstream’ policies influence either the broad social and economic conditions of society (e.g., taxation, education, social security) or the food and physical activity environments to make healthy eating and physical activity choices easier; ‘midstream’ policies are aimed at directly influencing population behaviours; and ‘downstream’ policies support health services and clinical interventions. A set of grids for analysing potential policies to support obesity prevention and management are presented. The general pattern that emerges from populating the analysis grids as they relate to the Australian context are that all sectors and levels of government, non-governmental organisations and private businesses have multiple opportunities to contribute to reducing obesity. The proposed framework and analysis grids provide a comprehensive approach to mapping the policy environment related to obesity, and a tool for identifying policy gaps, barriers and opportunities.

Keywords: obesity prevention, policy, framework
Introduction

The prevention and control of non-communicable diseases, including the reduction of obesity prevalence, has been recognised as a key area for public health action globally (1). Furthermore, the recently endorsed World Health Organization (WHO) action plan for the global strategy for the prevention and control of non-communicable diseases (2) identifies policy approaches as a core component of actions to address risk factors for obesity. It is well-recognised that changes in policy can drive changes in obesogenic environments (physical, economic, and socio-cultural) (3), and can prove effective in reaching multiple sectors of the community, including socio-economically disadvantaged populations where obesity prevalence is disproportionately high in middle and high-income countries (4, 5).

In this paper ‘obesity prevention policy’ means the system of laws, regulatory measures, courses of action, and funding priorities for the prevention of obesity [based on (6)]. We take a broad view of health policy, considering policies that affect the set of institutions, organisations, services, and funding arrangements of the health care system, as well as policies that influence actions by public, private and voluntary organisations that have an impact on health (7). Accordingly, this definition covers action on the environmental and socio-economic determinants of health as well as population behaviours and health care provision.

The evidence base regarding the effectiveness and cost-effectiveness of policy-based obesity prevention interventions is very small and building the empirical and modelled evidence for policy interventions needs to be a priority (8). Nevertheless, many authors have identified potential policy options available to government to prevent obesity (9 – 12). While the lists generated by these authors are useful in showing the wide range of policy options available, they do not necessarily reflect a comprehensive approach. Brownson et al. (13) propose a conceptual model for understanding the prevention of chronic diseases through environmental and policy approaches, but their framework does not extend to
sufficient detail to systematically identify the full range of obesity prevention policy options. As governments around the world seek a strategic approach to tackle obesity, it will be increasingly important to consider the various policy options through a framework that is both comprehensive and systematic.

This paper proposes a framework and a set of analysis grids for comprehensively identifying areas for obesity prevention policy action. The framework provides a structure to understand the context within which obesity prevention policies translate into health, economic, social and environmental outcomes. The analysis grids provide a systematic way of organising potential policy action areas by the sector to which they apply and the level of governance responsible for their administration.

Methods

The WHO framework for the implementation of the Global Strategy on Diet, Physical Activity and Health (DPAS) (14) was used as the foundation for the proposed Obesity Policy Action (OPA) framework. The WHO developed the framework to assist ministries of health, other government agencies, as well as other stakeholders to monitor the progress of their actions in implementing the DPAS. As the overlying global approach for activities to promote healthy diets and physical activity, the DPAS is well-suited to be applied to obesity prevention policy actions.

In an effort to provide specific guidance for governments seeking to comprehensively and systematically identify areas for obesity policy action as part of their implementation of the DPAS, the WHO framework is modified to allow analysis at multiple layers, utilising core concepts from the public health and health promotion literature.
In order to both inform the development of the proposed framework and to populate the analysis grids, a literature search was conducted to gain perspective on the obesity prevention policy actions previously recognised. The discussions, issues and examples sourced from the literature were categorised into areas amenable to policy intervention, or more simply ‘policy areas’. The authors then conducted a series of workshops with fellow policy researchers and experienced public health practitioners in Melbourne, Australia to discuss the policy areas identified. These workshops served to identify additional policy areas and clarify the scope of each policy area in an Australian context. Given the lack of evidence of the effectiveness of different policy options (8), a programme logic approach was used to identify the potential policy areas (15). Accordingly, the inclusion of particular policy areas as part of the framework should not be taken necessarily to mean that there is evidence supporting the effectiveness of policy actions in that area.

**Results**

**Modifying the WHO framework to comprehensively cover policy options**

In developing the proposed OPA framework, the WHO framework for implementation of the DPAS (14) was modified in three ways in an effort to encompass the broad nature and scope of policy options (Figure 1).

The first modification recognises the broad range of policy instruments available to policy-makers. Whereas the WHO framework identifies that strategic leadership contributes to the adoption of supportive policies and programmes, the OPA framework delineates this further by highlighting that governments have multiple policy instruments at their disposal with which to achieve policy objectives. These policy instruments include service delivery, government spending and taxing, advocacy, and laws and regulations, and are used by governments according to their perceived appropriateness, efficiency,
effectiveness, equity and workability (16). Policy instruments such as education campaigns are often considered ‘soft’ or politically weak instruments; whereas laws and regulations can be considered ‘hard’ instruments (17).

Secondly, the OPA framework depicts the intended impact of the various policy instruments. As illustrated in Figure 2, the framework recognises that some policy actions are directed at shaping the environment in which we live (affecting behaviour indirectly), whereas other policy actions are aimed at directly influencing behaviour, and still others are targeted at supporting health services and clinical interventions. In so doing, the framework incorporates three different public health approaches (the socio-ecological or ‘upstream’ approach, the behavioural or ‘midstream’ approach, and the health services or ‘downstream’ approach) to addressing the obesity epidemic. The differences in these approaches are detailed in Table 1 [based on (18 – 20)].

The final modification is to the outcomes of policy changes. While the WHO identified health, economic and social outcomes, the OPA framework also recognises that it is important to explicitly consider environmental outcomes. This is in line with the evolving concepts of the scope of nutrition sciences (‘New Nutrition Science’) (21) and the close links between unhealthy lifestyles and environmental degradation (22). We recognise that policy intervention outcomes can be mediated through changes in behaviour, e.g., more supportive physical environments may lead to individuals exercising more which results in positive health outcomes, or could have direct effects, e.g., changes in food composition can lead to positive health outcomes without individuals changing their behaviour.

It is noted that the WHO framework identifies the importance of continued monitoring, evaluation and research throughout the process. This is reinforced in the OPA framework where these aspects occur at each step of the process and serve as a feedback mechanism. These components are particularly important given the current lack of evidence of the impact of different policy options.
Analysis grids to systematically identify areas for policy action

While the proposed framework described above sets out the context within which obesity action policies are translated into health, economic, social and environmental outcomes, a further layer of analysis is needed to systematically identify where roles and responsibilities for policy action are located. In this section we present a series of analysis grids, corresponding to each of the areas depicted in Figure 2, to enable a practical and structured analysis of potential policy intervention areas.

Obesity policy areas can be systematically analysed across two dimensions: the level of governance that is primarily responsible for administering the policy action, and the sector or setting to which the policy action applies most directly (23). The levels of governance to include are dependent on the government structure of the particular country being analysed. The particular sectors and settings to include in the analysis are dependent on the policy objective and the environment targeted. We have populated each of the analysis grids with a selection of policy areas related to the Australian environment to demonstrate the way in which the analysis grids can be used for policy analysis in a particular country or policy setting. The Australian example may be relevant to other countries with similar social, economic, cultural and political contexts for policy making (e.g., some other OECD countries) but is likely to need modification for use in other countries.

Policy actions that influence underlying determinants of health in society

The social determinants of health are embedded in the economic, political and social circumstances within which individuals and communities live. These determinants of health influence the extent to which individuals and communities possesses the physical, social, and personal resources to identify and achieve personal aspirations, satisfy needs, and cope with the environment (24). The
burden of poor health and disease, including obesity prevalence, is not distributed randomly within and across populations; instead, it is disproportionately located with those individuals and communities that are economically, politically and socially disadvantaged (25).

A government’s policies for obesity action, and policies for chronic disease prevention more generally, need to address the underlying determinants of health. The framework for analysing policies in this area includes sectors corresponding to each of the determinants on one dimension; with the levels of governance on the other, as set out in Table 2. The analysis grid can be used to map potential policy intervention points or identify potential barriers to obesity prevention at each level of governance with respect to each determinant of health.

As illustrated in Table 2, potential policy areas to consider in this section include the financial, education, employment and social policies that impact health in general and obesity in particular. Examples include policy areas such as trade agreements between countries (international), migration policies, personal income tax regimes and social security mechanisms (national government), community housing and education facilities (state government), and local crime prevention policies (local government).

Policy actions that influence food and physical activity environments

The intention of obesity prevention policies with respect to the food system is typically to alter the food environment such that healthier choices are the easier choices. Similarly, obesity prevention policies targeting physical activity environments will seek to alter the environment to make increased levels of physical activity and decreased levels of sedentariness the easy choices. In order to systematically analyse the policy actions that influence these environments, it is necessary to consider the policy actions of each level of governance on each component of the food system and on all sectors that influence the environments
within which physical activity / inactivity predominantly occurs (23). An analysis of these policy areas are set out in Tables 3 and 4 [modified from (23)].

There is a broad range of policy areas influencing the food environment, including local government policies on land-use, local and / or state government policies on food safety, and policies on agricultural subsidies operating at national and international levels. Some potential policy action areas, such as restricting marketing of unhealthy foods, can span all levels of governance, ranging from local restrictions on the placement of billboards to cross-jurisdictional restrictions on broadcast advertising.

Policy areas influencing physical activity environments include urban planning policies (at a local and / or state level), transport policies (at state and / or national levels) as well as organisational policies on the provision of facilities for physical activity. Policy areas may include areas where existing policies serve as barriers to obesity prevention (e.g., local public liability laws that serve as a barrier to opening school grounds after hours) and areas where there are opportunities for action (e.g., taxation incentives for use of public transport).

**Policy actions that directly influence behaviour**

The midstream policy approach aims to directly influence behaviour to control the population’s level of energy intake (by individuals eating less food or consuming less energy-dense foods) and increase the population’s levels of physical activity. For policies to directly influence behaviour, they need to have a direct effect in the settings in which people live their lives. Key settings where people eat and / or can be physically active include early childhood settings, education settings (e.g., schools, universities, colleges), workplaces, community and recreational facilities, households, hospitals, prisons and the military (26). Table 5 sets out the analysis grid for examining these policy areas.
There are opportunities in settings such as schools, pre-schools and workplaces (27) to have setting-specific organisational policies about food that can and cannot be eaten, or requiring participation in physical activity. However, government policy instruments to directly influence behaviour will typically take the form of education and campaign-based programmes that promote healthy behaviours – with opportunities for each level of government to tailor these campaigns in targeting multiple settings. Other ‘harder’ government policy instruments, such as laws and regulations, which seek to stipulate the behaviour of individuals, are very unlikely to be used in this domain. This is true for adults, where there are no conceivable laws which would directly dictate required eating or physical activity behaviours, as well as for children, despite greater societal obligations to protect children against ill health. One possible example of a hard policy instrument in this area would be mandatory physical education in the school curriculum but even this is likely to be a physical education rather than a physical activity requirement.

**Policy actions that support health services and clinical interventions**

The downstream approach to obesity action represents actions supporting health services and clinical interventions for individuals. As with the other parts of the framework, policy actions using this approach can be analysed based on the sector to which the policy action applies and the level of government implementing the policy. As set out in Table 6, the sector represents the component of the health sector (i.e., primary health care, secondary health care, tertiary health care, and therapeutic goods including pharmaceuticals).

The opportunities for obesity prevention through health service delivery are primarily in the area of targeting children who are overweight or obese in an attempt to reduce the subsequent incidence of adult obesity. Otherwise, the role of the health system is mainly aimed at obesity management, e.g., surgical and / or therapeutic treatment of existing obesity and its complications. Potential policy
areas include increasing the number of dietitians and nutritionists in hospitals, and subsidisation of weight-loss medication.

**Discussion**

The proposed OPA framework provides a tool for adopting a comprehensive approach to obesity policy action that is strategic and systematic. It is designed to promote the integration of a combination of policy approaches to ensure a complementary and coherent response to obesity. The organisation of policy approaches into different analysis grids provides a useful means to highlight policy targets, identify who is responsible for policy actions, and define places of intervention.

By populating the analysis grids with areas for potential policy action, we have demonstrated the large number of areas in which policy can be used in efforts to address obesity, spanning multiple sectors and levels of governance. These policy action areas include areas where there are policy gaps or weaknesses, as well as areas where existing policies may be obesogenic, i.e., create an environment that contributes towards obesity. It is important to recognise that the analysis grids are not designed to indicate priorities between the different policy elements, nor describe any interactions or causative relations between these policy elements.

We argue that there are synergies to be gained from integrating policy activities across the different public health approaches (upstream, midstream and downstream), sectors and settings, and different levels of governance. For example, policy activities that help make the healthy choices the easy choices (e.g., traffic-light labelling on the front of food products) complement those activities that inform individuals about healthy choices and how to put them into practice (e.g., campaigns educating children on selecting healthy foods). Similarly, policy activities at a local government level (e.g., restricting the placement of billboards advertising unhealthy foods) can complement activities at
other levels of government (e.g., restricting television advertising of unhealthy foods to children) or in other sectors (e.g., taxes on unhealthy foods).

The set of policies influencing the underlying determinants of health can be seen as fundamental to obesity prevention efforts. Nevertheless, it is important to recognise that the obesity issue alone is unlikely to be a major driver of policy change in these areas. This component of the framework is most relevant in highlighting the inter-relations between policy actions. Critically, the effectiveness of other policy actions designed to prevent obesity (such as promoting participation in sports) may be constrained by the effects of policies that influence the underlying determinants of health (such as taxation and financial policies that exaggerate income inequalities). The paradox that emerges from this analysis is that although it is the health sector that is responsible for meeting the burden associated with the treatment of obesity and related chronic diseases, the sector has minimal policy leverage over the determinants of such health outcomes.

Policies influencing the food and physical activity environments represent the greatest potential for policy action. There are multiple areas in which each level of government can act to influencing the food environment. While this presents multiple levers for action, it also highlights the importance of a coordinated approach to policy development and implementation across all levels of government. A collaborative ‘whole of government’ approach, spanning multiple-sectors, is required to avoid fragmented, overlapping or contradictory policies. In the Australian context, the majority of policy action areas influencing physical activity environments appear to be at a local and / or state level, with less of a role for national or regional governments in this area.

Government policy action aimed at directly influencing behaviour often appears to be almost exclusively limited to education and social marketing programs. There do not appear to be plausible regulations that would direct eating and physical activity behaviours in the same way that there are regulations which
require specific behaviours for wearing seatbelts, not smoking in restaurants, drinking under-age, and obeying traffic and occupational health and safety laws. This observation argues against the notion that government intervention to reduce obesity is akin to a ‘nanny’ state.

Policy actions supporting health services are predominantly focused on obesity management rather than prevention. Nevertheless, activities in the primary care sector, such as monitoring, screening and referrals to other health professionals, should play an important role in tackling obesity. While this paper does not consider the cost effectiveness of policy intervention, it is worth noting that downstream policy actions tend to be expensive and have a lower reach, particularly when compared with upstream policy actions.

**Conclusion**

The proposed OPA framework provides a valuable tool to use as part of the process of developing, implementing, monitoring and evaluating obesity prevention policy at all levels of government. It could also prove useful as a communication aid to highlight areas where governments have active policies, or equally importantly, where governments are not acting to prevent obesity.

The large number of policy areas, spanning multiple sectors and levels of governance, highlights that there may be value in conducting ‘obesity impact assessments’ on new policy proposals, as part of a comprehensive government strategy to address obesity. These impact analyses could assist in ‘obesity-proofing’ new policies.

Where the framework is used to map the policy environment and identify potential policy areas for intervention, this represents only an initial step in the overall process of bringing about policy change and subsequent implementation. Selected policy areas would then need to be defined in more detail and analysed
to understand the broad influences on policies in the area, the existing regulatory environment, and opportunities for change. For example, when considering the ‘walking environment’ as a policy area, it would be important to identify the way in which ‘walkability’ can be measured, recognise the vested interests that promote a car-friendly environment, understand the way in which urban planning laws are implemented and enforced, and examine jurisdictions that have been successful in promoting walking. This analysis would provide the appropriate context to enable relevant stakeholders to prioritise policy areas at each level of government. This would lead to defining specific policy interventions, and modelling their likely health and economic impacts, as part of a comprehensive obesity policy.

Acknowledgements

The authors would like to thank Bebe Loff, Anna Peeters and Brad Crammond from Monash University for their contribution to the major concepts, and Tim Lobstein (IOTF) and Shiriki Kumanyika (University of Pennsylvania) for their comments on the manuscript.
References


<table>
<thead>
<tr>
<th>Table 1</th>
<th>Public health approaches to obesity prevention [based on (18 – 20)]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Socio-ecological (upstream) approach</td>
</tr>
<tr>
<td>Perspective of the obesity epidemic</td>
<td>The economic, social, and physical environments are major determinants of population eating and physical activity behaviour patterns.</td>
</tr>
<tr>
<td>Obesity prevention intervention targets</td>
<td>Policy interventions shape the circumstances and conditions which are the underlying determinants of health and social equity in society. Policy actions target the food environments, physical activity environments, and the broader socio-economic environments (including taxation, employment, education, housing, and welfare) thus indirectly influencing population behaviours.</td>
</tr>
<tr>
<td>Responsibility for action</td>
<td>Primarily governments; with the private sector responsible to some extent (corporate social responsibility)</td>
</tr>
<tr>
<td>Primary policy outcome measures</td>
<td>Improved prosperity, social equity and environmental sustainability, together with improved health outcomes</td>
</tr>
<tr>
<td></td>
<td>Behavioural (midstream) approach</td>
</tr>
<tr>
<td></td>
<td>Population eating and physical activity behaviour patterns are major determinants of obesity prevalence.</td>
</tr>
<tr>
<td></td>
<td>Policy interventions target population or sub-population behaviour change aiming to improve eating and physical activity behaviours, using policy instruments such as social marketing and programs.</td>
</tr>
<tr>
<td></td>
<td>Governments, civil society and the private sector</td>
</tr>
<tr>
<td></td>
<td>Improved population eating and physical activity behaviour patterns and obesity prevalence</td>
</tr>
<tr>
<td></td>
<td>Health services (downstream) approach</td>
</tr>
<tr>
<td></td>
<td>Individual behaviours, motivations, genes and metabolism are major determinants of the presence of obesity in patients.</td>
</tr>
<tr>
<td></td>
<td>Policy interventions support health services and clinical interventions. The focus is on managing and reducing existing weight problems in individuals and working with families to prevent overweight or obese children becoming overweight or obese adults. This includes medically-managed, individual-based behaviour change.</td>
</tr>
<tr>
<td></td>
<td>Governments, health professionals and non-government health services</td>
</tr>
<tr>
<td></td>
<td>Improved anthropometry and disease risk for individuals</td>
</tr>
</tbody>
</table>
**Table 2**  Examples of policy areas that influence underlying determinants of health in society (related to Australian context)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Local Government</th>
<th>State Government</th>
<th>National Government</th>
<th>International</th>
<th>Organisational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finance</td>
<td>● Fiscal policy</td>
<td>● Fiscal policy</td>
<td>● Personal income tax regime</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commerce and trade</td>
<td>● Business taxes</td>
<td>● Business taxes</td>
<td>● Trade agreements</td>
<td>● Location of operations</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>● Education facilities</td>
<td>● National curricula</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td>● Industrial relations</td>
<td>● Standard working hours</td>
<td>● Corporate social responsibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social affairs</td>
<td>● Crime prevention</td>
<td>● Community housing</td>
<td>● Migration policies</td>
<td>● Social security</td>
<td></td>
</tr>
<tr>
<td>Other sectors</td>
<td>● Access to telecommunications</td>
<td>● Environmental management</td>
<td>● Corporate social responsibility</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3  
Examples of policy areas that influence food environments (related to Australian context) [modified from (23)]

<table>
<thead>
<tr>
<th>Sector</th>
<th>Local Government</th>
<th>State Government</th>
<th>National Government</th>
<th>International</th>
<th>Organisational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary production</td>
<td>• Land-use management</td>
<td>• Primary production subsidies and taxes</td>
<td>• Primary production subsidies and taxes</td>
<td>• Primary production subsidies and taxes</td>
<td>• Product composition standards</td>
</tr>
<tr>
<td></td>
<td>• Community gardens</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food processing</td>
<td></td>
<td>• Food safety</td>
<td>• Product composition standards</td>
<td>• Product composition standards</td>
<td></td>
</tr>
<tr>
<td>Distribution</td>
<td></td>
<td>• Food transport</td>
<td>• Importation restrictions, subsidies and taxes</td>
<td>• Trade arrangements</td>
<td></td>
</tr>
<tr>
<td>Marketing</td>
<td>• Restrictions on marketing of unhealthy food</td>
<td>• Restrictions on marketing of unhealthy food</td>
<td>• Restrictions on marketing of unhealthy food</td>
<td>• Restrictions on marketing of unhealthy food</td>
<td>• Restrictions on marketing of unhealthy food</td>
</tr>
<tr>
<td></td>
<td>• Promotion of marketing of healthy food</td>
<td>• Promotion of marketing of healthy food</td>
<td>• Promotion of marketing of healthy food</td>
<td>• Promotion of marketing of healthy food</td>
<td>• Promotion of marketing of healthy food</td>
</tr>
<tr>
<td></td>
<td>• Marketing practices in schools</td>
<td>• Promotion of marketing of healthy food</td>
<td>• Nutrient content disclosures in marketing material</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Consumer protection (e.g., misleading advertising)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

86
<table>
<thead>
<tr>
<th>Retail</th>
<th>Catering / Food service</th>
<th></th>
</tr>
</thead>
</table>
| • Land-use management  
• Density of local fresh food retailers  
• Density of fast food outlets | • Nutrition information in restaurants  
• Food safety |  |
| • Products sold in schools |  | • Nutrition labelling  
• Health claims on food products  
• Incentive system for welfare recipients to buy healthy food  
• Food taxes / subsidies |  |
|  |  | • Nutrition labelling  
• Health claims on food products |  |
|  |  | • School food policies  
• Standards for food served in workplaces  
• Food procurement policies |  |
### Table 4
Examples of policy areas that influence physical activity environments (related to Australian context) [modified from (23)]

<table>
<thead>
<tr>
<th>Sector</th>
<th>Local Government</th>
<th>State Government</th>
<th>National Government</th>
<th>International</th>
<th>Organisational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure and planning</td>
<td>• Land use management (zoning)</td>
<td>• Urban planning</td>
<td>• Roads</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Walking environment</td>
<td>• Roads</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Cycling environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>• Physical education in schools</td>
<td></td>
<td></td>
<td>• School policies on physical education, physical activity and sport</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Facilities for physical activity in schools</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td>• Building design standards</td>
<td></td>
<td></td>
<td>• Facilities for physical activity in workplaces</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Availability of showers and change room facilities for staff</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>• Public transport</td>
<td>• Public transport</td>
<td>• Taxation policies on cars</td>
<td>• Trade arrangements on motor vehicles</td>
<td>• School travel policies</td>
</tr>
<tr>
<td>----------------------------</td>
<td>--------------------------</td>
<td>--------------------------</td>
<td>-----------------------------</td>
<td>----------------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td></td>
<td>• Parking restrictions</td>
<td>• Traffic control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Traffic control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Sport and recreation       | • Facilities for physical activity –built structures | • Public liability       | • Access of general community to school sport facilities |                             |                        |
|                            | • Facilities for physical activity –open spaces      |                          |                             |                                        |                         |
|                            | • Public liability                                          |                          |                             |                                        |                         |
### Table 5  Examples of policy areas that directly influence behaviour (related to Australian context)

<table>
<thead>
<tr>
<th>Setting</th>
<th>Local Government</th>
<th>State Government</th>
<th>National Government</th>
<th>International</th>
<th>Organisational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early childcare settings</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Food policies</td>
<td>• Active play policies</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• School food policies</td>
<td>• Physical activity requirements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
</tr>
<tr>
<td>Education settings (e.g.,</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Mandatory physical education / activity in schools</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>schools, universities)</td>
<td></td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workplaces</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td></td>
</tr>
<tr>
<td>Community and recreational facilities</td>
<td>• Educate neighbourhood stores on selling healthier products</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td></td>
</tr>
<tr>
<td>Households</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Mass media promotion of healthy foods and physical activity</td>
<td>• Mass media promotion of healthy foods and physical activity</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td></td>
</tr>
<tr>
<td>Other settings (e.g., hospitals, prisons, military)</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td>• Campaigns and programs promoting healthy eating and physical activity</td>
<td></td>
</tr>
<tr>
<td>Health sector component</td>
<td>Local Government</td>
<td>State Government</td>
<td>National Government</td>
<td>International</td>
<td>Organisational</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------</td>
<td>-----------------</td>
<td>---------------------</td>
<td>---------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Primary care</td>
<td>• Healthy lifestyle counselling</td>
<td>• Number of nutritionists / dietitians • Subsidies for healthy lifestyle counselling</td>
<td>• Primary care partnerships</td>
<td>• Career development opportunities for nutritionists / dietitians</td>
<td></td>
</tr>
<tr>
<td>Secondary care</td>
<td>• Number of nutritionists / dietitians in hospitals</td>
<td>• Number of nutritionists / dietitians in hospitals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertiary care</td>
<td>• Hospital waiting lists for treatment by specialists</td>
<td>• Subsidies for treatment by specialists</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Therapeutic goods</td>
<td>• Subsidies for weight-loss medication</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 1  Obesity Policy Action framework: high-level schema for policy development, implementation and evaluation [modified from (14)]
Figure 2  Obesity Policy Action framework: breakdown of ‘upstream’, ‘midstream’ and ‘downstream’ policy targets

**Socio-ecological (upstream) approach**
- Policy actions that shape the economic, social and physical (built and natural) environments
- Policy actions that influence underlying determinants of health in society
- Policy actions that influence the food system environments

**Lifestyle (midstream) approach**
- Policy actions that directly influence behaviour (reducing energy intake and increasing physical activity)
- Policy actions that influence physical activity environments

**Health services (downstream) approach**
- Policy actions that support health services and clinical interventions

---

**Process**
- Strategic policy and leadership

**Output**
- Policy instruments
  - Service delivery
  - Government spending and taxing
  - Advocacy
  - Laws and regulations

**Impact**
- Supportive environment
  - Behaviour change

**Outcome**
- Health services
  - Economic
  - Social
  - Environment

---

**Monitoring, evaluation and research**
Chapter 4: Role and potential impact of nutrient profiling interventions

Chapter overview

This chapter reports on Study B of this research. The chapter consists of a single manuscript entitled, “Applications of nutrient profiling: potential role in diet-related chronic disease prevention and the feasibility of a core nutrient profiling system”.

Manuscript 3


DEAKIN UNIVERSITY

STATEMENT OF CONTRIBUTION OF CO-AUTHORS

Declaration by candidate

In the case of the manuscript named above, the nature and extent of my contribution to the work was the following:

<table>
<thead>
<tr>
<th>Nature of contribution</th>
<th>Extent of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jointly developed the major concepts, led the writing of the manuscript, collated comments from other authors and responded to reviewers, approved the final manuscript, corresponding author</td>
<td>60%</td>
</tr>
</tbody>
</table>

The following co-authors contributed to the work:

<table>
<thead>
<tr>
<th>Name</th>
<th>Nature of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mike Rayner</td>
<td>Jointly developed the major concepts, drafted parts of the manuscript, provided comments on drafts of the manuscript, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>Lynn Stockley</td>
<td>Jointly developed the major concepts, drafted parts of the manuscript, provided comments on drafts of the manuscript, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>Peter Scarborough</td>
<td>Jointly developed the major concepts, drafted parts of the manuscript, provided comments on drafts of the manuscript, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>Wendy Snowdon</td>
<td>Jointly developed the logic pathway, provided comments on drafts of the manuscript, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>Boyd Swinburn</td>
<td>Jointly developed the major concepts, provided comments on drafts of the manuscript, reviewed and approved the final manuscript</td>
</tr>
</tbody>
</table>

---

**Declaration by co-authors**

The authors listed above have certified that:

1. The above declaration correctly reflects the nature and extent of the candidate’s contribution to this work, and the nature of the contribution of each of the co-authors.
2. They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise.
3. They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication.
4. There are no other authors of the publication according to these criteria.
5. Potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit.
6. They agree to the use of the publication in the student’s thesis and its publication on the Australasian Digital Thesis database consistent with any limitations set by publisher requirements.

---

**Principal supervisor confirmation**

I have sighted email or other correspondence from all co-authors confirming the above-mentioned certifications.

---

<table>
<thead>
<tr>
<th>Boyd Swinburn</th>
<th>25 October 2010</th>
</tr>
</thead>
</table>

---
Title: Applications of nutrient profiling: potential role in diet-related chronic disease prevention and the feasibility of a core nutrient profiling system

Authors: Gary Sacks 1*, Mike Rayner 2, Lynn Stockley 2, Peter Scarborough 2, Wendy Snowdon 1, 3, Boyd Swinburn 1

1 WHO Collaborating Centre for Obesity Prevention, Deakin University, Melbourne, Australia
2 British Heart Foundation Health Promotion Research Group, Department of Public Health, University of Oxford, United Kingdom
3 Pacific Research Centre for the Prevention of Obesity and Non-communicable Diseases (C-POND), Fiji School of Medicine, Fiji

* All correspondence to Gary Sacks, WHO Collaborating Centre for Obesity Prevention, Deakin University, 221 Burwood Highway, Melbourne VIC 3125, Australia. Tel +61(0) 3 9244 6036. Fax +61(0) 3 9244 6640. Email: gary.sacks@deakin.edu.au

Conflict of interest: The authors declare no conflict of interest.

Abstract

**Background and objectives:** A number of different nutrient profiling models have been proposed and several applications of nutrient profiling identified. This paper outlines the potential role of nutrient profiling applications in the prevention of diet-related chronic disease (DRCD), and considers the feasibility of a core nutrient profiling system, which could be modified for purpose, to underpin the multiple potential applications in a particular country.

**Methods:** The “Four ‘P’s of Marketing” (Product, Promotion, Place and Price) are used as a framework for identifying and classifying potential applications of nutrient profiling. A logic pathway is then presented that can be used to gauge the potential impact of nutrient profiling interventions on changes in behaviour, changes in diet, and, ultimately, changes in DRCD outcomes. The feasibility of a core nutrient profiling system is assessed by examining the implications of different model design decisions and their suitability to different purposes.

**Results and conclusions:** There is substantial scope to use nutrient profiling as part of policies for the prevention of DRCD. A core nutrient profiling system underpinning the various applications is likely to reduce discrepancies and minimise confusion for regulators, manufacturers and consumers. It seems feasible that common elements, such as a standard scoring method, a core set of nutrients and food components, and defined food categories, could be incorporated as part of a core system, with additional application-specific criteria applying. However, in developing and implementing such a system, several country-specific contextual and technical factors would need to be balanced.

**Keywords:** nutrient profiling, diet-related chronic disease, applications
Background

Nutrient profiling is commonly defined as “the science of categorising foods according to their nutritional composition” (O’Neill 2004; Rayner et al. 2005; Townsend 2010). Nutrient profiling is typically used to categorise foods (using words, graphics or numbers) according to either the nutrient levels in the food (e.g., ‘high fat’, ‘low fat’, ‘source of fibre’, ‘energy dense, nutrient poor’) or with respect to the effects of consuming the food on a person’s health (e.g., ‘healthy’, ‘healthier option’, ‘less healthy’, ‘good for your heart’). These categorisations can form an important part of policies aimed at improving public health nutrition and preventing diet-related chronic disease (DRCD) (Rayner, Scarborough & Stockley 2004).

Nutrient profiling is currently being used as part of a number of nutrition policy applications around the world, and the number of different nutrient profiling models has increased rapidly in recent years (Stockley, Rayner & Kaur 2008). The most common use of nutrient profiling is in nutrition signposting schemes aimed at assisting consumers to make healthier food choices. Such schemes have been devised by governments (e.g., the Swedish National Food Administration’s ‘Keyhole’ scheme (Larsson & Lissner 1996; Swedish National Food Administration 2009)), non-governmental organisations (e.g., the National Heart Foundation of Australia’s ‘Pick-the-Tick’ scheme (National Heart Foundation of Australia 2008)) and multi-stakeholder groups (e.g., the United States ‘Smart Choices’ programme (Smart Choices Program 2010) (now discontinued)). Many governments around the world (e.g., Australia and New Zealand (Food Standards Australia New Zealand 2008) and the European Union (European Food Safety Authority 2010)) have also used, or propose to use, nutrient profiling in the regulation of nutrition and health claims. Furthermore, the United Kingdom (UK) Office of Communications base their restrictions on television advertising of food and drink products to children on the nutrient profiling model developed by the UK Food Standards Agency (Office of Communications United Kingdom 2007b), and products available for sale in schools often rely on a nutrient
profiling model to determine foods eligible for sale (e.g., the Australian Health School Canteens Guidelines (NSW Department of Health and NSW Department of Education and Training 2006)).

As governments seek to develop comprehensive, multi-pronged strategies for the prevention of DRCD and obesity in particular (World Health Organization 2008; Sacks, Swinburn & Lawrence 2009), it will be increasingly important that policy interventions are complementary in both their design and impact. With multiple potential applications of nutrient profiling and the increasing number of different nutrient profiling models globally, there are risks of unnecessary duplication, discrepancies between models, and confusion for regulators, manufacturers and consumers. For example, without due care, the nutrient profiling model developed for one application may contradict the nutrient profiling model developed for another application. The aims of this paper are to identify the potential role of nutrient profiling applications in the prevention of DRCD and consider the feasibility of using a common nutrient profiling system to underpin the multiple potential applications. Such a system, defined here as a “core nutrient profiling system”, would have some, but not necessarily all, design elements and structures that are used consistently across all applications.

The structure of the paper is as follows. Firstly, a framework for identifying and classifying the potential applications of nutrient profiling is proposed. A logic pathway is then presented that can be used to gauge the potential impact of nutrient profiling interventions on DRCD. The implications of different nutrient profiling model design decisions and their suitability to different applications are then discussed, and the feasibility of a core system examined.

There are many aspects to nutrient profiling and this paper does not attempt to address all the issues that are currently the subject of considerable debate. In particular, it does not seek to consider in detail the process of developing a nutrient profiling model nor the different methods for validating models (as
distinct from evaluating nutrient profiling interventions). These issues are dealt with in many of the references to this paper and elsewhere.

**Framework for identifying and classifying potential applications of nutrient profiling**

Several authors have identified multiple potential applications of nutrient profiling (Stockley, Rayner & Kaur 2008; Lobstein & Davies 2009; Townsend 2010); however, the lists generated by these authors do not necessarily reflect a systematic approach. In order to assist researchers and policy makers to identify and classify potential applications in a comprehensive and systematic way, a classification framework is warranted. This can help to ensure that consideration is given to all the potential uses of a model during its development and subsequently.

One of the objectives of public health nutrition policy is to shift populations towards healthier diets through changes in the food environment and, ultimately, eating behaviour. Consequently, insights from marketing – which is centred on strategies to influence behaviour – are likely to be valuable. Indeed, marketing principles are increasingly used in public health interventions (Rayner 2007; French et al. 2009). With this in mind, it is proposed that the potential applications of nutrient profiling can be categorised using the “Four ‘P’s of Marketing” (Product, Promotion, Place and Price), originally proposed in 1960 (McCarthy 1960). Examples of potential applications of nutrient profiling, classified using the “Four ‘P’s” framework are shown in Table 1.

In relation to the ‘Product’ dimension, nutrient profiling can help to decide which products should or should not be fortified, and it can provide standards and guidelines for product formulation and reformulation. From a ‘Promotion’ perspective, nutrient profiling can be used to regulate and set guidelines for commercial marketing to consumers. It can also be used in motivating individuals
to adopt healthier diets through, for example, social marketing that promotes products that meet ‘healthier’ criteria. In regards to ‘Place’, governments are increasingly regulating the availability of certain foods in schools (both at meal times and through vending), hospitals, prisons, and other public institutions. Nutrient profiling models can help governments and other organisations decide which foods should or should not be made available for sale and/or consumption. With respect to ‘Price’, nutrient profiling provides a method for categorising foods for taxation (or subsidy) purposes, and can also be used to assess whether retailer price reductions are in line with public health goals. Furthermore, nutrient profiling can be used as part of government food assistance programmes to decide which foods should be subsidised and which not. Future applications of nutrient profiling could potentially be expanded to include rankings of meals and diets (rather than individual products), overall marketing strategies and the relative ‘healthiness’ of brands and companies.

Logic pathway for evaluating the potential impact of interventions based on nutrient profiling

While the previous section illustrates that there are many potential applications of nutrient profiling, there is very little direct evidence of the potential impact of these types of interventions on DRCD outcomes (Townsend 2010). In the absence of empirical effectiveness data, modelled estimates are necessary to assess the potential impact of these interventions (Carter et al. 2008). Such estimates need to be based on a logic pathway that outlines the steps by which a change in policy (such as the implementation of one of the nutrient profiling applications) may be expected to lead progressively to changes in behaviour, changes in diet, and, ultimately, changes in DRCD outcomes.

A suggested logic pathway for estimating the effect of a change in food policy on changes in health outcomes is depicted in Figure 1, building on logic models previously described (Swinburn et al. 2006). As obesity is a major component of
DRCD, and in recognition of the influence of physical activity on obesity, the logic pathway shown in Figure 1 also includes changes to physical activity environments. Furthermore, the logic pathway identifies that policies may have effects that are not explicitly related to health outcomes – these may include economic, social and environmental impacts (Sacks, Swinburn & Lawrence 2009), e.g., policies promoting lower consumption of red meat may result in lower green-house gas emissions (McMichael et al. 2007).

The “Four ‘P’s” framework is again used in the logic pathway to illustrate the way in which policy changes lead to changes in eating behaviour. It is recognised that different policies may seek to influence different determinants of consumer choice. Some policies are designed to change environments which then lead to behaviour change (e.g., a change in taxes may result in a change in consumer-end food prices leading to consumption changes); whereas other policies target behaviour directly (e.g., a social marketing campaign aimed at getting people to eat more vegetables). Similarly, some changes to the food environment, e.g., small changes to product composition, may alter diet directly – not mediated through observable behaviour change.

While the logic pathway is presented as linear, it is recognised that many components of the pathway are inter-related, with feedback loops. For example, changes in food serving sizes may result in full, partial or no compensation in other aspects of food intake (Rolls 2009, 2010). Furthermore, changes in physical activity behaviour may result in compensatory changes in eating behaviour (Blundell et al. 2003) and other aspects of physical activity (Lynch, Corbin & Sidman 2009; Baggett et al. 2010).

In depicting the impact of changes in dietary intake on disease outcomes, the logic pathway presented in Figure 1 recognises that for some diseases there are good markers of disease risk with good supporting evidence (e.g., effect of salt consumption on blood pressure and associated cardiovascular disease risk (He & MacGregor 2002)); whereas other diseases have fewer markers (e.g., changes in
fruit and vegetable intake on certain cancers (World Cancer Research Fund / American Institute for Cancer Research 2007)). The specific intermediate risk factors and health outcomes shown in Figure 1 are intended to be illustrative only, and are based on available evidence of the relation between risk factors and disease outcomes (Ezzati et al. 2004; World Cancer Research Fund / American Institute for Cancer Research 2007).

The logic pathway presented in Figure 1 is consistent with those underpinning a number of modelling studies of food policy changes on health outcomes. The interventions modelled in these studies include changes to food advertising (Office of Communications United Kingdom 2007a), food labelling (Zarkin et al. 1993), food taxes (Nnoaham et al. 2009), consumption of snack foods (Lloyd-Williams et al. 2009), and a broad range of obesity prevention interventions (Haby et al. 2006).

Feasibility of a core nutrient profiling system underpinning multiple applications

In considering the feasibility of a core nutrient profiling system to underpin multiple potential applications, it is necessary, firstly, to consider the different design elements of nutrient profiling models and the different options available for each element. When designing or selecting a nutrient profiling model for a particular application, it is necessary to consider the following questions (Scarborough, Rayner & Stockley 2007): are criteria to be across-the-board or food category specific; which nutrients and other food components should be included; which base or combination of bases (e.g. per 100g, per 100kJ or per serving) is to be used; should the model apply threshold levels or use scoring; and what cut-off numbers should the model adopt. Some of the different options available for each of these questions, their suitability for different purposes and the implications of selecting each option are outlined in Table 2. The discussions in the table are meant to be indicative only, and a broader range of options (and
the possibility of combining different options) are likely to be available for each design element. It is recognised that without performing extensive modelling to assess the implications of particular technical decisions on the way in which foods are categorised by a model, it is often not possible to determine the best characteristics of a model to suit the purpose of a particular application.

The different options available in designing and selecting nutrient profiling models are suited for different purposes and have their relative advantages and disadvantages. For example, it may be appropriate for a model used to set compositional standards for processed meats to assess only a very small number of nutrients (e.g., fat and sodium content); whereas, a greater number of nutrients are likely to be valuable for models used for food labelling purposes. As such, it appears unlikely that a single nutrient profiling model could meet the specific needs of every potential application. Nevertheless, there appears to be scope for some design elements to be common across multiple applications, with additional application-specific criteria applying where necessary. For example, nutrient profiling models which use scoring systems as their basis are more amenable to adaptation than those which only use thresholds. This is because once a scoring system is in place, different score thresholds can be adopted to suit different purposes. An example of this is the nutrient profiling model proposed by Food Standards Australia New Zealand (FSANZ) for the regulation of health claims (Food Standards Australia New Zealand 2008). The preferred model for determining the eligibility of foods to carry health claims was based on the UK Food Standards Agency nutrient profiling model for use in regulating broadcast advertisements for children (Office of Communications United Kingdom 2007b). However, FSANZ modified the original UK model (which uses a scoring system) to include an additional score threshold for a new food category (which includes edible oils, edible oil spreads, butter, margarine, and cheese).

In addition, it would appear sensible to base a core nutrient profiling system on a set of nutrients and food components for which data are commonly available. For example, many countries mandate that food labels include nutrition information
for a limited number of nutrients, and in many cases, these are the only nutrients for which food composition data are publicly available. In these cases, it may be difficult to include other food components in a nutrient profiling model used for regulatory purposes. Detailed modelling may be useful here in identifying indicator nutrients that may serve as adequate substitutes for other nutrients (Rayner et al. 2005).

Models that apply to all foods and beverages (‘across-the-board’ models) are well-suited to applications, such as marketing regulations, which assess foods across the full range of products. In contrast, applications that aim to compare products within categories, such as compositional standards, are likely to benefit from the increased specificity of models with multiple food categories (‘category-specific’ models). Current evidence suggests that nutrient profiling models designed to promote a healthy diet should be category-specific but with a limited number of categories (Scarborough et al. 2010). Accordingly, it would seem useful to base a core nutrient profiling system on a small number of defined food categories that are applied consistently across applications.

Discussion

This paper has examined the potential applications of nutrient profiling, classifying the potential applications using the “Four ‘P’s of Marketing” framework and outlining the potential role of these applications in the prevention of DRCD using a logic pathway. The paper has also considered the feasibility of a core nutrient profiling system to underpin the multiple potential applications. The paper found that there appears to be scope to incorporate a standard scoring method, a common set of nutrients and food components, and defined food categories as part of a core nutrient profiling system, provided that some additional application-specific criteria can be applied.
It is important to be cognisant of the scope and limitations of nutrient profiling. Nutrient profiling cannot be expected to address all DRCD problems. One reason for this is that the nutrient composition of individual foods is not the only determinant of the overall nutrient composition of diets. The portion sizes of individual foods that consumers eat, the frequency of their consumption, the variety of different foods which make up the diets and the combinations in which they are eaten also contribute to the healthiness of the nutrient composition of diets. Furthermore, consumers select foods predominantly on the basis of taste, price, convenience, mood and social norms with the nutritional value of the food usually being a minor factor (Drewnowski 2010; Vyth et al. 2010). In addition, ethical concerns (e.g., welfare standards for farm animals), religious concerns (e.g., methods of slaughtering animals), and environmental concerns (e.g., the amount of greenhouse gases emitted during food production) play a role in food selection decisions. Nutrient profiling models do not currently take these factors into account. Some of these other factors influencing food choices have been defined (e.g., ‘organic’, ‘free-range’) so that consumers can have greater confidence in the nature of the foods being purchased, but there is scope for extending this as the recent trial on communicating the greenhouse gas costs of the food production to consumers in Sweden demonstrates (Climate Labelling for Food 2010).

While there is potential for using a core nutrient profiling system across multiple applications, it is recognised that certain conditions would need to be in place to ensure successful development and implementation of such a system. Early and sustained engagement with relevant stakeholders, including governments, the food industry, academia, nutritionists and non-government organisations, is especially critical. Other conditions for success include a clearly defined purpose for the system, a pre-planned and transparent process for developing and reviewing the system, and a realistic approach to model development taking into account understandability, cultural sensitivity and enforceability. Furthermore, this paper has not considered issues relating to implementation, monitoring and evaluation of interventions involving nutrient profiling models. Important aspects
to consider here include, for example, a cost-benefit analysis of whether or not change from existing systems can be justified and, if so, managing the change from existing systems that are well-established; gaining government support across jurisdictions and departments; selecting a governance model for enforcement and monitoring; and evaluating the effectiveness of the system. These issues are likely to be country- and region-specific and there is an urgent need for national governments and international organisations (such as the World Health Organization (WHO)) to provide leadership in this area.

Conclusion

There is significant potential for nutrient profiling to be used as a policy tool to improve public health nutrition and reduce the burden of DRCD. As nutrient profiling models and applications proliferate, there are risks of unnecessary duplication, discrepancies between models, and confusion for regulators, manufacturers and consumers. Accordingly, it is important that countries undertake the necessary analysis and modelling to determine the basic structure of a core nutrient profiling system to underpin multiple potential applications, and to examine the technical considerations and long-term costs and benefits. This is a relatively new area of research and there remain several technical, policy and implementation issues to be addressed. However, the reality of multiple systems being developed and applied is already upon us. This increases the urgency for international organisations, such as the WHO, to provide guidance to countries on how to proceed in implementing coherent nutrient profiling systems which can better inform consumer choice and promote population health.
Acknowledgements

Some of the concepts included in this manuscript were developed as part of the preparation of a document currently being drafted for the World Health Organization (WHO) by Mike Rayner, Peter Scarborough and Lynn Stockley with the draft title “Guiding principles and manual for the development and implementation of nutrient profile models”. The authors would like to thank Mark Lawrence, Dorothy Mackerras and Veronique Braesco for comments made on early drafts of this manuscript. Gary Sacks is supported by a Deakin University Postgraduate Research Scholarship.
References


McCarthy, EJ 1960, Basic marketing : a managerial approach, 1st edn, R. D. Irwin, Homewood, IL.


Townsend, MS 2010, 'Where is the science? What will it take to show that nutrient profiling systems work?', American Journal of Clinical Nutrition, vol. 91, no. 4, pp. 1109S-15S.


Table 1  Potential applications of nutrient profiling classified using the “Four ‘P’s of Marketing” framework, based on examples previously identified (Stockley, Rayner & Kaur 2008; Lobstein & Davies 2009; Townsend 2010)

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Potential application of nutrient profiling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>• Compositional standards for specific foods &lt;br&gt;• Product reformulation targets and guidelines &lt;br&gt;• Restrictions on product fortification</td>
</tr>
<tr>
<td>Promotion</td>
<td>• Regulation of health and nutrition claims &lt;br&gt;• Food labelling (regulations, voluntary schemes and health-related endorsements) &lt;br&gt;• Menu labelling &lt;br&gt;• Marketing and advertising regulations &lt;br&gt;• Social marketing campaigns</td>
</tr>
<tr>
<td>Place</td>
<td>• Standards for food procurement (public and private) &lt;br&gt;• Standards for food provision (schools, hospitals, other organisations) including vending and fund-raising &lt;br&gt;• Import regulations (based on nutrient standards of particular foods)</td>
</tr>
<tr>
<td>Price</td>
<td>• Taxes and subsidies for producers, manufacturers, retailers and consumers &lt;br&gt;• Government food subsidies for vulnerable groups e.g., people on a low income &lt;br&gt;• Price-based promotions by manufacturers and retailers</td>
</tr>
<tr>
<td>Component of nutrient profiling model</td>
<td>Options available</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>------------------</td>
</tr>
</tbody>
</table>
| Number of categories                 | One (‘all foods’) or two (‘foods and beverages’), often referred to as ‘across-the-board’ | When the purpose requires comparing foods across the full range of products, e.g., for overall nutrition education and for supporting a shift in consumption from, say, higher fat biscuits to fruit | • No need to define categories  
• Some foods that are healthier options within their category may be categorised as less healthy overall (e.g., olive oil) | |
|                                      | More than two categories, often referred to as ‘food category specific’ | When the purpose requires comparing foods within categories e.g., shifting consumption from higher fat to lower fat biscuits | • Need to define categories  
• Some foods that are unhealthy overall may be categorised as healthy because they are healthier options within their category (e.g., meat pies)  
• A greater number of categories is likely to stimulate more product reformulation | • No consensus on how food categories should be defined  
• Can be difficult to allocate foods to food categories e.g., chocolate-coated biscuits could be regarded as confectionery |
| Nutrients and other food components included | A short list of nutrients and / or other food components | When aiming for a simple, practical model | • Likely to be more simple to use  
• A short list of nutrients may not reflect all public health concerns  
• Can be useful for targeting specific nutrient deficiencies e.g., iron |
| --- | --- | --- | --- |
| A long list of nutrients and / or other food components | When aiming for a model which reflects all nutritional concerns | • Applying a model with a long list of nutrients is likely to be more difficult to use  
• Has the potential to reflect all nutritional concerns | • There are problems in defining some nutrients (e.g., if fibre is to be used, the analytical method needs to be specified; and for fruits and vegetables to be used it is necessary to consider what degree of processing is acceptable)  
• Increasing the number of nutrients does not necessarily increase the sensitivity or specificity of models  
• Food composition data may not be available for all nutrients (e.g., in Australia it is compulsory to display only eight nutrients on the product label) |
<table>
<thead>
<tr>
<th>Base used</th>
<th>per 100g / 100ml</th>
<th>When using a model to categorise foods solely on the basis of the nutrient quality of the food</th>
<th>• Does not take into account the wide variation in water content of foods and drinks and so different criteria are needed for foods and drinks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Does not take into account the amount of food usually consumed. Foods with very small or very large serving sizes can be categorised in ways which appear anomalous (e.g., mustard can appear high in a particular nutrient but is eaten in very small quantities)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• The choice of base is connected with other choices such as the choice of the number of product categories. For example, if a ‘per 100g/ml’ base is selected there needs to be at least two categories: ‘foods’ and ‘beverages’</td>
</tr>
<tr>
<td></td>
<td>per 100 kJ</td>
<td>When using a model to categorise foods solely on the basis of the nutrient quality of the foods</td>
<td>• Is not affected by water content and so does not need different criteria for foods and drinks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Does not take into account the amount of food usually consumed. Food with very low or very high energy contents on a per 100g basis can be categorised in ways which appear anomalous (e.g., lettuce may appear high in some nutrients on an energy basis but a lot of lettuce needs to be eaten to provide those nutrients)</td>
</tr>
<tr>
<td>Method for categorising / ranking products</td>
<td>Thresholds</td>
<td>For simple models designed for a single purpose</td>
<td>Less suited to differentiating between products e.g., there is no discernable difference between products that narrowly fail to meet a threshold and those that are a long way from the threshold</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>------------</td>
<td>-----------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Likely to be most applicable to category-specific models, where different thresholds can be set for different food categories</td>
</tr>
</tbody>
</table>
| Scoring | For more complex models that can be tailored for different purposes | • More flexible in that models can be used for different purposes using different scoring levels depending on the application  
• Model may be harder for users to understand |
|---|---|---|
| Cut-off numbers Based on dietary recommendations | When there is a need to be consistent with dietary recommendations | • Maintains consistency across applications e.g., the ‘amber’ / ’red’ threshold numbers for the UK traffic light scheme are based on Guideline Daily Amounts (GDAs) (Food Standards Agency United Kingdom 2007)  
• Algorithms can be developed to combine numbers into a single output e.g., an overall score, index or a ratio |
| Based on existing legislation | When there is a need to be consistent with legislation already in place | • Maintains consistency across applications e.g., the ‘green’ / ‘amber’ threshold numbers for the UK traffic light scheme boundaries are based on the European Union nutrition claims legislation (Food Standards Agency United Kingdom 2007) |
Figure 1  Logic pathway: changes in food and physical activity policy to changes in health outcomes. The boxes labelled “…” indicate that there are likely to be other components to take into account that are not explicitly identified in that step of the pathway. Abbreviations used: $\Delta$: change in; BMI: body mass index; IHD: ischaemic heart disease; En density: energy density; phys activity: physical activity; Amt: amount; cons: consumed; veg: vegetable; g: grams; ml: millilitres
Δ Energy expenditure

Δ PHYSICAL ACTIVITY

Δ FOOD ENVIRONMENT

Product  Price  Place  Promotion

Δ Level of phys activity

Δ EATING BEHAVIOUR

Δ DIETARY INTAKE

Δ Fruit & veg intake
Δ Fish intake
Δ Fibre intake
Δ Calcium intake
Δ Salt intake
Δ Type of fat cons
Δ En density of food cons
Δ En density of drink cons
Δ En density of drink cons

Δ INTERMEDIATE RISK FACTORS

Δ Blood pressure
Δ Blood lipids

Δ ENERGY BALANCE

Δ ENERGY EXPENDITURE

Δ PHYSICAL ACTIVITY BEHAVIOUR

Δ POLICY

Product  Price  Place  Promotion

Other effects

Δ DIETARY INTAKE

Δ EATING BEHAVIOUR

Δ INTERMEDIATE RISK FACTORS

Δ HEALTH OUTCOMES

Cardio-vascular disease
Ischaemic stroke  IHD  Hypertensive heart disease

Cancer
Colorectal cancer  Kidney cancer  Oesophageal cancer  Stomach cancer  Lung cancer

Type 2 Diabetes  Osteoarthritis

Δ Blood pressure
Δ Blood lipids

Δ Type of fat cons
Δ En density of drink cons
Δ En density of drink cons
Δ Energy intake
Δ Amt (g) of food cons
Δ Amt (ml) of drink cons
Δ Fruit & veg intake
Δ Fish intake
Δ Fibre intake
Δ Calcium intake
Δ Salt intake

Δ En density of food cons
Δ En density of drink cons
Δ En density of drink cons
Δ Food environment

Δ Level of phys activity
Δ Sedentari-ness

Δ Weight / BMI

Δ Other effects

Δ Energy expenditure

Δ Policy

Δ Food environment

Δ Eating behaviour

Δ Intermediate risk factors

Δ Health outcomes

Δ Dietary intake

Δ Physical activity

Δ Physical activity behaviour

Δ Energy balance
Chapter 5: Relation between changes in energy balance and changes in body weight

Chapter overview

This chapter reports on Study C of this research. It consists of two manuscripts and a related letter to the editor, all published in the *American Journal of Clinical Nutrition*. The first manuscript estimates the relation between changes in energy balance and changes in body weight for adults. The second manuscript illustrates the way in which the relation can be applied by examining the relative contributions of increased energy intake and decreased physical activity to the obesity epidemic in the US. The letter to the editor was written in response to comments received on the first manuscript, and identifies important methodological issues regarding the regression model used.
Manuscript 4


DEAKIN UNIVERSITY

STATEMENT OF CONTRIBUTION OF CO-AUTHORS

Declaration by candidate

In the case of the manuscript named above, the nature and extent of my contribution to the work was the following:

<table>
<thead>
<tr>
<th>Nature of contribution</th>
<th>Extent of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinated the collation of the data from the various data sets, analysed the results, jointly formulated the major concepts, assisted in drafting the manuscript, provided comments on drafts of the manuscript, reviewed and approved the final manuscript</td>
<td>50%</td>
</tr>
</tbody>
</table>

The following co-authors contributed to the work:

<table>
<thead>
<tr>
<th>Name</th>
<th>Nature of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boyd Swinburn</td>
<td>Initiated the study, jointly formulated the major concepts, drafted the manuscript, collated comments from other authors and led the response to reviewers, reviewed and approved the final manuscript, corresponding author</td>
</tr>
<tr>
<td>Sing Kai Lo</td>
<td>Assisted with the statistical analysis, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>Klaas R Westerterp</td>
<td>Provided data for the study, assisted with interpretation of the findings, critically reviewed the manuscript, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>Elaine C Rush</td>
<td>Provided data for the study, assisted with interpretation of the findings, critically reviewed the manuscript, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>Name</td>
<td>Contribution</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Michael Rosenbaum</td>
<td>Provided data for the study, assisted with interpretation of the findings, critically reviewed the manuscript, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>Amy Luke</td>
<td>Provided data for the study, assisted with interpretation of the findings, critically reviewed the manuscript, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>Dale A Schoeller</td>
<td>Provided data for the study, assisted with interpretation of the findings, critically reviewed the manuscript, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>James P DeLany</td>
<td>Provided data for the study, assisted with interpretation of the findings, critically reviewed the manuscript, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>Nancy F Butte</td>
<td>Provided data for the study, assisted with interpretation of the findings, critically reviewed the manuscript, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>Eric Ravussin</td>
<td>Helped to initiate the study, assisted with interpretation of the findings, critically reviewed the manuscript, reviewed and approved the final manuscript</td>
</tr>
</tbody>
</table>

**Declaration by co-authors**

The authors listed above have certified that:

1. The above declaration correctly reflects the nature and extent of the candidate’s contribution to this work, and the nature of the contribution of each of the co-authors.
2. They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise.
3. They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication.
4. There are no other authors of the publication according to these criteria.
5. Potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit.
6. They agree to the use of the publication in the student’s thesis and its publication on the Australasian Digital Thesis database consistent with any limitations set by publisher requirements.
**Principal supervisor confirmation**

I have sighted email or other correspondence from all co-authors confirming the above-mentioned certifications.

<table>
<thead>
<tr>
<th>Boyd Swinburn</th>
<th>25 October 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervisor’s Name</td>
<td>Signature</td>
</tr>
</tbody>
</table>

![Signature Image]
Title: Estimating the changes in energy flux that characterize the rise in obesity prevalence

Authors: Boyd Swinburn 1*, Gary Sacks 1, Sing Kai Lo 1, Klaas R Westerterp 2, Elaine C Rush 3, Michael Rosenbaum 4, Amy Luke 5, Dale A Schoeller 6, James P DeLany 7, Nancy F Butte 8, Eric Ravussin 9

1 Faculty of Health, Medicine, Nursing, and Behavioural Sciences, Deakin University, Melbourne, Australia
2 Department of Human Biology, Maastricht University, Maastricht, Netherlands
3 Body Composition and Metabolism Research Centre at Auckland University of Technology, Auckland, New Zealand
4 Department of Pediatrics, Columbia University Medical Center, New York, NY
5 Stritch School of Medicine, Loyola University, Chicago, IL
6 Department of Nutritional Sciences, University of Wisconsin-Madison, Madison, WI
7 Department of Medicine, University of Pittsburgh, Pittsburgh, PA
8 Childhood Obesity Research Center, Baylor College of Medicine, Waco, TX
9 Pennington Biomedical Research Centre, Baton Rouge, LA

* All correspondence to Boyd Swinburn, WHO Collaborating Centre for Obesity Prevention, Deakin University, 221 Burwood Highway, Melbourne VIC 3125, Australia. Tel +61(0) 3 9251 7096. Fax +61(0) 3 9244 6640. Email: boyd.swinburn@deakin.edu.au

Conflict of interest: The authors declare no conflict of interest.

Abstract

**Background:** The daily energy imbalance gap associated with the current population weight gain in the obesity epidemic is relatively small. However, the substantially higher body weights of populations that have accumulated over several years are associated with substantially higher total energy expenditure (TEE) and total energy intake (TEI), or energy flux (EnFlux=TEE=TEI).

**Objective:** The objective was to develop an equation relating EnFlux to body weight in adults for estimating the rise in EnFlux associated with the obesity epidemic.

**Design:** Multi-center, cross-sectional data for TEE from doubly-labelled water studies in 1,399 adults aged 45.9 ± 18.8 years (mean ±SD) were analysed in linear regression models with natural log (ln) weight as the dependent variable and ln EnFlux as the independent variable, adjusted for height, age, and sex. These equations were compared with those for children and applied to population trends in weight gain.

**Results:** ln EnFlux was positively related to ln weight (β=0.71; 95% CI: 0.66, 0.76; R²=0.52), adjusted for height, age, and sex. This slope was significantly steeper than that previously described for children (β=0.45; 95% CI: 0.38, 0.51).

**Conclusions:** This relation suggests that substantial increases in TEI have driven the increases in body weight over the past three decades. Adults have a higher proportional weight gain than children for the same proportional increase in energy intake, mostly because of a higher fat content of the weight being gained. The obesity epidemic will not be reversed without large reductions in energy intake, increases in physical activity, or both.

**Keywords:** energy gap, obesity, energy balance, settling point
Introduction

Understanding and quantifying the energy dynamics which explain the obesity epidemic are important for benchmarking the significance of research findings (1), estimating the impact of public health interventions (2, 3) and public communications about the magnitude of the changes needed to reverse the epidemic (4). The term ‘energy gap’ has been applied to different aspects of energy balance dynamics related to obesity and unfortunately this has led to significant confusion about whether the epidemic is caused by (and can be reversed by) small or large differences in energy balance (5-10).

The different energy gap concepts are shown in Figure 1. The average daily excess of total energy intake (TEI) over total energy expenditure (TEE) which is needed to create weight gain over a period of time is referred to here more specifically as the ‘energy imbalance gap’. When applied to the average weight gain of whole populations during the rise of the obesity epidemic, this number is usually estimated to be quite small (e.g., 125kJ/day) (5) although more recent models consider it to be significantly larger (7). However, to maintain an ongoing energy imbalance gap to drive the weight gain, TEI needs to keep rising because TEE is also constantly rising towards a new equilibrium due to the increased body mass [comprised of both fat mass (FM) and fat-free mass (FFM)]. The increasing TEE is mainly due to the effect that the increases in FFM have on increasing resting metabolic rate (RMR) (6, 8) but also on the effect of increased weight on the energy cost of physical activity (PA). Eventually, both TEI and TEE (or more simply energy flux, EnFlux, because TEI-TEE) are higher than before weight gain. We call the difference in EnFlux between the two time points the ‘energy flux gap’, and this number can be quite large when applied across the decades of the obesity epidemic.

The equilibrium point for a population where the mean TEE, mean TEI and mean body weight are all in a dynamic balance is referred to here as a ‘settling point’ (6) and perturbations of TEI or TEE can result in a shift in body weight towards a
new settling point (11). Conceptualising changes in mean weight between two states of equilibrium or settling points assumes that time A and time B represent points of stable, dynamic equilibrium between EnFlux and body weight. Even if these time points are in the upswing of an obesity epidemic, on any one day the population can be considered to be virtually at a settling point because the energy imbalance gap is <1% of total EnFlux.

The purpose of this analysis was to develop an equation relating EnFlux to body weight in adults so that estimations of the ‘energy flux gap’ associated with the adult obesity epidemic can be made and the dominance of TEE or TEI in driving the epidemic can be deduced.

**Participants and methods**

**Participants**

Data from studies that had measured TEE using standard doubly-labelled water techniques (12) in 1,399 adults aged ≥18 years were collected from eight centers internationally – six in the US (13-17), one in the Netherlands (18), and one in New Zealand (19, 20). The inclusion of several centers meant that there was a spread of ethnicities in the database and that the net technical biases in measurements across centers would be minimized. Body weight was the dependent variable of interest with TEE (or EnFlux) being the main independent variable of interest with height, age, and sex being included as confounding variables. Ten outliers were deleted (weight >150kg, height >200cm, TEE < 4,000kJ/day or TEE > 23,000kJ/day). Written informed consent was given by participants and ethics approval was obtained by each of the participating institutions. The dataset used for the previous similar study of 963 children aged 4-18 years (6) was compared with the adult findings.
Statistical analysis

The assumptions used in the previous analysis for children (6) were applied: first, that the TEE measured by doubly-labelled water over ≈ two weeks is equivalent to TEI (i.e., EnFlux=TEE=TEI); and second, that EnFlux and body weight are interdependent and can be considered to be in a dynamic balance.

The distribution of body weight and EnFlux variables are known to be skewed (6, 21); therefore, both were converted to natural logarithms for analysis: ln weight in ln kg and ln EnFlux in ln kJ/day. This reduced the skewness of the variables, reduced the heteroscedasticity, and improved the linearity of the relation. Pearson product-moment correlations were calculated for the univariate analyses. For the multi-variate analyses, height (cm), age (years) and sex (males=0, females=1) were added as co-variates. The inclusion of ethnicity and study center as dummy variables greatly increased the complexity of the models and only gave a small increase in the R² value (<0.02), so these variables were not further included in the analyses. Similarly, the inclusion of more complex terms in the equation (such as ln Height, age², or ‘sex * ln EnFlux’) did not increase the R² and reduce the 95% CI for ln EnFlux. The equations presented are thus the parsimonious ones that nevertheless closely approximate the more complex equations. Statistical significance was defined at the 0.05 level.

Hierarchical multiple regression models were used with ln weight as the dependent variable. For the comparison between adults and children, the 95% bands (encompassing 95% of each population) were calculated with the effects of height, age, and sex removed to show the distinctness of the two populations in their relations between ln EnFlux and ln weight. All analyses used SPSS statistical software (Version 14.0 for Windows; SPSS Inc, Chicago, IL).
Results

The characteristics of the 1,399 participants are shown in Table 1 and demonstrate the wide range in age (18-98 years), weight (34-150 kg), and measured TEE (4.1–22.5 MJ/day) included in the sample. The relation for the raw data between weight and TEE (henceforth referred to as EnFlux) is shown in Figure 2 with weight as the independent variable. Viewed in this way, heavier people have a higher EnFlux with the relation being significant for men (β=93.0; 95% CI: 82.9, 103.1; P<0.0001; Intercept = 4,723), women (β=72.3; 95% CI: 65.6, 79.0, P<0.0001; intercept = 4,873) and both sexes combined (β=94.0, 95% CI 88.2, 99.8, P<0.0001; intercept = 3,945). Reversing the relation and log transforming the data gave the graph shown in Figure 3 (β=0.64; 95% CI: 0.60, 0.68; P<0.0001; intercept = -1.64). In this case, weight becomes the dependent variable. The R² was 0.43 (P<0.0001) for the univariate relation in the log transformed data and increased to 0.52 (P<0.0001) when the covariates of height, age, and sex were added (Table 2). The equation from this multivariate analysis and subsequent algebraic transformations are shown below.

Unstandardized coefficients derived from the regression model:

\[
\text{In Weight} = 0.712(\text{ln EnFlux}) + 0.005(\text{Height}) + 0.004(\text{Age}) + 0.074(\text{Sex}) - 3.431 \quad (\text{Equation 1})
\]

Take the antilog of both sides of Equation 1:

\[
\text{Weight} = \text{EnFlux}^{0.712} \cdot e^{0.005 \text{Height}} \cdot e^{0.004 \text{Age}} \cdot e^{0.074 \text{Sex}} \cdot e^{-3.431} \quad (\text{Equation 2})
\]

Transform into a ratio from time₁ to time₂ for considering the same population at different time points or population₁ versus population₂, with the same sex ratio (sex and constant variables cancel out):
If height and age are considered the same (for example, in comparing cross-sectional data of two populations with comparable age and height distributions), these variables also cancel out:

\[
\frac{Weight_2}{Weight_1} = \left( \frac{EnFlux_2}{EnFlux_1} \right)^{0.712} \left( e^{0.005 \text{Height}_2} \right)^{0.12} \left( e^{0.004 \text{Age}_2} \right) \text{ (Equation 3)}
\]

When the relation in Equation 4 is plotted over the range of ±20% change in EnFlux (i.e., EnFlux₂ = 0.8-1.2 x EnFlux₁), the relation with the change in body weight is virtually linear with a slope of 0.71 (Figure 4 – dashed line).

The 0.71 (95% CI: 0.66, 0.76) slope of the relation between EnFlux and body weight in adults was significantly different from that previously published for children of 0.45 (95% CI: 0.38, 0.51) (6). The effects of height, age, and sex were then removed for each of these populations separately, and the resultant scatter plots for adults and in children are shown in Figure 5 along with the regression lines and 95% prediction bands (containing 95% of data points) for each population. There was barely any overlap in the population groups and the steeper adult gradient means that for a given increase in EnFlux (e.g., a 10% increase in TEI), the proportional increase in weight for adults is greater (7.1%) than for children (4.5%). This is likely to reflect the higher proportion of FFM to FM accumulated by children due to growth effects and perhaps less of a reduction in PA with weight gain compared with adults. Whereas height and age were included in the models to derive the equation for children, they probably did not account for all the effects of growth. To test this, we analysed the relation between EnFlux and FFM for those participants who had available body-composition data (Table 3).
For adults, the β coefficient for ln EnFlux on ln FFM (dependent variable) adjusted for height, age, and sex was 0.48 (95% CI: 0.44, 0.51), whereas for children it was 0.31 (95% CI: 0.28, 0.34). Although still significantly different, the coefficients were much closer for FFM than for weight. Thus a 10% increase in TEI would be expected to increase weight and FFM in adults by 7.1% and 4.8%, respectively, whereas in children it would be expected to increase weight by 4.5% and FFM by 3.1%.

Discussion

This study showed that EnFlux, TEE and TEI are positively related to body weight, which implies that a high TEI is the main driver of higher body weights in modern populations. A cross-sectional relation cannot usually be used to determine causality, but in this case, the constraints of the first law of thermodynamics allows us to infer that a high TEI must be the major driver of higher body weight in modern populations. If obesity was primarily determined by lower PA (including higher sedentariness), one would expect that the consequent reductions in activity energy expenditure would result in a lower TEE (EnFlux) being related to higher body weight (i.e., a negative relation). The fact that the observed relation is strongly positive implies that the high EnFlux associated with a high body weight is because a high TEI is the main driver of both factors.

The slope of the relation (0.71) implies that a 10% higher TEI equates to a higher body weight of ≈7%. Thus, an increase in TEI of ≈5.5% per decade would therefore have been needed to drive the observed average weight gain of ≈4% (≈3kg per decade) for US adults since the early 1970s (22). Using dietary intake data for adults in the 1970s (23) with a 20% allowance for under-reporting (24) as a base, the energy flux gap for the three decades from the start of the obesity epidemic in the US in the 1970s would be ≈1,600kJ/day. This is a substantial
amount and small behavioural changes (4) will clearly not be sufficient to reverse the epidemic.

The generated equations can be extrapolated to provide further predictions about population weight differences in relation to behavioural differences in TEI or PA. The summary slope for adults linking body weight and EnFlux is shown in Figure 4 as the dotted line. Points A to E are all considered settling points or equilibria for populations of comparable age, height, and sex distributions where weight is stable. For population B, which has a TEI 10% higher than population A, the mean weight is predicted to be 7% higher (assuming comparable PA). Using absolute values, if the adult population in this study (Table 1) had a 10% higher TEI (i.e., 12,260 kJ/day instead of 11,145 kJ/day) the mean weight would be predicted to be 5.4kg higher, at 82.0kg. The TEE would, of course, also be 10% higher, largely because of the higher RMR, which increases in parallel with the weight gain. Conversely, if a population had a 10% lower TEI (10,031 kJ/day) at settling point C, the mean weight would be 5.4kg lower at 71.2kg.

The other scenarios in Figure 4 relate to differences in PA. If the energy cost of PA is consistently lower in one population (D) than another (A), with no compensatory differences in TEI, it is hypothesized that mean body weight for population D would be at some point vertically above the settling point for population A, with EnFlux remaining the same. In other words, at settling point D, the lower energy expenditure from reduced PA would have been exactly offset by the increase in RMR. Conversely, a higher level of PA without compensatory differences in TEI will place the settling point (E) vertically below population A; the higher cost of PA would be offset by the lower RMR because of the lower body weight. It is, therefore, concluded that a significant amount of the vertical variability about the regression lines in the scatter plots (Figures 2, 3 and 5) is due to differences in PA levels between individuals and the proportion of their weight that is FFM, both of which influence TEE and thus EnFlux.
It is hypothesized that combinations of behavioural differences will result in other settling points in the areas bounded by the ‘pure’ behaviour lines (dotted line for TEI and vertical line for PA). For example, a population with higher TEI plus lower PA than population A would be within the upper shaded area and one with a lower TEI plus higher PA would be in the lower shaded area. The quantitative nature of this construct means that this hypothesis is testable across populations. It is important to note that, in physiological terms, the energy cost of weight gain is substantially greater than the energy cost of weight loss (25, 26). Thus, Figure 4 may not be applicable to an individual person who is increasing or decreasing weight because the slopes for weight gain and weight loss would be different. In addition, experimental studies, such as the classic overfeeding and exercising studies by Bouchard et al. (27, 28), usually imposed large energy imbalances over a relatively short periods of time so a new equilibrium may not be reached and the physiological responses to large imbalances may be prominent (11, 29) and mask the true equilibrium status.

Whereas the main application of the constructs in Figure 4 is to compare across populations, the equations could be used to model population weight changes over long periods of time in response to behavioural changes (2) and should be more accurate than the simple, unbounded arithmetic that is sometimes used to predict weight change from a change in energy balance (1, 3, 30). For example, Dolan et al. (3) estimated that prompts to take the stairs would increase the mean TEE by ≈40 kJ/day (0.67kJ/ascent and descent of a step x 60 new steps/weekday) in those who responded to the prompts. For their hypothetical population (mean weight: 61kg), they used simple arithmetic to calculate that this would result in 300g weight loss per year and, by inference, because such calculations are unbounded, 3kg weight loss per decade. By our equations, 40 kJ/weekday or 30kJ/day would be 0.33% of TEE for a population with a mean weight 61kg and EnFlux of 9 MJ/day. This would translate to a shift from a population settling point of 61kg to a new settling point only 140g lighter (0.33% x 0.71 = 0.23%, 0.0023 x 61,000g) and this weight loss would not continue ad infinitum without
further behaviour changes. This avoids the trap of extrapolating small changes over long time periods to give unrealistic predictions of weight change.

An important assumption for these analyses is the concept of ‘settling points’ where TEI=TEE at a stable weight. As depicted in Figure 1, the energy imbalance gap is very small compared to the total energy flux and is considered negligible (or at least less than the reported precision of the doubly labelled water technique of $\approx 5\text{-}8\%$) for the 1-2 week period when TEE was measured. This a reasonable assumption, because the protocols for doubly-labelled water studies attempt to ensure weight maintenance over the measuring period and the energy cost of linear growth is not an issue for adults as it is with children.

The differences between adults and children in the relation between EnFlux and body weight are interesting: adults need a greater proportional weight change to reach a new settling point for a given proportional change in EnFlux. Most of the explanation seems to lie in the greater proportion of lean mass to FM put on by children as they gain weight. Additional contributors may be that weight gain reduces PA levels more in adults than it does in children.

In conclusion, the strength and direction of the relation between energy flux and body weight implicate substantial increases in energy intake as the main driver for the increase in adults’ weight observed over the recent decades and, conversely, large decreases in energy intake and/or large increases in PA will be needed to reverse the prevalence of obesity.
References


9. Butte NF, Ellis KJ. Comment on "Obesity and the Environment: Where Do We Go from Here?" Science 2003;301:598b-.


Table 1 Characteristics of the study participants

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Males</th>
<th>Females</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of subjects</td>
<td>652</td>
<td>747</td>
<td>1,399</td>
</tr>
<tr>
<td>Ethnicity (n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>528</td>
<td>559</td>
<td>1,087</td>
</tr>
<tr>
<td>Black</td>
<td>71</td>
<td>101</td>
<td>172</td>
</tr>
<tr>
<td>Hispanic</td>
<td>13</td>
<td>20</td>
<td>33</td>
</tr>
<tr>
<td>Asian</td>
<td>13</td>
<td>15</td>
<td>28</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>18</td>
<td>42</td>
<td>60</td>
</tr>
<tr>
<td>Other/unspecified/unknown</td>
<td>9</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>Age (years)</td>
<td>49.3 ± 18.0 (18 – 98) a</td>
<td>43.0 ± 19.1 (18 – 97)</td>
<td>45.9 ± 18.8 (18 – 98)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>83.5 ± 17.4 (46.5 – 149.7)</td>
<td>70.5 ± 18.7 (33.8 – 144.5)</td>
<td>76.6 ± 19.2 (33.8 – 149.7)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>176.5 ± 7.2 (152.0 – 197.0)</td>
<td>163.7 ± 6.9 (143.2 – 186.0)</td>
<td>169.6 ± 9.5 (143.2 – 197.0)</td>
</tr>
<tr>
<td>Total energy expenditure (kJ/day)</td>
<td>12,489 ± 2,796 (5,033 – 22,486)</td>
<td>9,971 ± 2,200 (4,126 – 18,104)</td>
<td>11,145 ± 2,793 (4,126 – 22,486)</td>
</tr>
</tbody>
</table>

a Mean ± standard deviation; range in parentheses (all such values)
Table 2 The hierarchical multiple regression model with the dependent variable being natural log-transformed body weight (ln weight in ln kg)

<table>
<thead>
<tr>
<th>Variable</th>
<th>β (std error)</th>
<th>t value</th>
<th>P value</th>
<th>95% CI for β</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln EnFlux</td>
<td>0.712 (0.025)</td>
<td>28.68</td>
<td>&lt;0.0001</td>
<td>0.663, 0.760</td>
</tr>
<tr>
<td>Age (y)</td>
<td>0.004 (0.000)</td>
<td>15.14</td>
<td>&lt;0.0001</td>
<td>0.004, 0.005</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>0.005 (0.001)</td>
<td>7.43</td>
<td>&lt;0.0001</td>
<td>0.004, 0.007</td>
</tr>
<tr>
<td>Sex b</td>
<td>0.074 (0.013)</td>
<td>5.52</td>
<td>&lt;0.0001</td>
<td>0.047, 0.100</td>
</tr>
<tr>
<td>Intercept</td>
<td>-3.431 (0.234)</td>
<td>-14.65</td>
<td>&lt;0.0001</td>
<td>-3.890, -2.971</td>
</tr>
</tbody>
</table>

a β coefficients are unstandardized

b Male = 0, Female = 1
Table 3  Characteristics of the adults and children with fat-free mass data

<table>
<thead>
<tr>
<th></th>
<th>Adults</th>
<th></th>
<th>Children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=897; male=43%)</td>
<td>(n=963; male=46%)</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>45.3 (17.1)</td>
<td>8.1 (2.8)</td>
<td>3.9-18</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>77.3 (19.9)</td>
<td>31.5 (17.6)</td>
<td>13.6-141.2</td>
</tr>
<tr>
<td>Fat-free mass (kg)</td>
<td>50.4 (11.2)</td>
<td>22.4 (10.0)</td>
<td>10.8-82.5</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>33.0 (10.5)</td>
<td>26.4 (8.4)</td>
<td>4.4-56.7</td>
</tr>
</tbody>
</table>
Figure 1  Schematic showing the energy balance characteristics of a population undergoing weight gain over a period of years. The ‘energy imbalance gap’ is defined as the small average daily imbalance between total energy intake (TEI) and total energy expenditure (TEE), whereas the ‘energy flux gap’, which is the higher TEI and TEE (energy flux) associated with the higher weight, is relatively large.
Figure 2  The relation between body weight and energy flux in adults [energy flux = total energy expenditure (TEE) measured by the doubly labelled water technique], shown as the raw data with body weight as the independent variable (Pearson’s correlation r=0.65, P<0.0001; n=1,399)
Figure 3  The relation between body weight and energy flux (EnFlux) in adults (EnFlux = total energy expenditure measured by the doubly labelled water technique), shown as natural log-transformed data with EnFlux as the independent variable (Pearson’s correlation $r=0.65$, $P<0.0001$; $n=1,399$). Ln, natural log.
Figure 4  The relation between energy flux and body weight (derived from Equation 4) is shown as the dotted line with a slope of 0.71. Compared with a population at point A, the settling points for other similar populations with a higher or lower energy intake (B and C, respectively) and lower or higher physical activity levels (D and E, respectively) are shown. A population with a combination of a higher energy intake and lower physical activity would fall into the top right shaded area, whereas a population with both a lower energy intake and a higher physical activity would fall into the lower left shaded area. TEE, total energy expenditure; TEI, total energy intake.
Figure 5  The relation between energy flux (EnFlux) and body weight in adults (n=1,399) and children (n=963) with both variables expressed as natural logs (Ln) with the effects of height, age, and sex removed. The lines represent the regression lines (derived from linear regression models) for each group with 95% prediction bands (containing 95% of each population).
Manuscript 5

Swinburn B, Sacks G, Ravussin E. Increased food energy supply is more than sufficient to explain the US epidemic of obesity. Am J Clin Nutr 2009;90(6):1453-6

DEAKIN UNIVERSITY

STATEMENT OF CONTRIBUTION OF CO-AUTHORS

Declaration by candidate

In the case of the manuscript named above, the nature and extent of my contribution to the work was the following:

<table>
<thead>
<tr>
<th>Nature of contribution</th>
<th>Extent of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undertook the analyses, contributed to the interpretation of results, drafted parts of the manuscript, provided comments on drafts of the manuscript, reviewed and approved the final manuscript</td>
<td>50%</td>
</tr>
</tbody>
</table>

The following co-authors contributed to the work:

<table>
<thead>
<tr>
<th>Name</th>
<th>Nature of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boyd Swinburn</td>
<td>Developed the initial concepts, led the writing of the manuscript, contributed to the interpretation of results, reviewed and approved the final manuscript, corresponding author</td>
</tr>
<tr>
<td>Eric Ravussin</td>
<td>Developed the initial concepts, contributed to the interpretation of results, reviewed and approved the final manuscript</td>
</tr>
</tbody>
</table>

Gary Sacks

Candidate’s Name  Signature  Date

25 October 2010
Declaration by co-authors

The authors listed above have certified that:

1. The above declaration correctly reflects the nature and extent of the candidate’s contribution to this work, and the nature of the contribution of each of the co-authors.
2. They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise.
3. They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication.
4. There are no other authors of the publication according to these criteria.
5. Potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit.
6. They agree to the use of the publication in the student’s thesis and its publication on the Australasian Digital Thesis database consistent with any limitations set by publisher requirements.

Principal supervisor confirmation

I have sighted email or other correspondence from all co-authors confirming the above-mentioned certifications.

Boyd Swinburn

25 October 2010

Supervisor’s Name

Signature

Date
Title: Increased food energy supply is more than sufficient to explain the US epidemic of obesity

Authors: Boyd Swinburn 1*, Gary Sacks 1, Eric Ravussin

1 WHO Collaborating Centre for Obesity Prevention, Deakin University, Melbourne, Australia
2 Pennington Biomedical Research Centre, Baton Rouge, LA, USA

* All correspondence to Boyd Swinburn, WHO Collaborating Centre for Obesity Prevention, Deakin University, 221 Burwood Highway, Melbourne VIC 3125, Australia. Tel +61(0) 3 9251 7096. Fax +61(0) 3 9244 6640. Email: boyd.swinburn@deakin.edu.au

Funding: No specific funding was received for this study.

Conflict of interest: The authors declare no conflict of interest.

Abstract

Background: The major drivers of the obesity epidemic are much debated and have considerable policy importance for the population-wide prevention of obesity.

Objective: The objective was to determine the relative contributions of increased energy intake and reduced physical activity to the US obesity epidemic.

Methods: We predicted the changes in weight from the changes in estimated energy intakes in US children and adults between the 1970s and 2000s. The increased US food energy supply (adjusted for wastage and assumed to be proportional to energy intake) was apportioned to children and adults and inserted into equations which relate energy intake to body weight derived from doubly-labelled water studies. The weight increases predicted from the equations were compared with weight increases measured in representative US surveys over the same period.

Results: For children, the measured weight gain was 4.0 kg and the predicted weight gain for the increased energy intake was identical at 4.0 kg. For adults, the measured weight gain was 8.6 kg, whereas the predicted weight gain was somewhat higher (10.8 kg).

Conclusions: Increased energy intake appears to be more than sufficient to explain weight gain in the US population. A reversal of the energy intake rise of ≈2,000 kJ/day (500 kcal/day) for adults and 1,500 kJ/day (350 kcal/day) for children would be needed to return to the mean body weights of the 1970s. Alternatively, large compensatory increases in physical activity (e.g., 110-150 min/day walking), or a combination of both, would achieve the same outcome. Population approaches to reducing obesity should prioritise reducing the drivers of increased energy intake.
**Introduction**

The relative contributions of increased total energy intake (TEI) and reduced physical activity to the obesity epidemic have long been debated (1-3) and quantitative methods are needed to estimate these relative contributions. Whereas a healthy, lower energy diet and regular physical activity need to be promoted for preventing weight gain and improving other health outcomes, it is important to know if one side or the other of the energy balance equation is the major driver of the rise in obesity. This would help to prioritize policies and programs so that prevention efforts could be better targeted towards reducing the underlying drivers of the epidemic. It also has clinical implications for understanding and countering weight gain in individuals.

We previously analysed the relations between body weight, TEI, and total energy expenditure (TEE) measured using doubly-labelled water techniques for children (n=963) (4) and adults (n=1399) (5). Energy flux was assumed to equal TEI and TEE because, on any given day, a population is virtually weight stable. Because these cross-sectional relations are constrained by the first law of thermodynamics, the equations can be used for predicting changes in weight in response to changes in energy intake and physical activity. A scatter plot between body weight and energy flux for adults is shown in Figure 1 (5). From the starting point of the mean energy flux and mean weight, a population can gain weight by increasing TEI alone (white arrow), decreasing physical activity alone (black arrow) or some combination of the two (vector lines between the two arrows).

We inserted food energy supply data from the 1970s and the 2000s into the equations for the white arrow to predict the weight increases, thus helping to answer the question about whether the observed increase in food energy supply (and thus food energy intake) was sufficient to explain actual weight increases for the US population over the same period. This analysis demonstrates the practical application of these equations to answer important public health questions.
Methods

The National Health and Nutrition Examination Surveys (NHANES) (6) provided the measured mean weights for the US children and adults in the 1970s (1971–1976) and the 2000s (1999–2002). The US food supply data for those same years, adjusted for food loss (spoilage and other waste), were used to estimate the per capita energy supply (7). The food supply data represent the amount of food available for potential consumption rather than the amount of food ingested, so these estimates of per capita energy supply are likely to represent overestimates of actual consumption, even after adjusting for food loss. In addition, food loss, particularly at the consumer level, is by nature difficult to measure accurately, and the United States Department of Agriculture (USDA) acknowledges that their estimates of retail, foodservice, and consumer food losses are probably understated (7,8). Nevertheless, the USDA further identifies that this food supply data is useful as an indicator of trends in consumption over time because many of the errors in the data are likely to be systematic, thus cancelling out when changes over time are examined (7).

The per capita energy supply was then apportioned between children (2-18 years) and adults. To do this, the 1970 and 2000 US census data (9) were used to derive the child:adult population proportions and the doubly-labelled water studies (4, 5) were used to derive data for energy intake proportions between children and adults (using the appropriate mean age and weight from the census and NHANES data). The apportioned energy supply data (henceforth called estimated energy intake) were then included in equations for children (4) and adults (5) to derive predicted weight gains, which were compared with their respective measured gains.
Results

The estimated food energy intake for children was 7.10 MJ/day (1,690 kcal/day) in the 1970s and 8.58 MJ/day (2,043 kcal/day) in the 2000s and for adults was 10.07 MJ/day (2,398 kcal/day) in the 1970s and 12.16 MJ/day (2,895 kcal/day) in the 2000s (Figure 2). These data were combined with the mean (±SEM) measured weights from the two NHANES surveys for children (39.1±0.9kg and 43.1±0.9kg) and adults (72.2±0.3kg, 80.8±0.4kg) to form the darker solid lines in Figure 3. The predicted body weights from the equations are plotted against the estimated energy intake and shown as the lighter dashed lines in Figure 3. For children, the predicted mean weights for the two periods were 35.1 to 39.1 kg, making the predicted increase identical to the measured increase (4.0 kg). For adults, the predicted mean weights for the two periods were 68.0 to 78.8 kg, making the predicted increase (10.8 kg) slightly larger than the measured increase (8.6kg). The fact that the predicted weight increase was greater than the measured increase implies that, if anything, concurrent physical activity may have increased over this time period but this was not directly measured.

Discussion

The predicted changes in weights derived from the equations suggest that increase in estimated energy intake is sufficient, by itself, to explain the increase in weight in the US population. Such findings are supported by studies using other approaches to the same question (10) and by epidemiological data showing that physical activity levels have not decreased, or have even increased, over the period of time that obesity prevalence has been increasing (11-14). For example, Westerterp and Speakman (11) compiled data from 13 US doubly-labelled water studies over two decades and showed that physical activity energy expenditure had apparently increased over that time.
The limitations of this study include the crudeness of the food supply figures and the assumptions made in allocating them across children and adults. The absolute differences between the measured mean body weights and the prediction equation estimations at each time point (equations underestimated by ≈2-4kg) are undoubtedly due to the different methodologies of the approaches. However, it is the comparison of the changes over time that is important since the systematic methodological differences will cancel out. Nevertheless, it is possible that secular changes in the food supply errors may have introduced a bias in the estimates over time. For example, high failure rates for new food products may have increased retail food losses in recent years as the number of new product introductions has risen (8); however, an increase in retail food losses is not supported by recent data indicating that directly measured aggregate supermarket losses are very similar to the estimates derived using the traditional USDA methods of calculating retail food loss (15). Similarly, an increasing trend towards eating away from home may have resulted in recent increases in food-service food losses, whilst, in contrast, technological advances in food processing may have decreased food production losses over time (8).

A further assumption is that the relation between energy flux and body weight, as shown in Figure 1, applied to the US population over the time period studied. The multi-country data used to generate those equations suggests that this positive relation between energy flux and body weight is applicable across populations.

These US findings probably apply to other high-income countries where increases in obesity have occurred without marked changes in urbanization, car ownership, or the built environment. However, whereas reductions in physical activity do not appear to be driving the increase in obesity in the US, the dominance of car transport in the US has probably allowed a steeper trajectory of weight gain than, for example, the Netherlands or Denmark where active transport is more the norm. This clarifies the role of energy intake and physical activity in the three major obesity epidemic questions: What are the drivers of the increasing prevalence (this study suggests it is dominantly energy intake); what are the
**moderators** which influence the steepness of the trajectory of weight gain (population differences in energy intake and/or physical activity levels), and; what are the solutions to reversing the epidemic (see below)? Countries, such as China, are undergoing the nutrition transition along with rapidly increasing urbanisation, mechanisation, and car ownership (16,17). Thus, their rise in obesity is likely due to a combination of increasing energy intake drivers and the declining moderators of active transport and physically active occupations.

For the US population to return to the mean weights of 1970s, the increased energy intake of approximately 1,500 kJ/day (350 kcal/day) for children (about one can of soda and a small order of French fries) and 2 000 kJ/day (500 kcal/day) for adults (about one large hamburger) would need to be reversed. Alternatively, compensatory increases in physical activity (≈150 and 110 minutes/day of extra walking respectively) would achieve similar results.

This study has important policy implications. Whereas ongoing efforts are needed to increase physical activity levels in the population, the priorities for reversing the obesity epidemic should focus on energy intake by addressing the obesogenic food environment drivers of the current energy over-consumption.
References

17. Popkin BM. The nutrition transition and obesity in the developing world. J Nutr 2001;131(3):871S-3S
Figure 1  The relation between energy flux (=total energy intake = total energy expenditure) and body weight (values normalized by logarithmic transformation) for a population of adults. The change in mean population weight in response to increasing energy intake alone (white arrow) and decreasing physical activity alone (black arrow) are shown.
Figure 2  Changes in estimated daily energy intake per capita (MJ/day) for US children and adults for the periods 1971-1976 (1970s) to 1999-2002 (2000s).
Figure 3  Estimated energy intake for children and adults plotted against the measured mean weights (darker, solid line) and the predicted mean weights (lighter, dashed line) for the 1970s and 2000s.
Letter to the Editor


DEAKIN UNIVERSITY

STATEMENT OF CONTRIBUTION OF CO-AUTHORS

Declaration by candidate

In the case of the manuscript named above, the nature and extent of my contribution to the work was the following:

<table>
<thead>
<tr>
<th>Nature of contribution</th>
<th>Extent of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undertook the analyses, contributed to the interpretation of results, drafted parts of the manuscript, provided comments on drafts of the manuscript, reviewed and approved the final manuscript</td>
<td>50%</td>
</tr>
</tbody>
</table>

The following co-authors contributed to the work:

<table>
<thead>
<tr>
<th>Name</th>
<th>Nature of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boyd Swinburn</td>
<td>Led the writing of the manuscript, contributed to the interpretation of results, reviewed and approved the final manuscript, corresponding author</td>
</tr>
<tr>
<td>Eric Ravussin</td>
<td>Reviewed and approved the final manuscript</td>
</tr>
</tbody>
</table>

Gary Sacks  
25 October 2010

______________________________  ________________________________  ________________________________
Candidate’s Name       Signature       Date
**Declaration by co-authors**

The authors listed above have certified that:

1. The above declaration correctly reflects the nature and extent of the candidate’s contribution to this work, and the nature of the contribution of each of the co-authors.
2. They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise.
3. They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication.
4. There are no other authors of the publication according to these criteria.
5. Potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit.
6. They agree to the use of the publication in the student’s thesis and its publication on the Australasian Digital Thesis database consistent with any limitations set by publisher requirements.

**Principal supervisor confirmation**

I have sighted email or other correspondence from all co-authors confirming the above-mentioned certifications.

![Signature]

Boyd Swinburn  
25 October 2010

---

Supervisor’s Name  Signature  Date
Title: Reply to KD Hall and CC Chow

Authors: Boyd Swinburn ¹, Gary Sacks ¹, Eric Ravussin ²

¹ WHO Collaborating Centre for Obesity Prevention, Deakin University, Melbourne, Australia
² Pennington Biomedical Research Centre, Baton Rouge, LA, USA

Conflict of interest: The authors declare no conflict of interest.

Dear Sir:

We welcome the insightful comments received from Hall and Chow [refer to Box 1 at end of manuscript] in response to our recent articles (1, 2). In our previous regression analyses (2, 3), we log-transformed body weight and energy flux (EnFlux = total energy expenditure = total energy intake) to reduce the skewness and heteroskedasticity of the data and increase the linearity of the relation. We believe that this is justifiable, and it gives a zero intercept (i.e., zero body weight means zero EnFlux), which is more plausible than the positive intercept given by the untransformed data. EnFlux and body weight are interdependent, and we elected to place EnFlux as the independent variable on the x axis because we were trying to predict weight from EnFlux and covariates such as height, age, and sex. Hall and Chow argue, with some justification, that EnFlux should be considered the dependent variable on the y axis, which would give the equation for adults as follows:

\[
\text{Ln EnFlux} = 0.521(\text{Ln Weight}) + 0.003(\text{Height}) + 0.005(\text{Age}) + 0.126(\text{Sex}) + 6.845
\]

Where Ln = natural logarithm for EnFlux in kJ/day and weight in kg, height is in cm, age is in years, and sex corresponds to males = 0 and females = 1.

The slope of this log relation without covariates is 0.668, which approximates the slope of the linear equation (94 kJ/kg/day) over the range of 60 to 100 kg (as shown in Figure 1) and closely matches the slope estimated by Hall et al. (4, 5) in their analyses. There is an urgent need to test the validity of these and other equations [e.g., Christiansen and Garby (6), Wang et al (7)] against longitudinal measures of energy expenditure and body weight in adults. Ideally, these would be adults exposed to normal secular and age-related changes in weight as opposed to adults involved in weight gain or weight-loss studies (which can trigger metabolic responses to counter weight change). When we tested the validity of our equations for children (which were derived with EnFlux on the x axis), our
equations predicted the mean weight change in children from three longitudinal studies (n = 212; mean follow-up: 3.4 years) to < 0.5% (3).

We note that our previous conclusion (1), that the increase in food energy supply is more than sufficient to explain the US epidemic of obesity, remains the same regardless of the regression equation used to predict population body weight on the basis of estimated energy intakes. The use of the new equation presented above, with body weight as the independent variable, would indicate a higher expected weight change than previously reported. This result, along with that of Hall et al. (4), appears to indicate an increase in food waste in the United States that has not been fully accounted for by the US Department of Agriculture (USDA) in their estimates of food availability adjusted for wastage. We believe that it would be valuable for the USDA to update its estimates of food waste so that the food energy supply data more closely parallel food energy intake.

References

1. Swinburn B, Sacks G, Ravussin E. Increased food energy supply is more than sufficient to explain the US epidemic of obesity. Am J Clin Nutr 2009;90:1453–6

Figure 1  Linear regression curve as reported by Swinburn et al (3) and power law (log) regression curve derived by using the same doubly-labelled water data with body weight as the independent variable.
Box 1  Hall KD, Chow CC. Estimating the quantitative relation between food energy intake and changes in body weight. Am J Clin Nutr 2010;91(3):816

Estimating the quantitative relation between food energy intake and changes in body weight

Dear Sir:

We read with great interest the recent pair of articles by Swinburn et al (1, 2) that address the important relation between changes in food energy intake and body weight. We recently proposed a mathematical model of adult human energy expenditure that quantitatively relates body weight to changes in food energy intake as well as in physical activity (3, 4). We were surprised to find that the predictions of the adult power law equation proposed by Swinburn et al differed significantly from our model—a result that was particularly perplexing because our results closely agree with the 94 kJ · kg⁻¹ · d⁻¹ regression line slope depicted in Figure 2 of Swinburn et al (2).

A plot of both the regression line and the power law relation reported by Swinburn et al, which were derived from the same doubly labeled water data, is shown in Figure 1. Clearly, the slope of the power law relation is much greater at the mean body weight where the curves intersect and will thereby result in an underestimate of weight change for a given increment of food intake. We believe that this difference resulted from the choice of regressing the logarithm of the body weight compared with the logarithm of the energy expenditure rather than vice versa.

It is well known that regression curves can be different when the coordinates of the data are exchanged because the regression procedure minimizes the square of the ordinate distance between the curve and the data. Placing the body-weight measurement on the abscissa is more appropriate because it has a much smaller uncertainty than the energy expenditure measurement. Transforming the data into logarithmic coordinates also amplifies any uncertainty because the slope of the regressed line in logarithmic coordinates is the power law exponent in linear coordinates. Thus, we believe that the power law equation proposed by Swinburn et al (2) predicts a steady state increment of body weight that is too small for a given change in food energy intake.

Our model predictions, which agree with Swinburn et al’s linear regression curve but not the power law, have been validated in cases...
of underfeeding and overfeeding and in longitudinal changes of 24-h energy expenditure in adults (3, 4). Our results fully agree with the main conclusion of Swinburn et al that the rise of the food energy supply is more than sufficient to account for the adult obesity epidemic and that suggests that there has been a progressive increase of food waste in America that has been underestimated by traditional food waste methods (3).

This research was supported by the Intramural Research Program of the NIH/NIDDK.

Neither author declared a conflict of interest.

Kevin D Hall
Carson C Chow
REFERENCES

Chapter 6: Impact of traffic-light nutrition labelling on food purchases in the UK

Chapter overview

This chapter reports on Study D of this research. The chapter consists of a single manuscript entitled, “Impact of front-of-pack 'traffic-light' nutrition labelling on consumer food purchases in the UK”.
Manuscript 6


DEAKIN UNIVERSITY

STATEMENT OF CONTRIBUTION OF CO-AUTHORS

Declaration by candidate

In the case of the manuscript named above, the nature and extent of my contribution to the work was the following:

<table>
<thead>
<tr>
<th>Nature of contribution</th>
<th>Extent of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worked with the UK Retailer to obtain the data, led the analysis of the results, drafted the manuscript, collated comments from other authors and responded to reviewers, reviewed and approved the final manuscript, corresponding author</td>
<td>80%</td>
</tr>
</tbody>
</table>

The following co-authors contributed to the work:

<table>
<thead>
<tr>
<th>Name</th>
<th>Nature of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mike Rayner</td>
<td>Assisted with the analysis of the results, commented on drafts of the manuscript, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>Boyd Swinburn</td>
<td>Assisted with the analysis of the results, commented on drafts of the manuscript, reviewed and approved the final manuscript</td>
</tr>
</tbody>
</table>

Gary Sacks

Candidate’s Name   Signature   Date

25 October 2010
Declaration by co-authors

The authors listed above have certified that:

1. The above declaration correctly reflects the nature and extent of the candidate’s contribution to this work, and the nature of the contribution of each of the co-authors.
2. They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise.
3. They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication.
4. There are no other authors of the publication according to these criteria.
5. Potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit.
6. They agree to the use of the publication in the student’s thesis and its publication on the Australasian Digital Thesis database consistent with any limitations set by publisher requirements.

Principal supervisor confirmation

I have sighted email or other correspondence from all co-authors confirming the above-mentioned certifications.

Boyd Swinburn

__________________________________________
Supervisor’s Name Signature Date

25 October 2010
**Title:** Impact of front-of-pack ‘traffic-light’ nutrition labelling on consumer food purchases in the UK

**Authors:** Gary Sacks 1*, Mike Rayner 2, Boyd Swinburn 3

1 School of Exercise and Nutrition Sciences, Deakin University, Melbourne, Australia
2 British Heart Foundation Health Promotion Research Group, Department of Public Health, University of Oxford, United Kingdom
3 WHO Collaborating Centre for Obesity Prevention, Deakin University, Australia

* All correspondence to Gary Sacks, WHO Collaborating Centre for Obesity Prevention, Deakin University, 221 Burwood Highway, Melbourne VIC 3125, Australia. Tel +61(0) 3 9244 6036. Fax +61(0) 3 9244 6640. Email: gary.sacks@deakin.edu.au

**Conflict of interest:** The authors declare no conflict of interest.

**Journal:** Health Promotion International. **Received:** 18 July 2009. **Accepted for publication:** 17 September 2009.
Abstract

Objectives: Front-of-pack ‘traffic-light’ nutrition labelling has been widely proposed as a tool to improve public health nutrition. This study examined changes to consumer food purchases after the introduction of traffic-light labels with the aim of assessing the impact of the labels on the ‘healthiness’ of foods purchased.

Methods: The study examined sales data from a major UK retailer in 2007. We analysed products in two categories (‘ready meals’ and sandwiches), investigating the percentage change in sales four weeks before and after traffic-light labels were introduced, and taking into account seasonality, product promotions, and product life-cycle. We investigated whether changes in sales were related to the healthiness of products.

Results: All products that were not new and not on promotion immediately before or after the introduction of traffic-light labels were selected for analysis (n = 6 for ready meals and n = 12 for sandwiches). For the selected ready-meals, sales increased (by 2.4% of category sales) in the four weeks after the introduction of traffic-light labels, whereas sales of the selected sandwiches did not change significantly. Critically, there was no association between changes in product sales and the healthiness of the products.

Conclusions: This short-term study based on a small number of ready meals and sandwiches found that the introduction of a system of four traffic-light labels had no discernable effect on the relative healthiness of consumer purchases. Further research on the influence of nutrition signposting will be needed before this labelling format can be considered as a promising public health intervention.
Introduction

The health burden from nutrition-related non-communicable diseases such as diabetes, cancer and cardiovascular disease is high and increasing in many countries around the world (Lopez et al. 2006). Accordingly, governments are actively seeking policy options aimed at improving public health nutrition (World Health Organization 2005). New forms of food labelling, and ‘front-of-pack’ nutrient signposting in particular, are viewed as potential tools for improving the nutrition of the population (Nestle and Jacobson 2005). A number of different front-of-pack nutrient signposting have been developed (Grunert and Wills 2007) and the most effective format has been vigorously debated (Lobstein et al. 2007).

A recent review of European research on consumer responses to front-of-pack labelling found that, while there are many studies into consumer preferences regarding front-of-pack labels, there is very little evidence and an urgent need for research into consumer use of front-of-pack nutrition information in a real-world setting (Grunert and Wills 2007). Supermarket sales data has great potential to be used as a tool to monitor and assess the impact of the introduction of new labelling schemes on food purchases (Tin Tin et al. 2007).

In 2006, the UK Food Standards Agency (FSA) recommended that food retailers and manufacturers in the UK place front-of-pack traffic-light labels on products in a range of categories. The labelling format recommended by the FSA consists of four separate colour-coded lights indicating the level of fat, saturated fat, sugar and salt in the product. A ‘red’ light indicates a ‘high’ level of that nutrient, an ‘amber’ light indicates a ‘medium level, and a ‘green’ light indicates a ‘low’ level, with nutrition criteria set by the FSA. The FSA states that a key objective of this traffic-light labelling is to help people make healthier food choices (Food Standards Agency 2008).

In 2006 and 2007, several supermarket chains in the UK started to include front-of-pack nutrition information, some following the FSA recommendations, with
others displaying percentage Guideline Daily Amounts (GDAs) with no colour-coding. There has been no independent evaluation of the impact of these labels on consumer purchases.

This paper aims to examine the impact that the introduction of the FSA-recommended front-of-pack traffic-light labelling scheme has had on food sales in a major UK supermarket chain.

**Methods**

This study used supermarket point-of-sales data from a major UK retailer (the Retailer). (Further details of the Retailer cannot be provided in order to protect the confidentiality of the Retailer.) The Retailer operates a chain of over 1,000 supermarket stores across the UK. The customers of the supermarket chain are closer demographically to the average UK shopper than those of any other UK retailer.

We examined total weekly product sales across all of the Retailer’s UK stores in 2007. The Retailer progressively introduced traffic-light labels on a number of its own-brand products across various food categories throughout 2007. The analysis reported here focuses on product sales in two categories: chilled pre-packaged meals (‘ready meals’) and fresh pre-packaged sandwiches (‘sandwiches’). These categories were selected for analysis, firstly, because these categories contained the greatest number of products with traffic-light labels and, secondly, because these categories included nutritionally diverse products. Prior to the introduction of traffic-light labels, all products in these categories had a table of nutrition information on the back-of-pack including information on percentage GDAs. Many products also had a summary of nutrition information on the front of pack. Besides the Retailer’s own-brand products, no other products had traffic-light labels.
Our study investigated the initial impact of the introduction of traffic-light labels on product sales. In the selected categories, we examined all products for which there were sales data before and after the introduction of traffic-light labels, but excluded those products that were on promotion (discounted in price or part of a promotional campaign) in the eight-week period surrounding the introduction of labels. For the ‘eligible’ products, we compared sales in the four weeks before and the four weeks after the introduction of traffic-light labels. By focusing on sales in a four-week period, we aimed to provide enough time to detect a discernable effect on sales due to the labels while minimising the potential impact of other factors, recognising that the supermarket is a highly dynamic environment. Weekly product sales as a percentage of total weekly sales in the category were examined in order to take account of seasonal fluctuations in the sales of the category as a whole. A linear mixed model was used to examine the association between weekly sales before and after the introduction of traffic-light labels. The model takes into account repeated measures of weekly sales for an individual product to examine the impact of traffic-light labels across the group of products over time.

The percentage change in sales of the eligible products in each category after the introduction of traffic-lights was compared to the relative healthiness of the products, using Spearman’s rank correlation. The ‘healthiness’ was determined by assigning three points for each ‘red’ traffic-light label on the product, two points for each ‘amber’ light and one point for each ‘green’ light, meaning that products could score a theoretical minimum of four points (‘healthiest’ products) and a maximum of twelve points (‘least healthy’ products). While it is recognised that other more sophisticated methods of measuring healthiness are available (Stockley et al. 2008) this method was selected for use in this study as it explicitly uses the nutritional information portrayed by the traffic-light system under examination here.

The changes in product sales by different customer demographic groups were analysed by incorporating additional information from the Retailer’s customer
loyalty card scheme. The sales data used for these purposes represented a subset of the total sales data used for the previous analyses. Through this scheme, the Retailer is able to segregate customer purchases based on the demographic characteristics of their loyalty card holders. The Mosaic segmentation (Experian 2007), which classifies UK consumers into 11 groups based on their socio-demographics, lifestyles, culture and behaviour, was used in segmenting customers into different groups. Eligible products were grouped according to their healthiness, and demographic differences in the change in the sales of these product groupings were examined.

All statistical analysis used SPSS statistical software (Version 14.0 for Windows, Chicago, IL, USA).

Results

Ready Meals

Traffic-light labels were introduced on a total of 23 of the Retailer’s own-brand products (15% of total Ready Meal lines) at various points during 2007. These products varied in their ‘healthiness’, with 12 products having no ‘red’ traffic-lights (only ‘green’ and ‘amber’ lights), six products having only one ‘red’ traffic-light and five products having more than one ‘red’ traffic-light. Only six of the 23 products were deemed eligible for an analysis of the impact of the introduction of traffic-light labels on sales. The other products were either on promotion immediately before or after the introduction of traffic-light labels (n=9) or traffic-light labels were introduced on brand new products (n=8) making it inappropriate to include them in the analysis.

Figure 1 depicts the sales of Ready Meals in 2007, with the sales of the six products deemed eligible for analysis separately identified in the graph, and the eight-week period (Weeks 33 – 41) surrounding the introduction of traffic-light
labels (Week 37) on these products highlighted. In addition to the introduction of traffic-light labels on these products at this time, the product packaging was changed, the product supplier was changed and the products were reformulated. As demonstrated in Figure 1, sales in the category were lower over the summer months (Weeks 14 – 40) compared to the winter months. Weekly spikes in sales were typically the result of individual product promotions. Ready Meals category sales increased by 2.5% in the four weeks after Week 37 compared with the preceding four weeks. For the set of six eligible Ready Meals, sales four weeks after the introduction of traffic-light labels increased by 2.4% (as a percentage of category sales) on sales four weeks before. By fitting a linear mixed model, we found that this difference in weekly sales (as a percentage of category sales) after the introduction of traffic-light labels was significant (P = 0.03).

Table 1 provides details of the changes in sales of each of the eligible Ready Meals after the introduction of traffic-light labels. Sales in all but one of the eligible products increased over this time, with changes in sales four weeks after the introduction of traffic-light labels ranging from a reduction of 31% to an increase of 148% for individual products compared with sales four weeks before.

Each of the products were allocated a healthiness score (Health Score) based on their traffic-light labels (refer to Table 1). The healthiest of the six Ready Meals received a score of 5 (Shepherds Pie), with the unhealthiest scoring 10 (Beef Stew and Dumplings). Crucially, there was no association between the healthiness of the products and the change in sales measured as a percentage of category sales (Spearman’s rank correlation = 0.21, P = 0.69).

We then analysed the change in sales of these products by different demographic groups, as it was considered possible that people from different groups may have responded differently to the introduction of traffic-light labels e.g., the labels may have appealed only to health-conscious shoppers or people from upper socio-economic groups. Table 2 presents this analysis of the change in sales of the six eligible Ready Meals segmented by customer demographic group, using the
Mosaic segmentation. Products were grouped, based on their Health Score, into healthier products, medium-healthy products and less-healthy products to enable an examination of the changes in sales based on the relative healthiness of the products. In almost all customer groups, the product classified as healthier increased in sales more than the products classified as less-healthy; however, in all groups, sales of the less-healthy products increased by more than the medium-healthy products. Thus, despite some differences in behaviour of different customer groups, this analysis still showed no consistent association between the healthiness of products and a change in sales after the introduction of traffic-light labels.

**Sandwiches**

Traffic-light labels were introduced on a total of 49 own-brand products (14% of total Sandwich lines) at various points during 2007. These products varied in their ‘healthiness’, with 25 products having no ‘red’ traffic-lights (only ‘green’ and ‘amber’ lights), 13 products having only one ‘red’ traffic-light and 11 products having more than one ‘red’ traffic-light. As indicated in Table 3, only 12 of the 49 products were deemed eligible for an analysis of the initial impact of the introduction of traffic-light labels on sales. The other products were either on promotion immediately before or after the introduction of traffic-light labels or traffic-light labels were introduced on new products making it inappropriate to perform a direct ‘before and after’ comparison.

**Figure 2** depicts the sales of Sandwiches in 2007, with the sales of the 12 products deemed eligible for analysis separately identified in the graph, and the eight-week period (Weeks 37 - 45) surrounding the introduction of traffic-light labels (Week 41) on these products highlighted. The majority of these products were also reformulated just prior to the introduction of traffic-light labels. As demonstrated in Figure 2, sales of Sandwiches were slightly higher over the summer months (Weeks 14 – 40) compared to the winter months. As with the sales of Ready Meals, weekly spikes in sales were typically the result of
individual product promotions. Sales in the Sandwiches category decreased by
0.7% in the four weeks after Week 41 compared with the preceding four weeks.
For the set of 12 eligible Sandwiches, sales four weeks after the introduction of
traffic-light labels decreased by 0.43% (as a percentage of category sales) on
sales four weeks before. However, when this was fitted in a linear mixed model,
the difference in weekly sales (as a percentage of category sales) after the
introduction of traffic-light labels was not significant (P = 0.14).

Table 4 provides details of the changes in sales of each of the eligible
Sandwiches after the introduction of traffic-light labels. Sales of most of the
eligible products decreased slightly after the introduction of traffic-light labels.

As with the Ready Meals above, each of the products were allocated a healthiness
score (Health Score) based on their traffic-light labels (refer to Table 4). The
healthiest of the 12 Sandwiches received a score of 6 (Chicken Salad Sandwich,
Chicken Stuffing & Red Onion Sandwich, Ham Salad Sandwich, Peking Duck
Wrap, Prawn Mayonnaise Sandwich, Tuna & Sweetcorn Sandwich), with the
unhealthiest scoring 9 (Cheese Sandwich, Cheese Ploughman’s Sandwich,
Cheese & Onion Sandwich). As with the Ready Meals, there was no association
between the healthiness of the products and the change in sales measured as a
percentage of category sales (Spearman’s rank correlation = -0.47, P = 0.12).
Analysis by customer demographic group also revealed no association between
product ‘healthiness’ and change in sales for any of the customer groups.

Discussion

This study of a small sample of products over a short time period found that sales
of Ready Meals increased immediately after the introduction of traffic-light
labels, whereas sales of Sandwiches did not change significantly after the labels
were introduced. However, it is difficult to attribute the observed increase in sales
of Ready Meals to the introduction of traffic-light labels as the products examined
were also reformulated at the time the labels were introduced and the product packaging and manufacturer was changed. Most critically from a public health perspective, this study found no association between the ‘healthiness’ of the products and the change in sales.

We made an effort to minimise the effect of influences other than the introduction of traffic-light labels on sales. We focused only on products for which we could perform a direct before and after comparison of sales, taking into account seasonal fluctuations in sales without the need to adjust sales figures for the effects of promotions, discounts and the impact of product life-cycles. This approach has several limitations. Firstly, the products we analysed represent only a small subset of the products that had traffic-light labels introduced. Secondly, we were only able to assess the immediate impact (four weeks) of traffic-light labels on sales. It is possible that consumers take longer than this to adjust their habits and that the impact of the labels could be greater over a longer period of time. Thirdly, we were not able to account for all factors influencing sales.

This is the first independent study to use supermarket sales data to analyse the impact of the introduction of traffic-light nutrition signposting on consumer food purchases. The strength of using supermarket sales data is that it reflects people’s actual purchasing behaviour in the ‘real-world’. Interestingly, the results do not correspond with the anecdotal evidence by UK supermarkets that indicated consumer shifts towards healthier products in response to front-of-pack nutrition signposting (Sainsbury’s 2006, Tesco 2006). These supermarkets did not disclose sufficient details of their methods when reporting their results to allow a more detailed comparison with the results presented here. Our results can be contrasted with previous research examining the way in which people believe they will respond to front-of-pack nutrition labels. Whereas people may have intentions of using front-of-pack labelling to select healthier options, this study indicates that this may not be reflected in their actual shopping behaviour.
Traffic-light labels have been widely promoted by public health groups around the world as a promising policy option for the promotion of public health nutrition based, at least in part, on the presumption that they would lead to a shift in consumer purchases towards healthier products. One possible explanation for the results of this study is that consumers did not understand the labels. This may imply that the formatting of the labels needs to be changed or that more effort needs to be spent on educating consumers on how to use the labels. Another potential explanation is that, in the categories investigated, traffic-light labels were only present on a small proportion of the products. It can be argued that the labels will have a greater and therefore more detectable effect on sales when all products are labelled in the same way, allowing consumers to more readily compare the information provided by traffic-light labels across products. There are a large number of other potential explanations and it is suggested that future research in this area incorporate the views of customers and other contextual factors.

It is important to note that this study has not looked at all the potential effects of the introduction of traffic-light labelling. Future research could examine longer-term impact of traffic-light labelling on sales, the impact of this labelling format on the reformulation of products, and on consumer awareness of what they are eating, regardless of the effects on purchasing behaviour.

Conclusion

This study provides evidence that the introduction of traffic-light labels did not substantially influence supermarket sales of Ready Meals and Sandwiches in the stores of one particular retailer in the UK. While these findings need further examination in other contexts, in other food categories and over a longer-time period, the results indicate that the use of front-of-pack labelling in this format and at this level of use may not be sufficient to influence consumer behaviour in a major way.
However, this study should not preclude the possibility of traffic-light labelling delivering public health benefits e.g., in situations where it is used on more products or when it is used in conjunction with other in-store activities designed to promote healthier choices. Furthermore the study has not looked at all the potential effects of the introduction of traffic-light labelling e.g. the reformulation of products to avoid ‘red’ lights and the level of nutrition awareness in the population.

Studies such as this should be used to develop and refine food labelling policies to meet the stated objectives of the policy. These findings should serve as a challenge to proponents of different forms of front-of-pack labelling to demonstrate the impact of other nutrition signpost formats on consumer purchases.

Acknowledgements

The authors would like to thank the staff at the Retailer for their kind support in providing the data for this study and their assistance with the analysis. The authors would also like to thank Peter Scarborough and Professor Sing Kai Lo for their assistance with the statistical analysis.
References


http://www.eatwell.gov.uk/ (accessed March 2009)


Tesco (2006) Informing the customer. PowerPoint presentation prepared by Hutchins, I


<table>
<thead>
<tr>
<th>Product description</th>
<th>Traffic-light labels</th>
<th>Health Score (RANK)</th>
<th>Sales for the 4 weeks BEFORE introduction of traffic-light labels (% of category sales)</th>
<th>Sales for the 4 weeks AFTER introduction of traffic-light labels (% of category sales)</th>
<th>CHANGE in sales after introduction of traffic-light labels (% of category sales) (RANK)</th>
<th>CHANGE in sales after introduction of traffic-light labels (% of own sales)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shepherds Pie (400g)</td>
<td>Green Green Green Amber</td>
<td>5 (1)</td>
<td>0.9%</td>
<td>2.2%</td>
<td>1.3% (1)</td>
<td>148%</td>
</tr>
<tr>
<td>Cumberland Pie (400g)</td>
<td>Amber Red Green Amber</td>
<td>8 (3)</td>
<td>0.3%</td>
<td>0.3%</td>
<td>0.0% (5)</td>
<td>12%</td>
</tr>
<tr>
<td>Lancashire Hot Pot (400g)</td>
<td>Amber Red Green Amber</td>
<td>8 (3)</td>
<td>1.6%</td>
<td>1.1%</td>
<td>-0.5% (6)</td>
<td>-31%</td>
</tr>
<tr>
<td>Liver &amp; Bacon with Mashed Potato (400g)</td>
<td>Amber Red Green Amber</td>
<td>8 (3)</td>
<td>0.4%</td>
<td>0.7%</td>
<td>0.3% (4)</td>
<td>82%</td>
</tr>
<tr>
<td>Sausage and Mash (400g)</td>
<td>Red Red Green Amber</td>
<td>9 (5)</td>
<td>0.8%</td>
<td>1.8%</td>
<td>0.9% (2)</td>
<td>116%</td>
</tr>
<tr>
<td>Beef Stew and Dumplings (400g)</td>
<td>Red</td>
<td>Red</td>
<td>Green</td>
<td>Red</td>
<td>10 (6)</td>
<td>0.6%</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----</td>
<td>-----</td>
<td>-------</td>
<td>-----</td>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>Total of eligible products</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.6%</td>
</tr>
</tbody>
</table>

*a Where products had the same health score, they received a ‘mean rank’*
Table 2  Percentage change in sales of eligible Ready Meals (grouped according to relative healthiness) by Mosaic customer demographic group (Experian, 2007)

<table>
<thead>
<tr>
<th>Customer group</th>
<th>CHANGE in sales 4 weeks before and 4 weeks after introduction of traffic-light labels (% of own sales)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Healthier products (Health Score &lt;= 5) (n = 1)</td>
<td>Medium-healthy products (Health Score = 6, 7 or 8) (n = 3)</td>
</tr>
<tr>
<td>‘Symbols of success’</td>
<td>81%</td>
<td>-19%</td>
</tr>
<tr>
<td>‘Happy families’</td>
<td>108%</td>
<td>-4%</td>
</tr>
<tr>
<td>‘Suburban comfort’</td>
<td>89%</td>
<td>-6%</td>
</tr>
<tr>
<td>‘Ties of community’</td>
<td>145%</td>
<td>2%</td>
</tr>
<tr>
<td>‘Urban intelligence’</td>
<td>47%</td>
<td>2%</td>
</tr>
<tr>
<td>‘Welfare borderline’</td>
<td>76%</td>
<td>-2%</td>
</tr>
<tr>
<td>‘Municipal dependency’</td>
<td>132%</td>
<td>17%</td>
</tr>
<tr>
<td>‘Blue collar enterprise’</td>
<td>110%</td>
<td>-5%</td>
</tr>
<tr>
<td>‘Twilight subsistence’</td>
<td>78%</td>
<td>7%</td>
</tr>
<tr>
<td>‘Grey perspectives’</td>
<td>92%</td>
<td>4%</td>
</tr>
<tr>
<td>‘Rural isolation’</td>
<td>103%</td>
<td>-3%</td>
</tr>
</tbody>
</table>
Table 3  Products in Sandwiches category highlighting products eligible for analysis

<table>
<thead>
<tr>
<th>Classification</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Retailer’s own-brand products</td>
<td>54</td>
</tr>
<tr>
<td>Traffic-light labels not introduced</td>
<td></td>
</tr>
<tr>
<td>Products on promotion immediately before traffic-light labels introduced</td>
<td>3</td>
</tr>
<tr>
<td>Products on promotion immediately after traffic-light labels introduced</td>
<td>21</td>
</tr>
<tr>
<td>Traffic-light labels introduced on brand new products</td>
<td>13</td>
</tr>
<tr>
<td><strong>Products with traffic-light labels eligible for analysis</strong></td>
<td><strong>12</strong></td>
</tr>
<tr>
<td>Total products in category</td>
<td>355</td>
</tr>
<tr>
<td>Product description</td>
<td>Traffic-light labels</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Chicken &amp; Onion Sandwich (Deep Fill)</td>
<td>Amber Green Green Amber 6 (3.5)</td>
</tr>
<tr>
<td>Chicken Salad Sandwich</td>
<td>Amber Green Green Amber 6 (3.5)</td>
</tr>
<tr>
<td>Ham Salad Sandwich</td>
<td>Amber Green Green Amber 6 (3.5)</td>
</tr>
<tr>
<td>Peking Duck Wrap</td>
<td>Amber Amber Green Green Amber 6 (3.5)</td>
</tr>
<tr>
<td>Prawn Mayonnaise Sandwich</td>
<td>Amber Green Green Amber 6 (3.5)</td>
</tr>
<tr>
<td>Tuna &amp; Sweetcorn Sandwich</td>
<td>Amber Green Green Amber 6 (3.5)</td>
</tr>
<tr>
<td>Chicken Salad Sandwich (Deep Fill)</td>
<td>Amber Amber Green Amber 7 (7)</td>
</tr>
<tr>
<td>Egg &amp; Bacon Sandwich (Deep Fill)</td>
<td>Red Amber Green Amber 8 (8.5)</td>
</tr>
<tr>
<td>Product</td>
<td>Health Score</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Ham &amp; Cheese Sandwich</td>
<td>Amber</td>
</tr>
<tr>
<td>Cheese Sandwich</td>
<td>Red</td>
</tr>
<tr>
<td>Cheese Ploughmans Cheese Sandwich (Deep Fill)</td>
<td>Red</td>
</tr>
<tr>
<td>Cheese &amp; Onion Sandwich</td>
<td>Red</td>
</tr>
</tbody>
</table>

Total of eligible products                    |              |         |           |           |              | 36.1%          | 35.7%          | -0.43%            | -1.9%             |

*Where products had the same health score, they received a ‘mean rank’*
Figure 1  Ready Meals sales in 2007 highlighting products eligible for analysis of impact of introduction of traffic-light labels in Week 37. Sales are expressed as units sold, indexed to sales in Week 1 of 2007.
Figure 2  Sandwiches sales in 2007 highlighting products eligible for analysis of impact of introduction of traffic-light labels in Week 41. Sales are expressed as units sold, indexed to sales in Week 1 of 2007.
Chapter 7: Impact of traffic-light nutrition information on food purchases in Australia

Chapter overview

This chapter reports on Study E of this research. It consists of a manuscript entitled, “Impact of ‘traffic-light’ nutrition information on online food purchases in Australia” as well as an additional section that reports the results of the survey conducted as part of the study.
Manuscript 7


DEAKIN UNIVERSITY

STATEMENT OF CONTRIBUTION OF CO-AUTHORS

Declaration by candidate

In the case of the manuscript named above, the nature and extent of my contribution to the work was the following:

<table>
<thead>
<tr>
<th>Nature of contribution</th>
<th>Extent of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jointly designed the study, led the analysis of the results, drafted the manuscript,</td>
<td>80%</td>
</tr>
<tr>
<td>collated comments from other authors and responded to reviewers, reviewed and approved</td>
<td></td>
</tr>
<tr>
<td>the final manuscript, corresponding author</td>
<td></td>
</tr>
</tbody>
</table>

The following co-authors contributed to the work:

<table>
<thead>
<tr>
<th>Name</th>
<th>Nature of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kim Tikellis</td>
<td>Jointly designed the study, commented on drafts of the manuscript, reviewed and approved</td>
</tr>
<tr>
<td>Lynne Millar</td>
<td>Assisted with the statistical analysis, commented on drafts of the manuscript, reviewed and approved</td>
</tr>
<tr>
<td>Boyd Swinburn</td>
<td>Jointly designed the study, commented on drafts of the manuscript, reviewed and approved</td>
</tr>
</tbody>
</table>

Gary Sacks

Candidate’s Name: ______________________  Signature: ______________________  Date: 25 October 2010
Declaration by co-authors

The authors listed above have certified that:

1. The above declaration correctly reflects the nature and extent of the candidate’s contribution to this work, and the nature of the contribution of each of the co-authors.
2. They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise.
3. They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication.
4. There are no other authors of the publication according to these criteria.
5. Potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit.
6. They agree to the use of the publication in the student’s thesis and its publication on the Australasian Digital Thesis database consistent with any limitations set by publisher requirements.

Principal supervisor confirmation

I have sighted email or other correspondence from all co-authors confirming the above-mentioned certifications.

Boyd Swinburn

________________
Supervisor’s Name

________________
Signature

________________
Date

25 October 2010
Title: Impact of ‘traffic-light’ nutrition information on online food purchases in Australia

Authors: Gary Sacks 1*, Kim Tikellis 2, Lynne Millar 1, Boyd Swinburn 1

1 WHO Collaborating Centre for Obesity Prevention, Deakin University, Melbourne, Australia
2 Nutrition Manager - ANZ, Fonterra, Australia

* All correspondence to Gary Sacks, WHO Collaborating Centre for Obesity Prevention, Deakin University, 221 Burwood Highway, Melbourne VIC 3125, Australia. Tel +61(0) 3 9244 6036. Fax +61(0) 3 9244 6640. Email: gary.sacks@deakin.edu.au

Funding: The ACE-Prevention project, of which this study forms a part, was funded by an Australian National Health and Medical Research Council Health Services Research grant (no. 351558). Gary Sacks is supported by a Deakin University Postgraduate Research Scholarship.

Potential conflicts of interest: GS, LM and BS declare that they have no competing interests. KT was employed by the supermarket involved with this study (the Retailer) at the time that the study was conducted, and is currently employed as a nutrition manager at a multi-national food company. The Retailer reviewed and approved the final manuscript prior to submission but was not involved in the analysis or preparation of the results.

Abstract

Objective: ‘Traffic-light’ nutrition labelling has been proposed as a potential tool for improving the diet of the population, yet there has been little published research on the impact of traffic-light nutrition labelling on purchases in a supermarket environment. This study examined changes to online consumer food purchases in response to the introduction of traffic-light nutrition information (TLNI).

Methods: The study consisted of a 10-week trial in a major Australian online grocery store. For the duration of the trial TLNI in the form of four colour-coded indicators representing the products’ relative levels of fat, saturated fat, sugar and sodium content, was displayed on the product listing page of 53 of the retailer’s ‘own-brand’ products in 5 food categories (milk, bread, breakfast cereals, biscuits and frozen meals). The changes in sales before and after the introduction of TLNI were examined both within the intervention store and in a comparison store. Results: TLNI had no discernible impact on sales, with the change in sales in the intervention store corresponding to changes in sales in the comparison store. No relation was observed between changes in sales and the relative healthiness of products.

Conclusion and implications: This limited, short-term study found no evidence to support the notion that TLNI is likely to influence behaviour change. Further research is needed to examine the impact of providing TLNI in different contexts, for a longer duration and on more products, with and without complementary awareness and information campaigns.

Keywords: nutrition labelling, online shopping, food purchases
Introduction

Governments around the world are actively seeking sustainable and cost-effective strategies to improve public health nutrition (1). New forms of food labelling have been proposed as potential tools for improving the nutrition of the population (2), and a number of different ‘front-of-pack’ nutrient signposting schemes have been developed (3) with the most suitable format vigorously debated (4-6).

One of the most commonly proposed ‘front-of-pack’ labelling schemes is a ‘traffic-light’ labelling system that highlights the total fat, saturated fat, sugar and sodium content on the front panel of food packages, with each nutrient colour-coded as red, amber, or green corresponding to ‘high’, ‘medium’, or ‘low’ levels of that nutrient (7). In the United Kingdom (UK) in 2006, the Food Standard Agency (FSA) recommended the use of this format of traffic-light labelling in selected food categories (7), and many UK supermarkets adopted traffic-light labelling as per the FSA guidelines. In Australia, a recent report by the National Preventative Health Taskforce recommended the implementation of a standardised front-of-pack nutrition labelling system (8), and public health advocates are calling for the mandatory adoption of front-of-pack traffic-light labelling (9). While there have been numerous studies investigating consumer perceptions of front-of-pack nutrition labelling in Australia (6,10) and internationally (5,11-12), there has been only limited evaluation of the effect of front-of-pack nutrient signposting on food purchases (13-14). As governments, industry groups and organisations consider various policy options for addressing diet-related disease and the obesity epidemic in particular, evidence of the impact of nutrient signposting schemes is likely to be highly valuable in informing these decisions.

This paper reports the results of a study that aimed to investigate the impact of the introduction of traffic-light nutrition information (TLNI) on online consumer food purchases in Australia. The objectives of the study were to trial TLNI in a
real-world food purchasing environment and to examine sales data to determine the degree to which the ‘healthiness’ of consumer purchases changed during the trial. The hypotheses were that sales of healthier products would increase and sales of less healthy products would decrease with the introduction of TLNI.

Methods

Study design

The study was conducted in conjunction with a major national supermarket chain in Australia (the Retailer). At the time of the study, in addition to a national network of supermarkets, the Retailer operated two online supermarkets where customers could purchase groceries via the Internet. These two online supermarkets sold the same set of products (including the full range of products sold in the Retailer’s physical supermarkets) at the same prices but the two stores had differing website addresses, corporate branding and user interfaces. The study was conducted as a 10-week trial (8 October 2007 – 16 December 2007) on one of the online supermarkets (the ‘intervention’ store). The intervention store serviced customers in the Sydney metropolitan area only; whereas the other online supermarket (the ‘comparison’ store) serviced customers nationally. Prior to the trial study, neither of the online supermarkets provided product-level nutrition information for any of the products sold.

For the duration of the trial, a set of four traffic-light indicators were displayed alongside the product listing for a selection of products on the intervention store, indicating the products’ relative levels of fat, saturated fat, sugar and sodium (Figure 1). The selected products included only the Retailer’s own-brand products (n=53) in the following food categories: milk (n=10), bread (n=11), breakfast cereals (n=19), biscuits (n=7), and frozen meals (n=6). These food categories were selected for the trial because it was felt that products in these categories exhibited the broadest range of different nutrient profiles, thereby
including a diversity of traffic-light indicators within each category. The trial was restricted to the Retailer’s own-brand products because the Retailer advised that these products were the only option for intervention given the commercial constraints around labelling branded products. The nutrition criteria for the traffic-light indicators were based on the criteria recommended by the UK FSA (15), adapted for the Australian environment (10) (Table 1). For the selected products, detailed nutrient information in the form of the nutrition information panel (NIP) and the traffic-light indicators was also added to the individual product pages. On the home page of the intervention store and on each of the selected category and product pages, a link was provided to a page providing information about the trial, an explanation of what the traffic-light indicators mean and how to interpret them, the criteria used for the traffic-light indicators, and general nutrition advice with a link to the Australian dietary guidelines (16). No nutrition information was provided on the comparison store site during the trial period.

Data analysis and statistical methods

Sales data (measured in units sold per product) were collected for the 53 selected products for the intervention store and the comparison store. Data were collected for the 10-week duration of the trial (trial period) and a corresponding 10-week period immediately preceding the trial (pre-trial period). The analyses of sales data from the comparison store were restricted to sales in New South Wales only in order to match the geographic region of the intervention store. The prices of products were equivalent in both stores throughout the analysis period. None of the selected products was on promotion or discounted in price in either store at any time during the analysis period.

In order to compare changes in sales by the relative healthiness of the products, two different methods were used to categorise the healthiness of each product. Both methods used the product’s traffic-light indicators as a means of classifying the product’s healthiness. In the first method, products were classified based on
their number of ‘red’ labels, with products with no ‘red’ labels distinguished from products with at least one ‘red’ label. In the second method, a healthiness score was calculated for each product based on the colours of the product’s traffic-light indicators, with one point allocated for each ‘green’ label, two points for each ‘amber’ label and three points for each ‘red’ label, for a possible range over all four traffic-light labels of 4 to 12 points. Under this method, products scoring less than 7 points were classified as ‘healthier’, and products scoring 7 points or more were classified as ‘less-healthy’.

The study utilised a within-subjects design, where product sales in the pre-trial period and the trial period were compared between conditions. Summative descriptive statistics were used to describe the data and within-subjects repeated measures analysis of variance (RM-ANOVA) was used to examine the association between product sales and stores, as well as product sales and healthiness of the product using both methods for classifying healthiness.

Results

Change in total sales

The total number of units sold, by category, during the pre-trial and trial periods across the intervention and comparison stores are shown in Table 2. For all 53 products investigated, the total number of units sold over the analysis period was substantially higher in the comparison store than the intervention store. In both stores, sales decreased from the pre-trial to the trial period in all categories except bread and biscuits. Due to the relatively low sales of breakfast cereals, biscuits and frozen meals, these categories were grouped together in the analyses that follow, with milk and bread retained as separate categories. As there was a large difference between sales in the intervention and comparison stores, only the interactions between product sales and stores are reported. A within-subjects RM-ANOVA showed that there was no significant interaction between product sales
and stores as sales from both stores changed at a similar rate between the pre-trial and the trial periods over the three categories: milk ($F(1, 9)=0.56, P>0.05$); bread ($F(1, 10)=2.19, P>0.05$); and ‘other products’ ($F(1, 31)=2.81, P>0.05$).

**Change in sales by healthiness of products**

The numbers of products in each category, classified according to their relative healthiness, are shown in Table 3. Of the 53 products, 14 products had at least one ‘red’ label, although only one bread and no milk or frozen meal products had a ‘red’ label. Using the alternative classification method based on a points score (described in the methods section), 29 products were classified as ‘healthier’ and 24 products were classified as ‘less-healthy’.

A within-subjects RM-ANOVA showed that, for the intervention store, there was no interaction between the presence of a ‘red’ label and the change in mean weekly product sales between the pre-trial period and the trial period for breads ($F(1,10)=0.2, P>0.05$) and ‘other products’ ($F(1, 31)=2.8, P>0.05$). The milk category was excluded from this analysis as there were no milk products with a red label. Similar results were obtained for the comparison store. This indicates that the changes in sales of products with ‘red’ labels were not significantly different to the changes in sales of products without ‘red’ labels. Similar results were obtained when the changes in sales were analysed based on the classification of products as ‘healthier’ and ‘less-healthy’.

**Discussion**

The results of this short-term study, on a small selection of products, indicate that the presence of online TLNI did not have a discernible impact on online food purchases. The changes in sales from the pre-trial period to the trial period in the intervention store corresponded to changes in sales in the comparison store, with
no observed relation between changes in sales and the relative healthiness of products (measured in various ways).

This is the first peer-reviewed study to use supermarket sales data to analyse the impact of the introduction of TLNI on supermarket food purchases in the Australian context. The key strength of using supermarket sales data is that it reflects people’s actual purchasing behaviour in the ‘real-world’, rather than intended behaviour (17). The study design enabled a ‘before and after’ comparison of sales in the intervention store as well as a comparison to corresponding sales in the comparison store. The use of such tightly-matched comparison data is highly valuable in this context as it reduces the potential confounding of the results due to factors such as seasonality and product life cycle effects. Furthermore, the online shopping environment is less subject to change compared to the physical supermarket environment, providing a more stable context in which to examine the impact of specific interventions such as the one in this study. A further strength of this study is that it demonstrates the feasibility of working with large supermarket retailers to conduct public health research.

The study has several limitations that limit the extent to which the results can be generalised. Firstly, the study is conducted in an online shopping context, and it is reasonable to expect that food purchasing behaviour differs in an online compared to a physical supermarket context. For example, in an online context, people may tend to purchase food products with which they are familiar, whereas they may be more likely to browse more extensively in a physical setting. Furthermore, the demographics of online grocery shoppers [the majority of whom are typically highly-educated, relatively wealthy females less than 55 years of age (18)] do not reflect the demographics of the population as a whole. Due to their demographic characteristics, it is likely that online grocery shoppers are more health-conscious than the population as a whole, and any effects of TLNI upon the already health conscious are likely to be minimal. Indeed, it may be more important to focus on different consumers where there might be more opportunity
to shift behaviours. A second key limitation of the study is that it involved only a small set of products, all of which were the Retailer’s own-brand products, with relatively small sales volumes. This may have limited the extent to which customers noticed the TLNI. Furthermore, the factors influencing the purchase of a supermarket’s own-brand products are likely to be different to those influencing purchases of a broader product set. Thirdly, the study was only able to assess the short-term impact (10 weeks) of TLNI on sales. It is possible that consumers take longer than this to adjust their habits and that the impact of the TLNI could be different over a longer period of time and if reinforced through several media. In addition, despite the use of comparison data, the analyses were not able to account for all factors influencing sales (e.g. taste, mood, convenience, price, habitual behaviour and pleasure) (11). A further potential confounder was that, in addition to the inclusion of TLNI, the NIP was also made available for the selected products on the intervention store. Changes in sales of products that did not receive TLNI during the trial period were also not assessed.

The results of this study can be compared with previous research that shows that changes to nutrition information at the point-of-purchase can be expected to have, at best, only modest effects on the healthiness of consumer food choices in supermarkets (19). It is consistent with results from the UK (14), which indicated no relation between changes in sales and the healthiness of products in response to TLNI in a supermarket environment. However, the results contrast with the results of a recent study in the United States context (13) that showed shifts in supermarket sales towards healthier products in response to a form of nutrient signposting (the “Guiding Stars” program) that indicated healthier products. It is not clear on the reasons for these contrasting results, but it is noted that the “Guiding Stars” program incorporated a large number of products and the program was accompanied by extensive educational materials. Qualitative analyses of the use of nutrient signposting in different contexts are likely to be valuable in explaining the contrasting results (11).
It is clear that further research is needed to examine the impact of TLNI and other forms of nutrition signposting in other contexts, especially in light of the increased recognition that considerable national differences exist in both understanding and use of front-of-pack nutrition information (12). Studies should be designed to include a higher proportion of labelled products across the full product range in an environment with a higher volume of sales, and should aim to minimise the effects of potential confounders.

Conclusions

In this age of increasingly-processed foods with diverse nutrition-related marketing, there is considerable government interest in a standardised front-of-pack nutrient signposting scheme that can better inform consumers. Beyond simply providing information, the extent to which an improved nutrition labelling scheme will influence people to choose healthier foods is open to question; and this limited, short-term trial found no evidence to indicate that it would. It is possible that a nutrient signposting scheme which is on all foods and beverages and is accompanied by an awareness and information campaign may influence food choices but this would need to be evaluated. It may be useful for advocates of different front-of-pack labelling formats to focus on the potential benefits of their preferred schemes with respect to informing consumers while further evaluations of other potential impacts are conducted.
References


Table 1  The nutrition criteria used to determine the traffic-light indicators of low (‘green’), medium (‘amber’) and high (‘red’), based on UK FSA (15), adapted for the Australian environment (10).

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Category</th>
<th>Low (‘green’) (per 100g)</th>
<th>Medium (‘amber’) (per 100g)</th>
<th>High (‘red’) (per 100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total fat</td>
<td>Food</td>
<td>≤3g</td>
<td>3.1g – 19.9g</td>
<td>≥20g</td>
</tr>
<tr>
<td></td>
<td>Drink</td>
<td>≤1.5g</td>
<td>1.6g – 9.9g</td>
<td>≥10g</td>
</tr>
<tr>
<td>Saturated fat</td>
<td>Food</td>
<td>≤1.5g</td>
<td>1.6g – 4.9g</td>
<td>≥5g</td>
</tr>
<tr>
<td></td>
<td>Drink</td>
<td>≤0.75g</td>
<td>0.76g – 2.49g</td>
<td>≥2.5g</td>
</tr>
<tr>
<td>Sugar</td>
<td>Food</td>
<td>≤5g</td>
<td>5.1g – 14.9g</td>
<td>≥15g</td>
</tr>
<tr>
<td></td>
<td>Drink</td>
<td>≤2.5g</td>
<td>2.6g – 7.4g</td>
<td>≥7.5g</td>
</tr>
<tr>
<td>Sodium</td>
<td>Food</td>
<td>≤120mg</td>
<td>121mg – 599g</td>
<td>≥600mg</td>
</tr>
<tr>
<td></td>
<td>Drink</td>
<td>≤60mg</td>
<td>61mg – 299g</td>
<td>≥300mg</td>
</tr>
</tbody>
</table>
Table 2  Total number of units sold by category during the pre-trial and trial periods across the intervention and comparison stores

<table>
<thead>
<tr>
<th>Category</th>
<th>Store</th>
<th>Units sold – Pre-trial period</th>
<th>Units sold – Trial period</th>
<th>Change in units sold (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>Intervention</td>
<td>2,166</td>
<td>1,973</td>
<td>-8.9</td>
</tr>
<tr>
<td></td>
<td>Comparison</td>
<td>17,053</td>
<td>15,625</td>
<td>-8.4</td>
</tr>
<tr>
<td>Bread</td>
<td>Intervention</td>
<td>1,050</td>
<td>1,112</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td>Comparison</td>
<td>9,511</td>
<td>10,150</td>
<td>6.7</td>
</tr>
<tr>
<td>Breakfast cereals</td>
<td>Intervention</td>
<td>443</td>
<td>420</td>
<td>-5.2</td>
</tr>
<tr>
<td></td>
<td>Comparison</td>
<td>2,624</td>
<td>2,476</td>
<td>-5.6</td>
</tr>
<tr>
<td>Biscuits</td>
<td>Intervention</td>
<td>97</td>
<td>120</td>
<td>23.7</td>
</tr>
<tr>
<td></td>
<td>Comparison</td>
<td>561</td>
<td>723</td>
<td>28.9</td>
</tr>
<tr>
<td>Frozen meals</td>
<td>Intervention</td>
<td>100</td>
<td>87</td>
<td>-13</td>
</tr>
<tr>
<td></td>
<td>Comparison</td>
<td>299</td>
<td>279</td>
<td>-6.7</td>
</tr>
<tr>
<td>Total</td>
<td>Intervention</td>
<td>3,856</td>
<td>3,712</td>
<td>-3.7</td>
</tr>
<tr>
<td></td>
<td>Comparison</td>
<td>30,048</td>
<td>29,253</td>
<td>-2.6</td>
</tr>
</tbody>
</table>
Table 3  The number of products in each category, classified according to their relative healthiness by two different methods

<table>
<thead>
<tr>
<th>Category</th>
<th>Total no. of products</th>
<th>Products with no ‘red’ labels</th>
<th>Products with at least one ‘red’ label</th>
<th>Products classified as ‘healthier’</th>
<th>Products classified as ‘less healthy’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Bread</td>
<td>11</td>
<td>10</td>
<td>1</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Breakfast cereals</td>
<td>19</td>
<td>11</td>
<td>8</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Biscuits</td>
<td>7</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Frozen meals</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>53</td>
<td>39</td>
<td>14</td>
<td>29</td>
<td>24</td>
</tr>
</tbody>
</table>
Figure 1  Illustration of the way in which traffic-light indicators were displayed on the product list page for the breakfast cereal category in the intervention store. Only the Retailer’s own-brand products were signposted with traffic-light indicators.

<table>
<thead>
<tr>
<th>Product Description</th>
<th>Fat</th>
<th>Sat Fat</th>
<th>Sugar</th>
<th>Sodium</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bran Flakes – 450g pkt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$4.95</td>
</tr>
<tr>
<td>Toasted Muesli – 500g pkt</td>
<td>MED</td>
<td>MED</td>
<td>HIGH</td>
<td>LOW</td>
<td>$5.20</td>
</tr>
<tr>
<td>Wheat Biscuits – 550g pkt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$6.20</td>
</tr>
<tr>
<td>Corn Flakes – 500g pkt</td>
<td>LOW</td>
<td>LOW</td>
<td>MED</td>
<td>HIGH</td>
<td>$5.50</td>
</tr>
</tbody>
</table>

Click here for more details on nutrition information and the new traffic light symbols
Customer survey

Introduction

The manuscript presented earlier in this chapter reported the results of Study E that aimed to assess the impact of traffic-light nutrition labelling on supermarket food purchases in Australia. The primary objective of the study was to conduct a trial to collect empirical evidence on the impact of traffic-light nutrition labelling on consumer food purchases. As part of the trial, customers were also surveyed to assess their understanding and perceived utility of traffic-light nutrition information. This section presents the methods and results of that survey.

Methods

During the trial, all visitors to the intervention store (see Section 2.8.2 for details of the study design) were invited to anonymously complete a self report questionnaire (the survey). The survey comprised nine questions divided into two sections. The five items in the first section concerned traffic-light information awareness and utility. The second section of four items consisted of demographic questions such as age, education level, household composition, and income. The survey questions are shown in the Appendix. The study was approved by the Ethics Committee of Deakin University (EC 237-2007), and all survey participants provided informed consent online.

Results

In total, 141 visitors to the intervention store during the trial period responded to the survey, while approximately 1,200 different customers placed orders in the store during that time. The demographic characteristics of the survey respondents are shown in Table 7.1, with the respondents relatively wealthier and better-
educated than the Australian population overall. Forty-three respondents (31%) indicated that they noticed the traffic-light nutrition information when shopping on the intervention store site during the trial period, and 84% of those respondents found the traffic-light nutrition information useful. One-hundred and thirty-four respondents (95%) felt that the traffic-light nutrition information was easy to understand and 117 respondents (83%) felt that they would like to see the traffic-light nutrition information used more broadly.

**Discussion**

The majority of survey respondents indicated that they felt the traffic-light nutrition information was useful, desirable and easy to understand. However, the very low level of response (participation rate) to the survey is likely to have introduced selection bias. Accordingly, the extent to which the results can be generalised is highly uncertain. Nevertheless, the results of this survey are consistent with another broader survey of Australian consumers that reported that consumers find traffic-light nutrition labelling easy to understand. This evidence should be used to inform the most appropriate labelling format in Australia and elsewhere. It is noted, however, that ease of understanding of nutrition labelling does not necessarily translate to use. This is perhaps reflected in this study’s observation that no changes in sales resulted from the introduction of traffic-light nutrition information.
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Frequency (n=141)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 -29 years old</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>30-65 years old</td>
<td>113</td>
<td>80</td>
</tr>
<tr>
<td>Over 65 years old</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td><strong>Highest level of education</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did not complete high school</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Completed high school</td>
<td>24</td>
<td>17</td>
</tr>
<tr>
<td>Completed tertiary education</td>
<td>89</td>
<td>63</td>
</tr>
<tr>
<td>Not specified / other</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td><strong>Household composition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household with children</td>
<td>67</td>
<td>48</td>
</tr>
<tr>
<td>Household without children</td>
<td>55</td>
<td>39</td>
</tr>
<tr>
<td>Not specified / other</td>
<td>19</td>
<td>13</td>
</tr>
<tr>
<td><strong>Household income</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than AUD50,000 per year</td>
<td>24</td>
<td>17</td>
</tr>
<tr>
<td>AUD50,000 – AUD100,000 per year</td>
<td>43</td>
<td>30</td>
</tr>
<tr>
<td>&gt; AUD100,000 per year</td>
<td>29</td>
<td>21</td>
</tr>
<tr>
<td>Not specified / other</td>
<td>45</td>
<td>32</td>
</tr>
</tbody>
</table>
Chapter 8: Cost-effectiveness modelling

Chapter overview

This chapter reports on Study F of this research. It consists of a single manuscript entitled, “‘Traffic-light’ nutrition labelling and ‘junk-food’ tax: a modelled comparison of cost-effectiveness for obesity prevention”.

Manuscript 8


DEAKIN UNIVERSITY

STATEMENT OF CONTRIBUTION OF CO-AUTHORS

Declaration by candidate

In the case of the manuscript named above, the nature and extent of my contribution to the work was the following:

<table>
<thead>
<tr>
<th>Nature of contribution</th>
<th>Extent of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed the study, performed aspects of the modelling, led the analysis of the results, drafted the manuscript, collated comments from other authors and responded to reviewers, reviewed and approved the final manuscript, corresponding author</td>
<td>80%</td>
</tr>
</tbody>
</table>

The following co-authors contributed to the work:

<table>
<thead>
<tr>
<th>Name</th>
<th>Nature of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>J Lennert Veerman</td>
<td>Jointly developed the BMI-DALYs model, assisted with applying the BMI-DALYs model, commented on drafts of the manuscript, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>Marj Moodie</td>
<td>Assisted with the analysis of results, commented on drafts of the manuscript, reviewed and approved the final manuscript</td>
</tr>
<tr>
<td>Boyd Swinburn</td>
<td>Assisted with the analysis of results, commented on drafts of the manuscript, reviewed and approved the final manuscript</td>
</tr>
</tbody>
</table>

Gary Sacks

25 October 2010

________________  __________________  _______________
Candidate’s Name   Signature      Date
Declaration by co-authors

The authors listed above have certified that:

1. The above declaration correctly reflects the nature and extent of the candidate’s contribution to this work, and the nature of the contribution of each of the co-authors.
2. They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise.
3. They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication.
4. There are no other authors of the publication according to these criteria.
5. Potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit.
6. They agree to the use of the publication in the student’s thesis and its publication on the Australasian Digital Thesis database consistent with any limitations set by publisher requirements.

Principal supervisor confirmation

I have sighted email or other correspondence from all co-authors confirming the above-mentioned certifications.

Boyd Swinburn

__________________________________________________________________________________________

Supervisor’s Name       Signature       Date

25 October 2010
Title: ‘Traffic-light’ nutrition labelling and ‘junk-food’ tax: a modelled comparison of cost-effectiveness for obesity prevention

Authors: Gary Sacks 1*, J Lennert Veerman 2, Marj Moodie 3, Boyd Swinburn 1

1 WHO Collaborating Centre for Obesity Prevention, Deakin University, Melbourne, Australia
2 School of Population Health, The University of Queensland, Brisbane, Australia
3 Deakin Health Economics, Deakin University, Melbourne, Australia

* All correspondence to Gary Sacks, WHO Collaborating Centre for Obesity Prevention, Deakin University, 221 Burwood Highway, Melbourne VIC 3125, Australia. Tel +61(0) 3 9244 6036. Fax +61(0) 3 9244 6640. Email: gary.sacks@deakin.edu.au

Funding: The ACE-Prevention project, of which this study forms a part, was funded by an Australian National Health and Medical Research Council Health Services Research grant (no. 351558). Gary Sacks is supported by a Deakin University Postgraduate Research Scholarship.

Conflict of interest: The authors declare no conflict of interest.

Abstract

Introduction: Cost-effectiveness analyses are important tools in efforts to prioritise interventions for obesity prevention. Modelling facilitates evaluation of multiple scenarios with varying assumptions. This study compares the cost-effectiveness of conservative scenarios for two commonly proposed policy-based interventions: front-of-pack ‘traffic-light’ nutrition labelling (traffic-light labelling) and a tax on unhealthy foods (‘junk-food’ tax).

Methods: For traffic-light labelling, estimates of changes in energy intake were based on an assumed 10% shift in consumption towards healthier options in four food categories (breakfast cereals, pastries, sausages, and pre-prepared meals) in 10% of adults. For the ‘junk-food’ tax, price elasticities were used to estimate a change in energy intake in response to a 10% price increase in seven food categories (including soft drinks, confectionery and snack foods). Changes in population weight and body mass index (BMI) by sex were then estimated based on these changes in population energy intake, along with subsequent impacts on disability-adjusted life years (DALYs). Associated resource use was measured and costed using pathway analysis, based on a health sector perspective (with some industry costs included). Costs and health outcomes were discounted at 3%. The cost-effectiveness of each intervention was modelled for the 2003 Australian adult population.

Results: Both interventions resulted in: reduced mean weight (traffic-light labelling: 1.3kg [95% uncertainty interval (UI): 1.2; 1.4]; ‘junk-food’ tax: 1.6kg [95% UI: 1.5; 1.7]); and DALYs averted (traffic-light labelling: 45 100 [95% UI: 37 700; 60 100]; ‘junk-food’ tax: 559 000 [95% UI: 459 500; 676 000]). Cost outlays were AUD81 million (95% UI: 44.7; 108.0) for traffic-light labelling and AUD18 million (95% UI: 14.4; 21.6) for ‘junk-food’ tax. Cost-effectiveness analysis showed both interventions were ‘dominant’ (effective and cost-saving).
Conclusion: Policy-based population-wide interventions such as traffic-light nutrition labelling and taxes on unhealthy foods are likely to offer excellent ‘value for money’ as obesity prevention measures.

Keywords: obesity prevention, cost-effectiveness, food taxes, nutrition labelling
Introduction

In response to the alarming rate of increase in obesity prevalence (1), governments around the world are actively seeking sustainable and cost-effective obesity prevention strategies (2). While policy-based interventions are likely to be key components of these strategies (3), there is limited empirical evidence of the effectiveness and cost-effectiveness of policy-based obesity prevention interventions (4). Accordingly, modelled estimates of the impact of policy-based interventions designed to prevent obesity are increasingly important to guide resource allocation decisions (5). This paper examines the potential impact of two policy-based population-wide interventions: front of-pack traffic-light nutrition labelling (TLL) and a tax on unhealthy foods (‘junk-food’ tax).

TLL schemes have been widely identified as potential tools for improving the nutrition of the population (6-7) and various food standards agencies and consumer groups around the world have recommended the introduction of front-of-pack TLL (8-9). While different front-of-pack TLL formats have been suggested, the most commonly proposed scheme highlights the total fat, saturated fat, sugar and salt content on the front panel of food packages, with each nutrient colour-coded as red, amber, or green corresponding to ‘high’, ‘medium’, or ‘low’ levels of that nutrient (10). In the United Kingdom (UK), the Food Standard Agency (FSA) recommended the use of this format of TLL in selected food categories in 2006 (8), and many supermarkets in the UK introduced TLL as per the FSA guidelines. However, there has been limited evaluation of the effect of TLL and other front-of-pack nutrient signposting schemes on food purchases (11-12). Furthermore, the cost-effectiveness of this type of intervention has not been widely researched (13).

The potential to use fiscal policy measures, such as targeted food taxes, as tools to alter the diet of the population has gained increasing attention in recent years (14-16). While Scandinavian countries such as Denmark, Finland and Norway are considering modifying taxes on foods as part of their efforts to improve nutrition
and combat obesity (17), there remains little research on the cost-effectiveness of
food taxes as an obesity prevention measure (18).

The aim of this study was to investigate and compare the potential cost-
effectiveness of the mandatory inclusion of front-of-pack TLL in selected food
categories, and a tax on a range of unhealthy foods, in the Australian context.
This analysis formed part of the Assessing the Cost-Effectiveness of Preventive
interventions (ACE-Prevention) project, which aimed to provide a comprehensive
analysis of the comparative cost-effectiveness of over 100 preventive intervention
options addressing the non-communicable disease burden in Australia.

**Methods**

**Overview**

All analyses undertaken in ACE-Prevention adhered to a detailed economic
protocol specifically designed for the project. A brief summary of the main points
is provided here. The interventions were assumed to be operating in steady-state
(running at their full effectiveness potential) and were measured against current
practice. In the absence of effect data from randomized controlled trials, the best
available evidence was used to model estimated changes in body mass index
(BMI) and disability-adjusted life years (DALYs) for the Australian adult
population (aged ≥20 years). The additional cost and the associated health
benefits of each intervention were used to calculate incremental cost-
effectiveness ratios (ICERs), defined here as the additional cost of one DALY
averted by the intervention when compared to current practice. ICERs were
expressed as both the gross cost (AUD) per DALY averted (including the cost
outlay for the intervention) and the net cost (AUD) per DALY averted (including
the cost outlay for the intervention less the health care costs saved as a result of
the intervention), with 2003 as the reference year. Costs and health outcomes
were discounted at 3%. In addition to this quantitative analysis, consideration was
given to issues that either influence the degree of confidence that can be placed in the ICERs or broader issues that need to be taken into account with regard to resource allocation decisions. These considerations include the strength of evidence, equity, acceptability to stakeholders, feasibility, sustainability, and other effects not captured in the modelling (19).

**Specification of the interventions**

The first intervention modelled was the mandatory inclusion of front-of-pack TLL on products sold in selected food categories in Australia. This was coupled with a one-year national social marketing campaign to educate and inform the population on how to interpret the labels – this was included as part of the intervention on the basis that adding a social marketing component to a policy intervention is considered good health promotion practice for enhancing behaviour changes (20). The food categories selected for the intervention were based on the guidelines issued by the UK FSA (10) which recommended the use of TLL on seven types of convenience foods including pre-prepared meals, pizzas, sausages, burgers, pies, sandwiches and breakfast cereals. This intervention was compared to current practice in Australia where it is mandatory to include the nutrient information panel on the back of each product sold, with no requirement for front-of-pack nutrition labelling. There is currently limited or no use of TLL in any form on products sold in supermarkets in Australia. The legislation for the intervention would be in the form of amendments to the labelling requirements already in place.

The second intervention modelled was the imposition of a tax on foods in selected ‘unhealthy’ food categories (biscuits, cakes, pastries, pies, snack foods, confectionery and soft drinks) that would have the effect of raising the consumer-end prices of these products by 10%. These categories were selected because the majority of foods in these categories are considered to be non-core foods that are high in saturated fat, sugar and / or salt. This intervention was compared to current practice in Australia where these foods, along with the majority of
processed foods, attract a 10% goods and services tax (GST), but are not subject to other sales or excise taxes. It is expected that the intervention tax would operate in a similar way to existing Australian excise taxes on alcohol, tobacco and petroleum, and would apply in addition to the GST. Both interventions were assumed to be permanent.

**Approach to assessment of benefit**

In the absence of direct evidence of the effect of the selected interventions on BMI and health outcomes, a logic pathway was used to identify the steps in estimating the impact of each intervention from an obesity perspective (Figure 1). At each stage of the logic pathway, the best available evidence, in some cases supplemented with reasoned assumptions, was used to estimate the likely effect of the interventions.

The latest available food consumption data for the Australian adult population, from the 1995 National Nutrition Survey (NNS) (21), were used as a starting point to model how each intervention would alter energy intake through a change in food purchasing behaviour, i.e., a switch from one food type to another. Changes in quantity purchased were assumed to lead to changes in what was actually eaten. No compensatory changes in physical activity levels were allowed for as there is no definitive evidence of compensatory effects one way or another, and no account was taken of any impacts of manufacturers potentially reformulating their products in response to the interventions.

A change in energy balance at the individual level (by sex) was modelled to a change in mean population body weight and BMI at the population level, using equations by Swinburn et al. (22-23). Using these equations, the linear slope of the relation between a change in energy balance and a change in body weight is 94 kJ/kg/day (95% confidence interval: 88.2 kJ/kg/day – 99.8 kJ/kg/day) for adults. In the primary analysis, the weight loss effect was assumed to be maintained for the lifetime of the cohort given the permanence and enduring
effect of the policies; however, various scenarios were also investigated in which the intervention effect reduced over time. While clinical interventions for weight loss have considerable decay in effectiveness over time, the effect of policy-based interventions are more likely to be sustained – just as a tobacco tax has a sustained effect on reduced tobacco consumption (24).

DALYs averted as a result of the changes in BMI were modelled, taking into account those diseases which have a demonstrated, significant contribution to risk from excess weight: stroke, ischemic heart disease, hypertensive heart disease, diabetes mellitus, osteoarthritis, post-menopausal breast cancer, colon cancer, endometrial cancer, and kidney cancer (25). This modelling employed a multi-state life table Markov model that simulates and compares two populations in separate life tables: a baseline population based on existing levels of morbidity and mortality for 2003 and an exposed population which is identical except that it receives the intervention (26). Due to lower body weights, the exposed population has a lower risk of each of the above-mentioned diseases, and the model calculates the effect that this has on prevalence and disease-specific mortality and morbidity. The model divides each population into 5-year age and gender cohorts and simulates the remaining lifetime of each cohort, summarising the changes in overall disability and total mortality between the two populations. All modelling was implemented in Microsoft Excel 2003 (Microsoft Corporation, USA).

**Estimating effect of traffic-light labels on changes in energy intake**

Nutrition labelling is well-recognised as an important component in helping consumers make healthy food choices (27). While there is limited evidence of the impact of nutrition labelling on health outcomes, a review of the impact of nutrition interventions found that changes to nutrition information at the point-of-purchase can be expected to have, at best, only modest effects on the healthiness of consumer food choices in supermarkets (28). However, there is limited evidence of the impact of front-of-pack nutrient signposting schemes, and TLL in particular, on consumer purchases (29). One study investigating the initial impact
of TLL in the UK found no impact on sales in two food categories (30), but this contrasts with recent US research into the impact of a front-of-pack nutrient signposting scheme that reports significant shifts in sales towards healthier products (12). In light of the limited and sometimes conflicting evidence, a hypothetical threshold analysis was conducted to estimate the likely effect of TLL on energy intake.

The effect of the intervention on dietary intake was analysed at the food category level as this is the lowest level of detail available in the 1995 NNS (21). The targeted food categories were mapped to the following NNS food categories: ‘breakfast cereals’ (single source, e.g., bran, wheat breakfast biscuits, puffed rice, corn flakes; and mixed sources, e.g., muesli, wheat flakes with added fruit and nuts and breakfast bars); ‘pastries’ (which includes meat pies, quiches); ‘mixed dishes where cereal is the major component’ (which includes pizza, hamburgers, packet pasta and sauce); and ‘sausages, frankfurters and saveloys’. The average energy density of foods consumed in each food category was calculated for adults (aged ≥20 years) by sex using the average consumption in each food group (in grams per person per day), the proportion of energy obtained from each food group, and the average total energy consumption per person per day.

In the absence of evidence indicating the effect of TLL on food purchases, the impact of consumers shifting their food purchases from foods with more ‘red’ or ‘amber’ labels (typically corresponding to foods with higher energy densities) to foods with more ‘green’ labels (typically corresponding to foods with lower energy densities) was estimated. The scenario in which the intervention would result in a 10% decrease in average energy density in each of the selected food categories was examined, with the conservative assumption that this shift in purchasing behaviour would occur only for 10% of the adult population. These assumptions were estimated to fall between the different effect estimates in the above-mentioned studies (12,28,30). By way of example, a shift from a typical toasted muesli product (‘red’ label for sugar, ‘amber’ labels for fat and saturated fat, ‘green’ label for salt) to a typical low-fat untoasted muesli product (‘amber’
label for sugar, ‘green’ labels for fat, saturated fat and salt) equates to a reduction in energy density of 10.5% (1 792 kJ/100g to 1 603 kJ/100g). Similarly, a shift from cornflakes (‘red’ label for salt, ‘amber’ label for sugar, ‘green’ labels for fat and saturated fat) to wheat biscuits (‘amber’ label for salt, ‘green’ labels for fat, saturated fat and sugar) equates to a 9.1% reduction in energy density (1 640 kJ/100g to 1 490 kJ/100g).

Using the new average energy densities for each food category, and assuming that average weight of foods consumed at a category and a total level remained unchanged, the change in total energy consumed per person per day was calculated separately for males and females.

**Estimating effect of the ‘junk-food’ tax on changes in energy intake**

There is growing evidence that higher prices of unhealthy foods and beverages relative to healthy ones are associated with reductions in BMI and the prevalence of overweight and obesity (18,31). While there are few studies investigating the effects of targeted food taxes on behaviour and health, evidence from modelling studies in the UK indicate that targeted food taxes and subsidies could produce modest but meaningful changes in food consumption and substantial reductions in diet-related diseases (17,32). There does not appear to be any published evidence of the cost effectiveness of a tax on unhealthy food in the Australian context.

The UK studies highlight the importance of including both own and cross-price elasticities of demand in estimating the way in which consumption will change in response to price changes (17,32). The own-price elasticity of demand predicts the percentage change in consumption (quantity bought) of that item for a 1% rise in price, whereas the cross-price elasticity of demand predicts how the consumption of an item will respond to a price increase in another item (32). Given the lack of a comprehensive set of price elasticities published for Australia, the UK National Food Survey (NFS) estimates of price elasticities (33) were used to model changes in food consumption in response to the tax intervention.
As with the TLL intervention, the effect of the intervention on dietary intake was analysed at the food category level from the 1995 NNS (21). The food categories targeted by the intervention correspond to the following NNS food categories: ‘sweet biscuits’, ‘savoury biscuits’, ‘cakes, buns, muffins, scones and cake-type desserts’, ‘pastries’, ‘mixed dishes where cereal is the major component’, ‘batter-based products’, ‘snack foods’ (including ‘potato snacks’, ‘corn snacks’, ‘extruded snacks’ and ‘pretzels and other snacks’), ‘confectionery’ and ‘soft drinks, flavoured mineral waters and electrolyte drinks’. The tax was assumed to be implemented in such a way as to have the effect of raising the consumer-end prices of the targeted products by 10%, and elasticities of demand were used to calculate the resultant change in consumption for each food category. The change in total energy consumed per person per day was then calculated separately for males and females.

**Assessment of costs**

Intervention costs were assessed from a health-sector perspective, excluding the cost of disease-related productivity losses. In addition, some costs to the food industry (e.g., the cost of changing food labels) were also included as they were directly related to the intervention. In accordance with the ACE-Prevention evaluation protocol, the interventions were assumed to be operating under steady-state conditions, meaning that costs involved in the set-up, research and development of the intervention (e.g., costs related to the development of the nutrition criteria for traffic-light labels) were excluded, but costs associated with the implementation of the intervention itself (e.g., costs of the social marketing campaign regarding traffic-light labels) were included.

Cost offsets were assessed as future health sector costs saved because of the reduction in obesity-related conditions as a result of intervention exposure. All costs were adjusted to real prices in the 2003 reference year using the relevant Health Price Index from the Australian Institute of Health and Welfare (34), or
the Consumer Price Index from the Australian Bureau of Statistics (ABS) if the
costs occurred outside the health sector (35).

Estimates of the costs of implementing the legislation (including costs related to
legislative activities, and administration and enforcement of laws once passed for
a period of 10 years) were based on the estimates for Australia by the World
Health Organization’s WHO-CHOICE project (36) and are consistent with other
studies on regulatory interventions (37). The cost of the social marketing
campaign for the TLL intervention was based on the Victorian ‘2 fruit and 5 veg’
campaign, and includes the total national costs for television, radio, print and
transit advertising, sports/arts sponsorship and point of sale promotion for one
year (38). The costs to industry of changing product labels for the TLL
intervention were estimated based on the estimated costs of implementing
‘country of origin’ labelling in Australia, prepared for Food Standards Australia
New Zealand (FSANZ) (39). While it is acknowledged that implementing TLL
may be more complex than ‘country of origin’ labelling, it was also felt that if
industry were given sufficient lead time, the costs of changing packaging for TLL
would be significantly reduced due to changes in product packaging that occur as
a part of natural product life-cycles. Nevertheless, in an effort to remain
conservative, the full cost estimates from the FSANZ report (which estimated the
costs of changing the labelling of all pre-packaged food items in Australia) were
included, even though the TLL intervention is only targeting products in four
food categories. Thus, the cost estimates represent the cost of implementing TLL
on all pre-packaged food products.

Uncertainty and sensitivity analyses

The estimates for each cost element and the changes in mean weight resulting
from the interventions include 95% uncertainty intervals (UIs). The model then
calculated 95% UIs for DALYs, net costs and ICERs using Monte Carlo
A series of scenarios were examined to investigate the degree to which the key parameters influencing the intervention effect would need to change in order for the interventions to exceed the commonly-used Australian cost-effectiveness threshold of AUD50 000 per DALY averted (i.e., become cost-ineffective) (5,40-41).

Results

Change in consumption, energy intake and body weight

Estimates of the likely impact of the TLL intervention on changes in energy density of foods consumed and resultant changes in energy intake are presented in Table 1. The energy intake of the population affected by the intervention was estimated to decrease by 154kJ/day and 88kJ/day for males and females respectively. Using the equations by Swinburn et al. (22-23), this equates to a 1.6kg (95% UI: 1.5kg; 1.7kg) reduction in mean population body weight for males and a 0.9kg (95% UI: 0.9kg; 1.0kg) reduction for females, or a 1.3kg (95% UI: 1.2kg; 1.4kg) reduction for the affected population as a whole.

Estimates of the likely impact of the tax intervention on changes in foods consumed and resultant changes in energy intake are presented in Table 2. It is noted that while the tax applies only on the food categories specified in the intervention description above, consumption in other categories (e.g., ‘regular bread and rolls’ and ‘cheese’) changed due to the effect of cross-price elasticities. It is estimated that energy intake would decrease by 174kJ/day and 121kJ/day for males and females respectively. This equates to a 1.9kg (95% UI: 1.7kg; 2.0kg) reduction in mean population body weight for males and a 1.3kg (95% UI: 1.2kg; 1.4kg) reduction for females, or a 1.6kg (95% UI: 1.5kg; 1.7kg) reduction for the affected population as a whole.
Costs

The cost elements and their associated values for each intervention are presented in Table 3. The TLL intervention is less affordable than the tax intervention, with the mean cost outlay for the TLL intervention of AUD 81 million (95% UI: 44.7; 108.0) almost five times as large as the mean cost outlay of AUD 18 million (95% UI: 14.4; 21.6) for the tax intervention. The bulk of the cost of the TLL intervention (75%) falls on industry, and it is likely that these costs would be passed on to the consumer.

Cost-effectiveness results

The cost-effectiveness results are presented in Table 4. The tax intervention results in more DALYs averted than the TLL intervention (559 000 DALYs averted compared with 45 100), primarily because the TLL intervention was modelled to have an impact on the purchases of only 10% of the adult population whereas the tax intervention impacts on the total population. As a consequence, the cost offsets are significantly higher for the tax intervention. Both interventions are classified as ‘dominant’ because they result in health gains combined with cost savings.

For the TLL intervention, if the effect of the intervention was assumed to decay progressively down to no effect after 10 years, and the intervention was assumed to have an impact on only 2.5% (rather than 10%) of the adult population, the median ICER (without cost offsets) would increase to AUD50 000 per DALY averted (or AUD40 000 per DALY averted if cost offsets are included). For the tax intervention, even if the effect of the intervention was assumed to decay progressively down to no effect after 10 years, and if the effect of the price elasticities was 20 times less than what was estimated, the intervention would remain dominant (when cost offsets are included). It is noted that the size of the effect of the interventions on energy intake is estimated as linear, such that a doubling of the tax rate would double the change in energy intake and the
resultant BMI units and DALYs averted. Similarly, if the TLL intervention was deemed to shift the energy density of purchases by 5% (rather than 10%), this would halve the intervention benefit.

**Other policy-relevant considerations**

In addition to the results of the technical analysis presented above, other policy-relevant issues were considered. For the TLL intervention, there is weak evidence about the extent to which this intervention would influence consumer behaviour. The intervention would likely benefit all social strata, including low-income and low-educated groups (42). There are other plausible benefits of the intervention, such as the potential reformulation of products to improve their nutrient profile in response to the introduction of the labelling, that were not included in the technical analysis. The effect of these other benefits could potentially be substantial (43). The intervention is likely to be acceptable to all groups except private industry which is likely to protest about the cost of changing the food labels. It is likely that the additional cost per product would be passed on to consumers but the change in consumer-end prices would likely be minute given the large volumes of units sold.

For the tax intervention, there is also weak evidence indicating specifically how this intervention will influence consumer behaviour and its overall impact on diet and diet-related disease. The intervention is likely to be regressive; however, the health benefits of the tax are also likely to be relatively greater in lower income groups (17). The intervention would raise substantial revenue for the government (which is not included in the current analysis). Based on national household expenditure data in 2003/2004 (44), expenditure on cakes and biscuits, soft drinks, and confectionery amounted to AUD21 per household per week, indicating that a 10% tax on these products would raise taxation revenue in excess of AUD855 million each year (not taking into account changes in consumption in response to the tax). This revenue could be put towards health promotion activities, or used to subsidise healthy foods. Nevertheless, there is
likely to be widespread opposition to the implementation of the tax, from treasury, industry groups and consumers. The specific way in which the tax would be operationalised in the Australian context is uncertain, and there may be concerns about the feasibility of this type of tax on food products.

**Discussion**

This cost-effectiveness analysis showed that both the TLL and the ‘junk food’ tax interventions were likely to be ‘dominant’ (both effective and cost-saving) in the Australian context under current modelling assumptions. This modelling exercise suggests that policy-based population-wide interventions such as these are likely to offer excellent ‘value for money’ as obesity prevention measures.

This study can be compared to other similar cost-effectiveness analyses of potential obesity prevention interventions in the Australian context. In the ACE-Obesity study that evaluated 13 interventions targeted at adolescents (19), the policy-based intervention (‘reduction of television advertising of high fat and/or high sugar foods and drinks to children’) was also dominant and emerged as the intervention likely to offer the greatest health benefit (mean of 37 000 DALYs averted) (19). Furthermore, both interventions in this study compare favourably to diet and exercise interventions to reduce overweight in adults (26). Using the same mathematical model as used here, diet and exercise interventions had median ICERs (including cost offsets, but excluding patient time and travel costs) in the order of AUD15 000 per DALY (26).

The ACE Prevention project, of which this study forms part, also studied the cost-effectiveness of interventions targeting other behavioural determinants of health, such as alcohol consumption (37) and physical activity (45). Generally speaking, the results of the project showed that policy-based interventions that target whole populations tend to be more effective and cost-effective than interventions that aim to convince individuals to change their behaviour. A study by the
Organisation for Economic Co-operation and Development (OECD) into the cost-effectiveness of a broad range of interventions for the prevention of chronic disease also found that the majority of policy-based interventions were likely to be cost-effective, with fiscal measures estimated as cost saving (46). However, the evidence-base for the policy-based interventions is often less strong, partly due to the fact that randomised controlled trials are not feasible for most policy-based interventions.

The key strengths of this study are that it combines technical analysis (using the best available evidence) with other considerations of importance to decision makers, utilises extensive uncertainty analysis, and employs assumptions which are both transparent and conservative (47). The limitations of this study are predominantly around the quality of the evidence supporting the effect of the interventions. The direct evidence supporting the likely impact of the interventions on consumer behaviour is relatively weak – particularly for the TLL intervention. To counter this uncertainty, the assumptions underpinning the estimates of the change in food consumption resulting from the intervention were conservative, and several different scenarios of intervention effect were examined. As more evidence of the effects of these types of interventions becomes available, these assumptions can be revisited. A further limitation is that the analyses were conducted at the food category level, rather than at the product level. If more finely-grained data on population dietary intake were to be available this would greatly increase the precision of these types of analyses.

Further research in this area could be undertaken to investigate other scenarios for the design and implementation of these interventions. For example, this model could be used to analyse the effects of different taxes and subsidies, targeted at different food categories. Furthermore, traffic-light labels could be applied to all food categories – not just the four categories investigated here. In that case, the effect of shifts in food purchases between food categories (e.g., from confectionery towards healthier snacks) could be investigated in addition to the within-category shifts modelled here. It would also be valuable to perform similar
analyses in other countries and contexts, and to estimate the impacts of the interventions on both adolescents and adults. Furthermore, other health impacts of these interventions beyond their effects on BMI and obesity-related diseases (e.g., on other diet-related chronic-disease) merit further study.

The implications of this study are that both a tax on unhealthy foods and traffic-light labelling are likely to be highly cost-effective and have sizeable effects on population health, including on lower-educated and less-wealthy people. Despite a degree of uncertainty around the size of the benefits, both interventions should be considered for implementation in Australia and other countries as part of a comprehensive obesity prevention strategy. The soft policy approaches (e.g., education campaigns) that are currently favoured by governments are unlikely to succeed in the absence of strong policy-driven approaches which can influence behaviours. The parallel evidence from smoking prevention efforts, where taxes and warning labels have proven effective (24), gives confidence that an ‘implement and evaluate’ approach is needed.

Acknowledgements

The ACE-Prevention project was funded by an Australian National Health and Medical Research Council Health Services Research grant (no. 351558). Gary Sacks is supported by a Deakin University Postgraduate Research Scholarship. Jan Barendregt and Megan Forster played crucial roles in the development of the BMI to DALYs model. The authors are grateful to Theo Vos, Rob Carter and Anne Magnus for their support in conducting this study.
References


Table 1  Effects of traffic light labelling on energy intake by food category targeted by the intervention

<table>
<thead>
<tr>
<th>Food category</th>
<th>Sex</th>
<th>Average consumption (g/day)</th>
<th>Average energy density (kJ/g)</th>
<th>Estimated adjusted average energy density in response to intervention (kJ/g)</th>
<th>Estimated change in energy intake (kJ/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast cereals (single and mixed source)</td>
<td>Males</td>
<td>28.5</td>
<td>14.0</td>
<td>12.6</td>
<td>-39.8</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>19.4</td>
<td>13.9</td>
<td>12.5</td>
<td>-26.9</td>
</tr>
<tr>
<td>Pastries</td>
<td>Males</td>
<td>39.3</td>
<td>10.4</td>
<td>9.4</td>
<td>-40.9</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>25.1</td>
<td>10.7</td>
<td>9.7</td>
<td>-26.9</td>
</tr>
<tr>
<td>Mixed dishes where cereal is the major ingredient</td>
<td>Males</td>
<td>71.2</td>
<td>8.1</td>
<td>7.3</td>
<td>-57.5</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>36.8</td>
<td>7.5</td>
<td>6.8</td>
<td>-27.7</td>
</tr>
<tr>
<td>Sausages, frankfurts, and saveloys</td>
<td>Males</td>
<td>14.5</td>
<td>10.7</td>
<td>9.6</td>
<td>-15.5</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>6.3</td>
<td>10.7</td>
<td>9.6</td>
<td>-6.7</td>
</tr>
<tr>
<td>Total</td>
<td>Males</td>
<td>4 013.7</td>
<td>-</td>
<td>-</td>
<td>-153.6</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>3 221.1</td>
<td>-</td>
<td>-</td>
<td>-88.3</td>
</tr>
</tbody>
</table>

* Based on the Australian 1995 national nutrition survey (21)
Table 2  Effects of ‘junk-food’ tax intervention on energy intake by food category

<table>
<thead>
<tr>
<th>Food category</th>
<th>Sex</th>
<th>Average consumption (g/day) *</th>
<th>Estimated adjusted average consumption (g/day) in response to intervention</th>
<th>Average energy density (kJ/g) *</th>
<th>Estimated change in energy intake (kJ/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular breads, and rolls</td>
<td>Males</td>
<td>109.0</td>
<td>109.8</td>
<td>10.8</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>74.2</td>
<td>74.7</td>
<td>10.9</td>
<td>5.7</td>
</tr>
<tr>
<td>Cereal-based products and dishes</td>
<td>Males</td>
<td>154.1</td>
<td>137.8</td>
<td>10.8</td>
<td>-175.7</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>100.1</td>
<td>89.5</td>
<td>11.3</td>
<td>-119.7</td>
</tr>
<tr>
<td>Cheese</td>
<td>Males</td>
<td>16.2</td>
<td>16.9</td>
<td>15.0</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>13.0</td>
<td>13.6</td>
<td>13.8</td>
<td>7.7</td>
</tr>
<tr>
<td>Muscle meat</td>
<td>Males</td>
<td>63.3</td>
<td>64.9</td>
<td>8.2</td>
<td>13.5</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>32.2</td>
<td>33.0</td>
<td>8.1</td>
<td>6.8</td>
</tr>
<tr>
<td>Poultry and other feathered game</td>
<td>Males</td>
<td>26.3</td>
<td>27.0</td>
<td>8.8</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>17.6</td>
<td>18.1</td>
<td>8.5</td>
<td>3.9</td>
</tr>
<tr>
<td>Sausages, frankfurts, and sausages</td>
<td>Males</td>
<td>14.5</td>
<td>14.1</td>
<td>10.7</td>
<td>-3.9</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>6.3</td>
<td>6.1</td>
<td>10.7</td>
<td>-1.7</td>
</tr>
<tr>
<td>Category</td>
<td>Males</td>
<td>Females</td>
<td>Total</td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>--------</td>
<td>---------</td>
<td>-----------</td>
<td>-------</td>
<td>---------</td>
</tr>
<tr>
<td>Snack foods</td>
<td>3.8</td>
<td>3.2</td>
<td>20.4</td>
<td>-4.6</td>
<td>-4.0</td>
</tr>
<tr>
<td>Confectionery</td>
<td>9.1</td>
<td>8.5</td>
<td>18.2</td>
<td>-13.1</td>
<td>-12.4</td>
</tr>
<tr>
<td>Soft drinks, flavoured mineral waters</td>
<td>236.3</td>
<td>126.0</td>
<td>1.4</td>
<td>-14.9</td>
<td>-12.4</td>
</tr>
<tr>
<td>and electrolyte drinks</td>
<td>225.7</td>
<td>120.3</td>
<td>1.2</td>
<td>-14.9</td>
<td>-12.4</td>
</tr>
<tr>
<td>Total</td>
<td>4 013.7</td>
<td>3 221.1</td>
<td>-</td>
<td>-173.9</td>
<td>-120.5</td>
</tr>
</tbody>
</table>

* Based on the Australian 1995 national nutrition survey (21)
<table>
<thead>
<tr>
<th>Cost element (and payer)</th>
<th>Values a</th>
<th>Sources and assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of implementing, administering and enforcement of legislation (government) b</td>
<td>14.4; 18.0; 21.6</td>
<td>Most likely value based on World Health Organization (WHO) estimate for Australia of cost of changing legislation regarding alcohol use (36). Other values = most likely estimate ±20%</td>
</tr>
<tr>
<td>Cost of social marketing campaign for traffic-light labels (government)</td>
<td>1.9; 2.8; 3.6</td>
<td>Most likely value based on results of cost-effectiveness evaluation of a national fruit and vegetable social marketing campaign (38). Other values = most likely estimate ±30%</td>
</tr>
<tr>
<td>Cost of changing food labels (industry) c</td>
<td>24.0; 62.0; 97.0</td>
<td>Estimate based on projected cost of implementing ‘country-of-origin’ labelling in Australia 39. Minimum value assumes minor changes to existing labels; maximum value assumes major changes to existing labels; most likely value reflects a mid-range estimate of extent of changes required</td>
</tr>
</tbody>
</table>

a Values are minimum; most likely; and maximum. In the uncertainty analysis, a triangular uncertainty distribution is used whereby the greatest probability of being chosen is the value representing the top of the triangle (i.e., the most likely value), while the probability of other values being chosen tapers off towards the extremes of the base of the triangle (i.e., the minimum and maximum values). All amounts in AUD million, with 2003 as the reference year

b Both the traffic-light labelling and ‘junk-food’ tax interventions will incur this cost element

c Includes cost of changing food labels for all pre-packaged food products – not just the products in the food categories targeted by the traffic-light labelling intervention
Table 4  Cost-effectiveness analyses for the traffic-light labelling and ‘junk-food’ tax interventions, for the scenario in which intervention effect is assumed to be permanent

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Traffic-light labelling intervention *</th>
<th>‘Junk-food’ tax intervention *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affected population</td>
<td>10% of adults (≥20 years) in Australia in 2003</td>
<td>All adults (≥20 years) in Australia in 2003</td>
</tr>
<tr>
<td>Number of people affected by intervention (48)</td>
<td>1.5 million</td>
<td>14.5 million</td>
</tr>
<tr>
<td>BMI reduction per person</td>
<td>Males: 0.5 (0.4; 0.6) Females: 0.3 (0.3; 0.4)</td>
<td>Males: 0.6 (0.5; 0.7) Females: 0.5 (0.4; 0.6)</td>
</tr>
<tr>
<td>Total BMI units saved (thousand units)</td>
<td>623 (514; 736)</td>
<td>7 632 (6 203; 9 062)</td>
</tr>
<tr>
<td>Total DALYs averted</td>
<td>45 100 (37 700; 60 100)</td>
<td>559 000 (459 500; 676 000)</td>
</tr>
<tr>
<td>Gross cost per DALY averted (AUD)</td>
<td>1 800 (1 360; 2 170)</td>
<td>30 (20; 40)</td>
</tr>
<tr>
<td>Total cost offsets (AUD million)</td>
<td>455 (385; 560)</td>
<td>5 550 (4 700; 6 370)</td>
</tr>
<tr>
<td>Net cost per DALY averted (with cost offsets)</td>
<td>Dominant</td>
<td>Dominant</td>
</tr>
</tbody>
</table>

* Median estimates shown with 95% uncertainty interval indicated in parentheses

Abbreviations: BMI, body mass index; DALY, disability-adjusted life year
Figure 1  Logic pathways for modelling the effect of the traffic-light labelling and ‘junk-food’ tax interventions for obesity prevention
Chapter 9: Discussion

9.1 Chapter overview

This chapter summarises the key results from this research and their implications for public health policy and practice. The primary limitations of the research are identified, and directions for future research are highlighted. Given that the conclusions of the six individual studies that made up the thesis have already been discussed in their respective manuscripts, the focus of this chapter is instead on the thesis as a whole, the way in which the six studies inter-relate, and the conclusions that can be drawn from the collective results.

9.2 Key findings and their public health implications

9.2.1 Policy framework

In Study A, a framework was developed for comprehensive and systematic identification of areas for obesity prevention policy action. The framework incorporated multiple approaches for addressing obesity, and organised areas for potential policy action by the level of governance responsible for their implementation and the sector or setting to which they apply. The analysis grids that made up the framework provide a tool for all levels and sectors of governments to use in developing and implementing their obesity prevention strategies and actions. With respect to the research as a whole, the framework is important in illustrating the overall context within which individual policy interventions, such as front-of-pack traffic-light nutrition labelling, are likely to fit into an overall obesity prevention strategy.

By populating the analysis grids with examples of potential areas for policy action in the Australian context, several key insights emerged. Firstly, it is clear
that all sectors and levels of government (local, state, national and international), NGOs and private industry have multiple opportunities to contribute to obesity prevention. Secondly, opportunities for policy intervention in the food system are widespread across all levels of governance; whereas, potential policy areas for promoting physical activity are predominantly local and state government responsibilities. Thirdly, the broad range of potential obesity prevention policy areas indicates that a coordinated approach to policy development and implementation will be needed in order to ensure a coherent overall response, with policy actions that are complementary in nature.

9.2.2 Nutrient profiling

Study B investigated the potential role of nutrient profiling for obesity prevention, and considered the feasibility of using a common nutrient profiling system to underpin the multiple potential applications. The study identified that there is substantial scope to use nutrient profiling as part of interventions aimed at influencing food environments and nutrition behaviour. In addition, the study elucidated that a common nutrient profiling system was vital to ensure coherent policy implementation and to minimise the confusion that is likely to result from the use of multiple different nutrient profiling models. The analysis indicated that the development of a common nutrient profiling system appeared feasible – although several technical factors and other considerations would need to be taken into account in implementing such a system in a specific country or region. The study concluded that national governments and international organisations, such as the WHO, need to take a lead in developing and recommending the use of a common nutrient profiling system.

As part of Study B, a framework (the “Four ‘P’s of Marketing”) was proposed to classify the potential applications of nutrient profiling based on the intended target of the interventions and the mechanisms by which they aim to influence behaviour. This classification framework is intended to be complementary to the
analysis grid framework from Study A. While the analysis grid framework can be used to identify the level of governance responsible for policy actions and the sector or setting to which interventions apply, the “Four ‘P’ s of Marketing” framework is suitable for use when considering the intended target and potential impact of specific interventions. Indeed, the “Four ‘P’ s of Marketing” was used as part of the logic model developed in Study B to demonstrate the pathways by which nutrient profiling interventions can affect health outcomes. This logic pathway forms an important part of the process of modelling the potential impacts of policy interventions, and was used as part of the modelling conducted in Study F.

9.2.3 Energy balance equation for adults

In Study C, an equation to predict mean population body weight change in response to a given change in mean energy balance was developed for adults. The equation was derived directly from the observed relation between TEE (from doubly-labelled water) and body weight in previously conducted cross-sectional studies. The slope of the linear relation between changes in energy balance and body weight derived in Study C was shown to be equivalent to the slope from a similar linear equation developed using a different methodology by Hall et al.127,134 The equivalence in the two equations provides confidence in the magnitude of the relation; however, there remains a need to validate these results against longitudinal measures of TEE and body weight.

Study C illustrated one of the ways in which the equation can be applied, by estimating the relative contributions of increased energy intake and reduced physical activity to the US obesity epidemic. This analysis showed that increases in energy intake were more than sufficient to explain the increases in population body weight in the US from the 1970s. This provides evidence that population approaches to preventing obesity should prioritise efforts to reduce the drivers of increased energy intake. Therefore, these results imply that the aspects of the
policy framework developed in Study A that focus on the food system are likely to be of greater importance for obesity prevention than the aspects focused on physical activity environments. While this implication is likely to be controversial (with probable opposition from the food industry and those who advocate for increases in physical activity), it is consistent with several other recent studies that highlight increased food consumption as the primary driver of the obesity epidemic in high-income countries.134,146-147

The equation developed in Study C can also be used as part of models that aim to estimate the potential impact of policy interventions on health outcomes. Given the paucity of empirical evidence in this area, the way in which changes in energy intake and expenditure relate to changes in body weight at the population level are vital to understanding potential intervention effects.

9.2.4 Empirical evidence of the impact of traffic-light nutrition labelling on food purchases

Studies D and E investigated the impact of traffic-light nutrition labelling on consumer food purchases. Both studies found that the introduction of traffic-light nutrition labelling on a small selection of supermarket ‘own-brand’ products did not impact on the relative healthiness of food purchases in the short-term. The studies demonstrated that it is both practical and feasible to work with supermarkets to conduct public health research. In addition, the studies added to the evidence that supermarket sales data are valuable tools in monitoring population food purchases and evaluating public health interventions.143

The results of Studies D and E are important in informing the ongoing debate regarding front-of-pack nutrition labelling in Australia and internationally. The implication of the results is that if front-of-pack nutrition labelling (in any format) is to be recommended as a public health intervention then it is important to be clear about its intended effects. The fact that this research did not demonstrate
changes in purchasing behaviour in the specific contexts investigated does not necessarily mean that the labelling did not have other effects or that it would not have other effects in other circumstances (for example, where traffic-light nutrition labelling was implemented more broadly and accompanied by an awareness and information campaign). These other effects could include impacts on food producers (who may reformulate their products in order to give them a more favourable nutritional profile) and on consumers both directly (influencing their purchases in the short- and long-term) and indirectly (through effects on their nutrition awareness). Interestingly, those from the food industry who oppose the implementation of traffic-light nutrition labelling (and spend millions of dollars lobbying against it) presumably do so on the assumption that there are likely to be significant effects. It is, therefore, important that each of the potential effects of front-of-pack nutrition labelling is evaluated in a range of contexts.

Importantly, the results of Studies D and E do not necessarily mean that more research is needed before action is taken to improve the comprehensibility of nutrition labelling. For example, it could reasonably be argued that traffic-light nutrition labelling should be implemented on the grounds that, firstly, consumers have a right to know the nutritional content of food and they find traditional (back-of-pack) nutrition information confusing and difficult to use, and, secondly, there is growing evidence that consumers prefer traffic-light labelling to other forms of front-of-pack nutrition labelling. Moreover, as multiple different forms of front-of-pack nutrition labelling are introduced by different stakeholders, there is growing risk of even greater confusion for consumers. There is a strong need for government leadership in standardising labelling formats, and the current regulatory review in Australia is an ideal opportunity for this to be demonstrated.
9.2.5 Cost-effectiveness modelling

The final study in this thesis, Study F, modelled the likely cost and potential impact of two promising applications of nutrient profiling: front-of-pack traffic-light nutrition labelling and a tax on foods in a selection of unhealthy food categories. The scenarios modelled in Study F showed that both interventions were likely to offer excellent ‘value for money’ from an obesity prevention perspective in Australia. Furthermore, the results indicated that the tax intervention was likely to be substantially more effective than the nutrition labelling intervention. The study also indicated that while these interventions were likely to be sustainable, other policy-relevant factors (such as the likely opposition to these interventions from private industry, their degree of affordability in the short-term, and the financial impact of the tax on low-income groups) need to be taken into account in considering their implementation.

9.3 Limitations of the research and directions for future research

There are several limitations to the research, many of which have already been identified in the description of the scope of each study (Chapter 2) and in the ‘Discussion’ section of each of the manuscripts. This section highlights the key limitations, and notes ways in which these could be addressed in future research.

9.3.1 Stakeholder involvement

The research conducted as part of this thesis did not actively engage the key stakeholder groups (such as politicians, bureaucrats, NGOs and the food industry) that typically play a role in the policy-making process.\textsuperscript{32} For example, the cost-effectiveness modelling study (Study F) did not include stakeholders in the process of specifying the interventions and interpreting the results. In addition,
the analysis of the feasibility of a common nutrient profiling system (Study B) did not include stakeholder consultation as part of the study design, yet it was recognised that early stakeholder engagement was likely to be critical to the successful implementation of such a system. This lack of stakeholder involvement is, firstly, likely to mean that important stakeholder perspectives and insights have not been taken into account, and, secondly, is likely to reduce the immediate influence of the research on policy decisions.

Future research in this area should aim to involve stakeholders as part of the research process – as is recommended by the ACE methodology. The challenge for researchers is how to successfully engage the relevant decision makers. At a local level, best practice guidelines have been identified for engaging stakeholders for community-based obesity prevention interventions but different strategies are likely to be required at the state, national and international levels. It is likely to be necessary to align the research with the stakeholders’ interests and identify appropriate forums in which to engage stakeholders. It may be that the most likely method of ensuring government involvement is if they directly fund the research or if it is run under their auspices. Where the food industry is involved, or directly, funds research, it will be important to have transparency with respect to the nature of the relationships between researchers and the food industry.

9.3.2 Narrow focus on obesity prevention

The framework developed in Study A and the logic model developed in Study B identified that potential obesity prevention policy interventions were likely to have impacts beyond obesity, for example, on other DRCDs more generally, and on economic, social and environmental outcomes. However, the modelling in Study F and the objectives of the research as a whole were focused on obesity prevention. This research design was adopted in order to manage the scope of the overall research project; however, it is recognised that the focus on obesity alone
is inconsistent with the integrated approach to DRCD prevention recommended by the WHO. Ideally, government efforts should be targeted at the development of a ‘DRCD prevention strategy’ rather than simply an ‘obesity prevention strategy’. Furthermore, other government strategies, such as those for addressing climate change, should be integrated with actions to prevent DRCDs.152

Future research should aim to be less siloed in nature, and consider the impacts of policy interventions as broadly as possible. From a modelling point of view, it has already been demonstrated that it is possible to take into account the impact of an intervention on health outcomes related to obesity, physical activity (independent of its effect on body weight) and fruit and vegetable consumption in the Australian context.153 Furthermore, recent international research, for example in the Pacific region154 and in the UK111, has modelled the effect of food policy interventions on DRCDs. The methods used in these studies need to be built upon and applied in other contexts.

9.3.3 Portfolio of interventions

Studies A and B highlighted the importance of a comprehensive policy response to obesity prevention, comprising multiple interventions across various sectors and levels of governance. However, the design of Studies D, E and F aimed to consider the impact of individual interventions in isolation. While this reductionist approach is important to try to identify the most promising interventions, it is unlikely to reflect the way in which interventions would be implemented in practice. It is unclear whether the impact of multiple interventions is likely to be greater than, less than, or equal to the sum of its parts.

Future research should aim to collect empirical data on the collective impact of multiple interventions operating contemporaneously. For example, it would be valuable to investigate the impact of front-of-pack traffic-light nutrition labelling combined with a tax on unhealthy foods (e.g., the tax could be designed to target
the products with ‘red’ labels), with an associated social marketing campaign. While it may prove difficult to construct a controlled trial to gather this type of evidence prior to policy implementation, it may be possible to do so – particularly if good monitoring data are available. It is certainly possible to do ‘before and after’ trials of policy interventions, that is, using the ‘before’ state as the control situation. It may also prove practical to gather evidence at the local level, e.g., from community-based interventions, and then apply the results more broadly. In the absence of direct evidence, it may be that parallel evidence, e.g., from tobacco control, is best-suited to informing researchers and policy makers on likely intervention effects and of any joint costs and benefits.  

Another method for understanding the impact of multiple interventions is to adopt a ‘systems approach’ to gathering evidence and modelling outcomes. This approach sees interventions not merely as single events but rather as processes within dynamic systems in which many events occur concurrently. Under this approach, the analysis is expanded to include the changes created in the system (including networks, roles, relationships and settings) as a result of interventions. This type of research is more likely to take into account the impact of adopting a comprehensive obesity strategy than reductionist approaches.

The ACE approach to prioritising interventions as part of an overall portfolio is to model the likely impact of interventions separately and then develop an implementation pathway for a particular disease area, with interventions ordered by their cost-effectiveness. Using this approach, it is assumed that the full benefit of the first intervention applies, with the available benefit for subsequent interventions reduced accordingly. Importantly, it may be necessary to understand only the likely order of magnitude of individual intervention effects in order to construct an overall portfolio. For example, a portfolio may consist of groups of interventions that are highly likely to be cost-effective, groups of interventions that may or may not be cost-effective but are considered important for other reasons (e.g., shifting community norms), and groups of interventions that are unlikely to be cost-effective on their own but are important as part of supporting...
the overall portfolio (e.g., social marketing campaigns). In this case, understanding precisely whether the combined effects of multiple interventions are cumulative or otherwise is perhaps less important.

### 9.3.4 Effects on different socio-economic groups

This research did not consider, in any great detail, the impact of policy interventions on different socio-economic groups. However, obesity levels (and many other indicators of poor health) are disproportionately high in socio-economically disadvantaged populations.\(^{41,160}\) Accordingly, it is important that policy interventions aim to reduce these inequalities, or, at the very least, do not exacerbate them.\(^{32,160}\) This is particularly relevant when considering taxes on unhealthy food, which are likely to be economically regressive.\(^{111}\)

The differential effects of policy interventions on various socio-economic groups should be a focus of future research. This requires data to be collected on how different groups respond to different interventions. From a modelling point of view, the impact of interventions on different socio-economic groups could be taken into account in a similar way to which age and gender were modelled as part of this research.

### 9.3.5 Range of nutrient profiling interventions

The majority of this research focused on two population-wide applications of nutrient profiling: front-of-pack traffic-light nutrition labelling and a tax on selected unhealthy foods. While the results indicated that these interventions were likely to prove effective uses of government funds, they should certainly not be taken to mean that all nutrient profiling interventions are likely to be cost-effective. It would be worthwhile to model other similar interventions (for example, a tax on a broader range of unhealthy products combined with a subsidy
of healthier products; or traffic-light menu labelling in restaurants) to understand their comparative cost-effectiveness. It would also be valuable to gather evidence and evaluate the cost-effectiveness of other nutrient profiling interventions. In the case of Study F, the intervention that targeted ‘Price’ (the tax intervention) was shown to be more effective than the intervention that targeted ‘Promotion’ (the labelling intervention). It would be interesting and informative to know if this was indicative of a broader pattern, and if price was a stronger leverage point than the other ‘P’s in the “Four ‘P’s of Marketing” framework. Indeed, there is some evidence showing that price is the most important factor for consumers when making food purchase decisions, and that sales promotions (involving price discounts) can lead to changes in sales of up to 3000% for promoted products.161

In order to evaluate interventions that target food purchases, it is imperative that accurate measures of food purchases are used. The potential to use supermarket sales data for monitoring food purchases is now well-established, and future research should aim to make better use of this data for public health purposes.

9.4 Conclusion

This thesis has investigated the role and potential impact of obesity prevention policy interventions. It has demonstrated that there is substantial scope to use nutrient profiling as part of a broad obesity prevention strategy. The research has presented empirical data to inform the ongoing debate of the potential impact of front-of-pack nutrition labelling, and provided modelled evidence of population-wide obesity prevention interventions that are likely to offer excellent ‘value for money’ for governments. This thesis has clearly demonstrated that policies for changing food environments need to be centre stage in obesity prevention efforts.

The research has advanced the tools, techniques, and concepts required to model potential intervention effects, and identified directions for future research in this area. These future research directions include:
involvement of key stakeholders as part of the research process;
consideration of DRCDs beyond just obesity, and the inclusion of environmental outcomes in addition to health outcomes;
understanding the impact of multiple interventions implemented together as part of a policy portfolio;
evaluating the differential effects of interventions on different socio-economic groups; and,
greater use of supermarket sales data for public health purposes.

The research calls for action from national governments and international organisations, such as the WHO, in a number of key areas:

- develop strategies for obesity prevention that are comprehensive, systematic and evidence-based, with coherent policy actions that are complementary in nature;
- take the lead in developing and recommending the use of a common nutrient profiling system to underpin the multiple potential applications of nutrient profiling; and,
- develop regulations that standardise nutrition labelling in a format that is likely to maximise consumer understanding.

In calling for government leadership in this area, it is fitting to end this thesis with the following quote by Downie et al.162

“Failure to regulate powerful concerns which damage health serves to perpetuate the freedom of choice of those with a great deal of power (major business and others with vested interests in unhealthful products or activities) to exploit those with relatively little (the public).”
References

49. Townsend MS. Where is the science? What will it take to show that nutrient profiling systems work? Am J Clin Nutr 2010;91(4):1109S-15S.


130. Butte NF, Ellis KJ. Comment on "Obesity and the environment: where do we go from here?". Science 2003;301:598.


Appendix

Study E: Survey questions

Traffic-light symbols

We are currently running a trial of new traffic-light symbols. These symbols are being trialled on a small range of categories on the site.

1. Have you seen the traffic-light symbols on the site?

Please click the response that applies best

- Yes
- No

[If ‘Yes’ display Question 2. If ‘No’, display a screen showing a product list page for a particular food category, highlighting the area where the traffic-light symbols appear, and then display Question 2.]

2. How would you rate the usefulness of the traffic-light symbols in helping you choose healthier options?

Please click the response that applies best

- Very useful
- Quite useful
- Not very useful
- Not useful at all

3. How easy do you think the traffic-light symbols are to understand?

Please click the response that applies best

- Very easy to understand
- Quite easy to understand
- Quite difficult to understand
- Very difficult to understand

4. Would you like to see the traffic-light symbols used on all categories of food on the site?

Please click one response

- Yes
- No
- Don’t care
5. Would you like to see the traffic-light symbols used more broadly (e.g., on the packaging of food products in supermarkets)?

Please click one response
- Yes
- No
- Don’t care

Demographics

1. How old are you?

Please click one response
- Under 18
- 18 – 29
- 30 – 65
- Over 65

2. What is the highest level of education that you have completed?

Please click the response that applies best
- Did not complete high school
- Completed high school (Year 12 or equivalent)
- Completed tertiary education
- Other

3. Which of the following best describes your household situation?

Please click the response that applies best
- Single person household
- Living with a partner / friend(s)
- Family with children living at home
- Family with children who have left home
- Other

4. What is your total annual household income (before tax)? [OPTIONAL QUESTION]

Please click the response that applies best
- Less than $10,000 per year
- $10,000 - $50,000 per year
- $50,000 - $100,000 per year
- Over $100,000 per year