Nutrition during pregnancy:
An evaluation of maternal dietary intake and the
development of foetal adiposity

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A thesis submitted for the degree of PhD (Nutrition and Dietetics)

May 2013
Statement of originality

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university of other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to the final version of my thesis being made available worldwide when deposited in the University’s Digital Repository**, subject to the provisions of the Copyright Act 1968.

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Acknowledgement of collaboration

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........................................

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I hereby certify that this thesis is submitted in the form of a series of published papers of which I am a joint author. I have included as part of my thesis a written statement from each co-author, endorsed by the Faculty Assistant Dean (Research Training), attesting to my contribution to the joint publications.

........................................

Michelle Blumfield
Acknowledgements

I would like to acknowledge the following people who have contributed to my thesis.

Firstly, I must acknowledge my PhD supervisors, Professor Clare Collins, Dr Alexis Hure, Dr Lesley MacDonald-Wicks and Professor Roger Smith. You have each made my PhD journey a truly wonderful and rewarding experience. Thank you for your endless time, knowledge and support. I am forever grateful and really cannot thank you enough.

I would also like to thank Professor Stephen Simpson and Professor David Raubenheimer for sharing their expertise, time and providing continual support throughout this journey. Your collaboration has been really valued.

Several other researchers played an important role in the completion of my thesis. I would like to thank Dr Amanda Patterson for her expert advice and contribution to the cross-sectional study. Thank you to Dr Patrick McElduff for his statistical support and patience in explaining the statistical analyses. Professor Warwick Giles must also be acknowledged for his professional guidance surrounding the collection of foetal ultrasound data in the WATCH study. I particularly appreciate the research assistance from Hannah Lucas with regards to the WATCH study, as well as her continued enthusiasm to help out in any way she could. Thank you for all your efforts, they have been really appreciated.

I also appreciate the time and commitment from our WATCH study participants. Thank you for continuing to support this research. I would also like to acknowledge the participants of the Australian Longitudinal Study on Women’s Health and the Women’s Health Australia staff for generously providing the Australian data that was analysed in the cross-sectional study.

I would also like to thank all the other research higher degree students, and staff within Nutrition and Dietetics, at the University of Newcastle, for ongoing support and encouragement. I would particularly like the acknowledge Julia Martin, James Bray and Dr Lana Mitchell for their advice, encouragement and discussions.

I must also acknowledge the support of my family and friends over the past four years. My husband, Justin, I thank you for your unconditional love, emotional support and patience. Your understanding, strength and belief in my abilities, not to mention your proof reading skills and oral presentation advice, have been amazing. Finally, a big
thank you to my mum (Anna) for always knowing the right thing to say at the right time, and encouraging me to embark on the PhD journey in the first place.

This research was supported by a University of Newcastle Research Scholarship (Central), a scholarship top-up from the Newcastle Permanent Charitable Foundation, and a 2012 University of Newcastle Completion Scholarship.
Publication and presentations arising from this thesis

Manuscripts in peer-reviewed journals: Published


Conference abstracts: Published in peer-review journals


Conference abstracts: Published in conference proceedings


Other presentations

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<tbody>
<tr>
<td>ACEBAND</td>
<td>Australian Centre for Evidence Based Nutrition and Dietetics</td>
</tr>
<tr>
<td>AGHE</td>
<td>Australian Guide to Healthy Eating</td>
</tr>
<tr>
<td>AI</td>
<td>Adequate intake</td>
</tr>
<tr>
<td>ALSWH</td>
<td>Australian Longitudinal Study on Women’s Health</td>
</tr>
<tr>
<td>AMDR</td>
<td>Adequate macronutrient distribution range</td>
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<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
</tr>
<tr>
<td>APD</td>
<td>Accredited practicing dietitian</td>
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<tr>
<td>ARI</td>
<td>Acceptable range of intake</td>
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<tr>
<td>BAT</td>
<td>Brown adipose tissue</td>
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<tr>
<td>BMI</td>
<td>Body mass index</td>
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<tr>
<td>CI</td>
<td>Confidence interval</td>
</tr>
<tr>
<td>CT</td>
<td>Computed tomography</td>
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<tr>
<td>CVD</td>
<td>Cardiovascular disease</td>
</tr>
<tr>
<td>DHA</td>
<td>Docosahexaenoic fatty acid</td>
</tr>
<tr>
<td>DPA</td>
<td>Docosapentaenoic fatty acid</td>
</tr>
<tr>
<td>DRI</td>
<td>Dietary reference intake</td>
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<tr>
<td>DQES</td>
<td>Dietary Questionnaire of Epidemiological Studies</td>
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<tr>
<td>EAR</td>
<td>Estimated average requirement</td>
</tr>
<tr>
<td>EPA</td>
<td>Eicosapentaenoic fatty acid</td>
</tr>
<tr>
<td>EURRECA</td>
<td>EURopean micronutrient RECommendations Aligned Network of Excellence</td>
</tr>
<tr>
<td>FFQ</td>
<td>Food frequency questionnaire</td>
</tr>
<tr>
<td>FSANZ</td>
<td>Food Standards Australia New Zealand</td>
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<tr>
<td>g</td>
<td>Gram</td>
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<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>GLM</td>
<td>Generalised linear model</td>
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<tr>
<td>HDL</td>
<td>High-density lipoprotein</td>
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<td>HFD</td>
<td>High fat diet</td>
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<tr>
<td>IGF</td>
<td>Insulin-like growth factor</td>
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<tr>
<td>IQR</td>
<td>Interquartile range</td>
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<tr>
<td>kcal</td>
<td>Kilocalorie</td>
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<td>kJ</td>
<td>Kilojoule</td>
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<tr>
<td>LDL</td>
<td>Low-density lipoprotein</td>
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<td>mg</td>
<td>Milligram</td>
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<tr>
<td>MOOSE</td>
<td>Meta-analysis of Observational Studies in Epidemiology</td>
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<tr>
<td>MRI</td>
<td>Magnetic Resonance Imaging</td>
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<tr>
<td>MUFA</td>
<td>Monounsaturated fatty acids</td>
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<td>NCD</td>
<td>Non-communicable disease</td>
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<tr>
<td>NE</td>
<td>Niacin Equivalent</td>
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<tr>
<td>NRV</td>
<td>Nutrient Reference Value</td>
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<tr>
<td>NUTTAB</td>
<td>Nutrient Data Tables for use in Australia</td>
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<tr>
<td>NZ</td>
<td>New Zealand</td>
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<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
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<tr>
<td>PAR</td>
<td>Predictive adaptive response</td>
</tr>
<tr>
<td>P:C</td>
<td>Protein to carbohydrate</td>
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<td>P:NP</td>
<td>Protein to non-protein</td>
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<tr>
<td>PUFA</td>
<td>Polyunsaturated fatty acids</td>
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<td>RDA</td>
<td>Recommended dietary allowance</td>
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<td>Recommended dietary intake</td>
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<tr>
<td>RE</td>
<td>Retinol equivalents</td>
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<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>SBS</td>
<td>Subscapular</td>
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<tr>
<td>SD</td>
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<tr>
<td>SES</td>
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<td>Suprailiac</td>
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<tr>
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<td>Type 2 Diabetes Mellitus</td>
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<tr>
<td>µg</td>
<td>Microgram</td>
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<tr>
<td>UK</td>
<td>United Kingdom</td>
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<tr>
<td>UL</td>
<td>Upper limit</td>
</tr>
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<td>USA</td>
<td>United States of America</td>
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<tr>
<td>WAT</td>
<td>White adipose tissue</td>
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<td>WATCH</td>
<td>Women and Their Children’s Health</td>
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<tr>
<td>WFR</td>
<td>Weighed food record</td>
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Abstract

Early life environmental factors, including maternal dietary intake and nutritional status during pregnancy, can program offspring health outcomes in later life. Given the rapid worldwide burden of non-communicable conditions (e.g. obesity, type 2 Diabetes Mellitus (T2DM) and cardiovascular disease), early prevention by optimising maternal, foetal and infant nutrition has been identified as a strategy that is likely to be beneficial and cost effective. The primary purpose of this thesis is to evaluate the dietary intakes of women during pregnancy, and to investigate the relationship between maternal intake and foetal body composition. Three research studies were undertaken to meet these aims.

A systematic review of the available literature determined the energy, macronutrient and micronutrient intakes of pregnant women in developed countries, and appraised the nutritional adequacy of intakes compared to current recommendations. Meta-analyses provided evidence that the dietary intakes of pregnant women do not match with international recommendations. Energy and carbohydrate intakes were generally below recommendations, total fat and saturated fat intakes were generally above recommendations, while protein intakes were within the recommendations. Secondly, pregnant women reported suboptimal micronutrient intakes with folate, iron and vitamin D intakes consistently below nutrient recommendations in all geographical regions.

A cross-sectional study evaluated the dietary intakes of Australian women of reproductive age by pregnancy status, in comparison to national food group recommendations. This determined whether their eating patterns achieved the recommended intakes of nutrients important for pregnancy. Data were obtained from the Australian Longitudinal Study on Women’s Health (ALSWH), young cohort aged 25 – 30 years in 2003 (n 9076). Pregnancy status was self-reported as pregnant (n 606), trying to conceive (n 454), given birth in the last 12 months (n 829) or other (n 5597). Diet was assessed using a validated 74-item food frequency questionnaire (FFQ). Daily food group servings and nutrient intakes were compared to the Australian Guide to Healthy Eating (AGHE) and Australian Nutrient Reference Values (NRVs). The study found that the AGHE does not enable pregnant women to meet all the NRVs and further the contemporary eating pattern of Australian women that do achieve nutrient intake targets does not align with the AGHE recommendations for daily servings of food groups.
Longitudinal data, collected prospectively as part of the Women and Their Children’s Health (WATCH) study from a cohort of 179 pregnant women, was used to evaluate whether maternal macronutrient intakes are associated with foetal body composition and secondly, whether the macronutrient content of maternal diet is associated with the adequacy of micronutrient intakes, compared to Australian dietary recommendations. Linear mixed-model regression analyses and parametric response surfaces provided evidence that there may be a target maternal macronutrient profile associated with optimal foetal body composition. The development of foetal abdominal visceral area throughout gestation was positively associated with higher maternal protein intakes, decreased starch intakes and a higher protein to carbohydrate (P:C) ratio. Foetal midthigh lean area was positively associated with increased maternal PUFA intakes and decreased SFA intakes. Response surfaces for micronutrient intakes were optimized when the percentage energy was within intermediate protein (18-20%E), intermediate fat (28-30%E) and intermediate carbohydrate (50-54%E) intakes. Results suggest a moderate protein intake may support pregnant women to consume the largest variety of nutrients across all food groups.

In conclusion, the study findings presented in this thesis provide evidence that dietary intakes during pregnancy commonly fail to achieve target NRVs and that current dietary selection models to guide the food consumption of pregnant women in Australia may require revision. Findings also suggest that foetal body composition and maternal micronutrient adequacy may be modifiable by nutritional interventions in the mother, with a particular emphasis on protein as a key driver of these relationships. These results are likely to have important implications for the offspring’s risk of non-communicable disease, and key recommendations for future research to support optimal health outcomes are provided.