Antenatal Weighing
&
Gestational Weight Gain

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A thesis submitted to the University of Newcastle, Australia in fulfilment of the requirements for the Degree of

Doctor of Philosophy (Community Medicine & Clinical Epidemiology)

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DECLARATIONS

Statement 1

Statement of Originality

I hereby certify that the work embodied in the thesis is my own work, conducted under normal supervision. The thesis contains no material which has been accepted, or is being examined, for the award of any other degree or diploma in any university or 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. 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 and any approved embargo.

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I hereby certify that this thesis is in the form of a series of papers. I have included as part of the thesis a written declaration from each co-author, endorsed in writing by the Faculty Assistant Dean (Research Training), attesting to my contribution to any jointly authored papers.

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CO-AUTHOR STATEMENT

By signing below, I confirm that the Research Higher Degree candidate **Shanna Maree Fealy** contributed to the research question, methodological design, data analysis, data interpretation and writing of the listed manuscripts included in this thesis by publication.

1. **Fealy, S.**, Taylor, R.M., Foureur, M., Attia, J., Ebert, L., Bisquera, A., & Hure, A. J. (2017). Weighing as a stand-alone intervention does not reduce excessive gestational weight gain compared to routine antenatal care: a systematic review and meta-analysis of randomised controlled trials. *BMC pregnancy and childbirth, 17*(1), 36: doi.org/10.1186/s12884-016-1207-2

2. **Fealy, S**., Davis, D., Foureur, M., Attia, J., Hazelton, M., & Hure, A. (2020). The return of weighing in pregnancy: A discussion of evidence and practice. *Women & Birth, 33*(2), 119-124: doi:10.1016/j.wombi.2019.05.014

3. **Fealy, S**., Attia, J, Leigh, L., Oldmeadow, C., Hazelton, M., Foureur, M., Collins, C.E., Smith, R., Hure, A. (2021). A revalidation of the Weight Related Behaviours Questionnaire within an Australian Pregnancy Cohort. *Midwifery*, 97: doi.org/10.1016/j.midw.2021.102951

4. **Fealy, S**., Attia, J., Leigh, L., Oldmeadow, C., Hazelton, M., Foureur, M., Collins, C.E., Smith, R., Hure, A. (2020). Demographic and social-cognitive factors associated with gestational weight gain in an Australian pregnancy cohort. *Eating Behaviors*, *39*: doi.org/10.1016/j.eatbeh.2020.101430

5. **Fealy, S**., Leigh, L., Hazelton, M., Attia, J., Foureur, M., Oldmeadow, C., Collins, C.E., Smith, R., Hure, A. (submitted 4th February 2021). Translation of the Weight Related Behaviours Questionnaire into a short-form psychosocial assessment tool for the detection of women at risk of excessive gestational weight gain. (under review with *Appetite* journal).

6. **Fealy, S**., Jones, D., Davis, D., Hazelton, M., Foureur, M., Attia, J., Hure, A. (submitted 22nd January 2020). Pregnancy weight a balancing act: The experience and perspectives of women participating in a pilot randomised controlled trial. (under review with *The Qualitative Report* journal).

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Lastly, Shanna you did it!

LIST OF PUBLICATIONS ARISING FROM THIS THESIS

Fealy, S., Taylor, R.M., Foureur, M., Attia, J., Ebert, L., Bisquera, A., & Hure, A. J. (2017). Weighing as a stand-alone intervention does not reduce excessive gestational weight gain compared to routine antenatal care: a systematic review and meta-analysis of randomised controlled trials. *BMC pregnancy and childbirth, 17*(1), 36. doi.org/10.1186/s12884-016-1207-2 **(Chapter 2)**.

Fealy, S., Davis, D., Foureur, M., Attia, J., Hazelton, M., & Hure, A. (2020). The return of weighing in pregnancy: A discussion of evidence and practice. *Women & Birth, 33*(2), 119-124. doi.10.1016/j.wombi.2019.05.014 **(Chapter 3**).

Fealy, S., Attia, J, Leigh, L., Oldmeadow, C., Hazelton, M., Foureur, M., Collins, C.E., Smith, R., Hure, A. (2021). A revalidation of the Weight Related Behaviours Questionnaire within an Australian Pregnancy Cohort. *Midwifery*, 97: doi.org/10.1016/j.midw.2021.102951 **(Chapter 4)**.

Fealy, S., Attia, J., Leigh, L., Oldmeadow, C., Hazelton, M., Foureur, M., Collins, C.E., Smith, R., Hure, A. (2020). Demographic and social-cognitive factors associated with gestational weight gain in an Australian pregnancy cohort. *Eating Behaviors*, *39*. doi.org/10.1016/j.eatbeh.2020.101430 **(Chapter 5)**.

MANUSCRIPTS UNDER REVIEW

Fealy, S., Leigh, L., Hazelton, M., Attia, J., Foureur, M., Oldmeadow, C., Collins, C.E., Smith, R., Hure, A. (submitted 4th February 2021). Translation of the Weight Related Behaviours Questionnaire into a short-form psychosocial assessment tool for the detection of women at risk of excessive gestational weight gain. (under review with *Appetite* journal) **(Chapter 6)**.

Fealy, S., Jones, D., Davis, D., Hazelton, M., Foureur, M., Attia, J., Hure, A. (submitted 22nd January 2020). Pregnancy weight a balancing act: The experience and perspectives of women participating in a pilot randomised controlled trial. (under review with *The Qualitative Report* journal) **(Chapter 7)**.

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PRESENTATIONS ARISING FROM THIS THESIS

1. **Fealy S**., (2018) Visiting Scholar Travel Grant Scheme presentation, University of Leeds, School of healthcare "Antenatal Weighing and Gestational Weight gain".
2. **Fealy S**., (2019) Research Visiting Fellow Grant Scheme, The University of Illinois – Chicago – College of Nursing "Antenatal Weighing and Gestational Weight gain".

ADDITIONAL PUBLICATIONS CO-AUTHORED DURING CANDIDATURE

Throughout the duration of my candidature, I have worked as an academic lecturer in Nursing and Midwifery for the University of Newcastle, Port Macquarie Campus (2013 – 2019), Charles Sturt University, Port Macquarie Campus (2019 – current) and as a practicing Registered Nurse and Midwife for the Mid North Coast Local Health District (2005 – current). In these roles and in addition to my thesis topic, I have collaborated and contributed to a variety of research projects in the field of Nursing, Midwifery, and Public Health. I have additionally participated in the co-supervision of research higher degree students. This has resulted in the following additional publications and conference proceedings.

1. Hure A, Gresham E, Lai J, Anderson A, Martin J, **Fealy S**, Blumfield M, (2014). Nutrition in pregnancy: The balancing act, *International Journal of Birth and Parent Education*, 1, 7-12.

2. **Fealy, S**., Hure, A., Browne, G., & Prince, C. (2014). Developing a clinical care pathway for obese pregnant women: A quality improvement project. *Women & Birth*, *27*(4), e67-e71.

3. Taylor, R. M., **Fealy, S. M**., Bisquera, A., Smith, R., Collins, C. E., Evans, T. J., & Hure, A. J. (2017). Effects of nutritional interventions during pregnancy on infant and child cognitive outcomes: A systematic review and meta-analysis. *Nutrients*, *9*(11).

4. Barnett, M. J., **Fealy, S**., & Wilson, A. (2019). Barriers and enablers for smoking cessation amongst pregnant women: An Umbrella Review. *Women & Birth*, *32*(4), 310-317.

5. **Fealy, S.**, Chan, S., Wynne, O., Dowse, E., Ebert, L., Ho, R., Zhang, M.W., & Jones, D. (2019). The Support for New Mums Project: A protocol for a pilot randomized controlled trial designed to test a postnatal psychoeducation smartphone application. *Journal of Advanced Nursing*, 75(6), 1347-1359.

6. **Fealy, S**., Jones, D., Hutton, A., Graham, K., McNeill, L., Sweet, L., & Hazelton, M. (2019). The integration of immersive virtual reality in tertiary nursing and midwifery education: A scoping review. *Nurse Education Today*, *79*, 14-19.

7. Dowse, E., Chan, S., Ebert, L., Wynne, O., Thomas, S., Jones, D., **Fealy, S**., Evans, T.J., & Oldmeadow, C. (2020). Impact of Perinatal Depression and Anxiety on Birth Outcomes: A Retrospective Data Analysis. *Maternal and Child Health Journal,* 24, 718-726.

Book Chapter

Jones, D., Hazelton, M., Evans, D., Pento, V., Siang See, Z., Van Leugenhaege, L., & **Fealy, S**. (in press) The Road to Birth: Using Extended Reality to visualize pregnancy anatomy. In *Human-centric Computing and Information Sciences - Digital Anatomy*, Springer.

Published Conference proceedings

1. **Fealy, S**., Jones, D., Ebert, L., Dowse, E., Wynne, O., & Chan, S. (2017). "Supporting new Mums"–Developing a postnatal psycho-educational smartphone application for first time mothers. *Women & Birth*, *30*, 31.

2. Tierney, O., & **Fealy, S**. (2017). Postnatal Maternity Outpatient Clinic: An innovation in postnatal care. *Women & Birth*, *30*, 32.

3. Jones, D., Siang See, Z., Billinghurst, M., Goodman, L., & **Fealy, S**. (2019). Extended Reality for Midwifery Learning: MR VR Demonstration. In *The 17th International Conference on Virtual-Reality Continuum and its Applications in Industry*, 1-2.

Unpublished Conference proceedings

1. **Fealy, S**., & Tierney, O. (2014). Not "Just" a Midwife: The future face of Midwifery. *Southern Cross University Nursing & Midwifery Conference,* Coffs Harbour.

2. **Fealy, S**., & Prince, C. (2014). Addressing Obesity in Pregnancy in the Hastings Macleay. *Southern Cross University Nursing & Midwifery Conference,* Coffs Harbour, Australia.

3. **Fealy, S**., Tierney, O., Jones, D., & Ebert, L. (2014). Midwifery Student's Perceptions of Working with Midwifery Lecturers During Clinical Placement, *Queensland State Midwifery Conference; Midwives-The Next Generation,* Gold Coast, Queensland, Australia.

4. **Fealy, S**., & Tierney, O. (2016) Developing a "Postnatal Maternity Outpatient Clinic (PMOC). *Mid North Coast Local Health District Rural Innovation and Research Symposium*, Coffs Harbour, Australia.

5. **Fealy, S**., Jones, D., Ebert, L., Dowse, E., Wynne, O., Zhang, M., Ho, R., & Chan, S. (2016). Developing a "Postnatal Psychoeducational" smartphone application for first time mothers. *E-Mental Health International Conference*. Centre for Brain and Mental Health Research, Newcastle, Australia.

6. **Fealy, S**., Jones, D., Ebert, L., Dowse, E., Wynne, O., Zhang, M., Ho, R., & Chan, S. (2017). Supporting New Mums "Postnatal Psychoeducational" smartphone application for first time mothers. *Mid North Coast Local Health District Rural Innovation and Research Symposium*, Coffs Harbour, Australia.

7. Jones, D., & **Fealy, S**. (2018) Keynote speakers – "Immersive technology in nursing and midwifery education: virtual and augmented technology". *New South Wales (NSW) Nurses and Midwives Association Professional Day*, Rosehill, New South Wales, Australia.

8. Jones, D., & **Fealy, S**. (2018). Invited Speakers - "The Road to Birth". *International IEEE-GEM conference,* Galway Ireland.

9. Jones, D., & **Fealy, S**. (2018). "Invited guest presentation – "Compromised neonate virtual reality project". iLife team Oxford University, United Kingdom.

10. Jones, D., & **Fealy, S.** (2019). Research Visiting Scheme – "Road to Birth Digital Technology presentation". *The University of Illinois – College of Medicine,* Champaign / Urbana, Illinois, United States of America.

11. Jones, D., & **Fealy, S.** (2019). Research Visiting Scheme – "Road to Birth Digital Technology presentation". *Carle Foundation Hospital - Research Institute personnel,* Champaign / Urbana, Illinois, United States of America.

12. Jones, D., & **Fealy, S**. (2019). Research Visiting Scheme – "Road to Birth Digital Technology presentation". *The University of Illinois – Chicago College of Nursing,* Chicago, United States of America.

13. Jones, D., & **Fealy, S**. (2020). Lightening talk – "Transformative technologies virtual and mixed realities in health education and research". *Charles Sturt University - Faculty of Sciences Teaching and Learning Forum,* Wagga Wagga, New South Wales, Australia.

14. Jones, D., & **Fealy, S**. (2020) Invited speakers – "Anatomy in The Digital Age Webinar – Immersive Technology in Maternity Care". *French Academy of Surgery*, Paris, France via *ZOOM.*

AWARDS OBTAINED DURING CANDIDATURE

1. 2014 – Australian Government Research Training Program (RTP) Scholarship.
2. 2014 - University of Newcastle, Faculty of Health, Teaching Excellence Award.
3. 2015 - The Mid North Coast Local Health District Quality & Innovation Grant, ($5,000), Establishment of the Postnatal Maternity Outpatient Clinic (PMOC).
4. 2016 - The Mid North Coast Local Health District Higher Degree by Research Support Grant, ($1,500), contribution towards open access publication of PhD systematic review manuscript.
5. 2016 - The Mid North Coast Local Health District Research Support Grant, ($17,697), Supporting New Mums: A psychoeducation application, pilot randomised controlled trial.
6. 2017 - Hunter Medical Research Institute (HMRI) Project Grant, ($20,000), Supporting New Mums: psychoeducation application, pilot randomised controlled trial.
7. 2017 – School of Nursing and Midwifery Travel Grant, ($1,000), contribution towards attendance at the Australian College of Midwives, National Conference, Adelaide.
8. Faculty of Health and Medicine Research Conference Travel Grant, ($750), contribution towards attendance at the Australian College of Midwives, National Conference, Adelaide.
9. 2017 - School of Nursing and Midwifery Travel Grant, ($500), contribution towards attendance at the Newcastle Nursing and Midwifery Conference.
10. 2018 – Commonwealth Scientific and Industrial Research Organisation (CSIRO) ON Prime and ON Accelerate grant funding, ($25,000).
11. 2018 – School of Nursing and Midwifery Travel Grant, ($500), contribution towards attendance at the International Conference, IEEE- GEM Galway Ireland.
12. 2018 - Faculty of Health and Medicine Research Conference Travel Grant, ($2,000), contribution towards attendance at the International Conference, IEEE- GEM Galway Ireland.
13. 2019 - Faculty of Health and Medicine Research Visiting Fellow Grant, ($6,000), contribution towards travel to the University of Illinois, Champaign /Urbana and Chicago Campuses, to establish research relationships.

CONTRIBUTION STATEMENT

The body of work detailed in this thesis by publication has resulted in six publications. I was the PhD student responsible for this project. A summary of my contributions and involvement are detailed below.

Chapter 2

Weighing as a stand-alone intervention does not reduce excessive gestational weight gain compared to routine antenatal care: a systematic review and meta-analysis of randomised controlled trials

I was the primary reviewer and lead author of this systematic review. The majority of support and guidance during the review and manuscript development process was provided by primary supervisor Dr Alexis Hure. Specifically, Dr Hure conceived the study and provided guidance with the design and writing of the review protocol, inclusion/exclusion criteria, initial screening of retrieved articles, checked data extraction and contributed to the drafting, editing and review of the manuscript. With the support of research librarian Debbie Booth, I designed and conducted the initial and final primary and secondary literature search strategies. I lead the screening process, quality appraisal process, data extraction process and was responsible for coordination and writing of the review manuscript and responding to reviewer comments during the peer review publication process. Fellow colleague Dr Rachel Taylor was the second reviewer contributing to the article screening process, quality appraisal process, and contributed to editing the manuscript for publication. Statistical analysis was conducted by Dr Alessandra Bisquera an external statistician from the Hunter Medical Research Institute Clinical Research Design and Statistics unit. Dr John Attia provided additional guidance with the study design, interpretation of statistical data, editing and reviewing of the systematic review manuscript. Both Dr Maralyn Foureur and Dr Lyn Ebert contributed to the editing of the manuscript and assisted with responding to reviewer comments during the peer review publication process.

Chapter 3

The return of weighing in pregnancy: A discussion of evidence and practice

I was the lead author of this narrative review and synthesis. Specifically, I was responsible for the article's conceptualisation, design, writing of the manuscript for publication and responding to reviewer comments during the peer review publication process. Dr Alexis Hure contributed to the paper's development, editing, and reviewing the manuscript. Dr Maralyn Foureur, Dr Deborah Davis, Dr John Attia and Dr Michael Hazelton all contributed by editing and reviewing the manuscript before and after submission to the peer reviewed journal Women & Birth.

Chapters 4 – 6

The Weight-Related Behaviours Questionnaire

The Weight-Related Behaviours Questionnaire (WRB-Q) was originally developed and validated by researchers from the United States of America within a large pregnancy cohort, recruited between March 1995 - December 1996. The questionnaire was deployed for the collection of psychosocial data as part of the Women and Their Children's Health (WATCH) prospective longitudinal cohort study.

The Women and Their Children's Health (WATCH) prospective longitudinal cohort study

Formative work on the WATCH study was conducted by Dr Alexis Hure and senior researchers Dr Roger Smith and Dr Clare Collins. The study was initially conducted to investigate the developmental origins of health and adult disease specifically, investigating maternal and child health, nutrition, and health behaviour, from pregnancy up to four years post birth. This thesis involves analysis of WATCH cohort data, specifically analysis of the WRB-Q data collected between June 2006 and December 2007. This data has been used to inform the following thesis chapters.

1. A revalidation of the Weight-Related Behaviours Questionnaire within an Australian pregnancy cohort **(Chapter 4)**.
2. Demographic and social-cognitive factors associated with gestational weight gain in an Australian Pregnancy Cohort **(Chapter 5)**.

3. Translation of the Weight-Related Behaviours Questionnaire into a short-form psychosocial assessment tool for the detection of women at risk of excessive gestational weight gain **(Chapter 6)**.

I was the research lead for all the above listed studies. Specifically, I contributed by assisting with the overall research conceptualisation, data extraction, interpretation of results, full manuscript preparation, submission of articles for publication and responding to peer review comments. Dr Alexis Hure provided primary supervision and guidance contributing to the studies conceptualisation, design, manuscript preparation, editing and review of all manuscripts. Statistical methodology and analysis for the three manuscripts were performed by Dr Lucy Leigh and Dr Christopher Oldmeadow, external statisticians from the Hunter Medical Research Institute. Dr John Attia provided additional statistical support and contributed by reviewing interpretation of statistical results, editing and reviewing of all manuscripts. Dr Michael Hazelton and Dr Maralyn Foureur contributed by editing and reviewing all manuscripts. Dr Clare Collins and Dr Roger Smith were lead researchers of the WATCH study and contributed to the listed studies by providing permissions for use of WATCH study data, editing and reviewing all manuscripts.

Chapter 7

The Eating 4 Two Pilot Randomised Controlled Trial

Trial design and intervention development

The Eating 4 Two trial was an Australian pilot multicentre randomised controlled trial conducted under the stewardship of Chief Investigator Dr Deborah Davis from the University of Canberra. The Eating 4 Two trial was a pregnancy weight management trial with the aim to test the effectiveness of a mobile health (mhealth), smartphone / tablet application (app). The Eating 4 Two application was designed by experts in the field of midwifery, nutrition, dietetics and obstetrics, in conjunction with pregnant women. The application was developed for both Apple iOS and Android platforms. All formative work on the design of the Eating 4 Two trial protocol and smartphone application was conducted by Chief Investigator Dr Deborah Davis and her research team. I was responsible for the conduct of research for one arm of the Eating 4 two trial within one regional New South Wales trial site, as the research midwife.

Ethics approval

I was responsible for obtaining ethical approval for the Eating for Two trial in the state of New South Wales. This involved the preparation, submission and obtaining ethical approvals from the Mid North Coast Local Health District, Human Research Ethics Committee (HREC) and the University of Newcastle's HREC, due to the original research protocol being approved by the Australian Capital Territory HREC only.

- Australian Capital Territory Human Research Ethics Committee: HREC/17/ACT/1 (**Appendix A11**).
- Mid North Coast Local Health Human Research Ethics Committee: SSA/17/NCC/13 (**Appendix A12**).
- University of Newcastle Human Research Ethics Committee: H-2017-0074 (**Appendix A13**).

This process involved translating and completing all ethics and health district site specific documentation and liaising with industry stakeholders such as clinical governance representatives, directors of nursing and midwifery, midwifery unit managers and midwifery staff. It also involved the adaption of the Eating 4 Two protocol and associated participant information statements and consent forms, to the regional trial site (**Appendix A14 and A15**).

Participant recruitment

I was the research midwife for this trial site and coordinated the screening and recruitment of participants in this arm of the Eating 4 Two study. This involved engagement with health service management, staff, the dissemination of recruitment materials and advertisements, as well as liaising with the Hunter Medical Research Institute's media department for the preparation of a social media post to promote the study. I was responsible for following up with interested participants and providing additional trial information as required.

Data collection, entry and management

As the research midwife, I was responsible for collaborating with the Eating 4 Two trial research leads and for the coordination and collation of participant consent forms. I was responsible for the collection and management of trial data from this site. I was additionally responsible for the coordination, conduct of, and transcription of, qualitative interviews at the regional trial site.

Data analysis

The Eating 4 Two trial chief investigator Dr Deborah Davis gave permission for me to analyse the qualitative interview data collected at the regional trial site and allowed for the data to contribute to this thesis. I conceptualised the qualitative study featured within this chapter choosing a qualitative descriptive methodology and lead the qualitative data analysis. Dr Donovan Jones and co-supervisor Dr Michael Hazelton contributed to the data analysis process. Qualitative data was de-identified and then transcribed verbatim by an external transcription service. Transcriptions were then transferred to, and managed in, the qualitative software program NVivo.

Pregnancy weight gain a balancing act: The experience and perspectives of women participating in a pilot randomised controlled trial (Chapter 7).

I was the lead author for this qualitative study paper responsible for the conceptualisation, research methodology, analysis, interpretation of results, full manuscript preparation and submission for peer review. Dr Alexis Hure contributed to the development, editing, and reviewing of the manuscript. Dr Donovan Jones and Dr Michael Hazelton contributed to the qualitative analysis and interpretation of findings as well as contributed to editing of the manuscript. Dr John Attia and Dr Maralyn Foureur contributed by editing and reviewing the manuscript for publication. Dr Deborah Davis was the Chief Investigator of the Eating 4 Two trial and contributed to the study by providing permissions for use of trial data and manuscript editing and review.

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LIST OF ABBREVIATIONS

AtWG	Attitudes towards Weight Gain
AUC	Area Under the Curve
BI	Body Image
BMI	Body Mass Index
CI	Confidence Interval
CO	Career Orientation
COREQ	Consolidated criteria for Reporting Qualitative research
COSMIN	Consensus-based Standards for the selection of health Measurement Instruments
CFA	Confirmatory Factor Analysis
DOHaD	Developmental Origins of Health and Disease
EGWG	Excessive Gestational Weight Gain
EFA	Exploratory Factor Analysis
FaMR	Feelings about the Motherhood Role
GDM	Gestational Diabetes Mellitus
GRM	Graded Response Model
GWG	Gestational Weight Gain
ICC	Item Characteristic Curve
IIF	Item Information Function
IGWG	Inadequate Gestational Weight Gain
IOM	American Institute of Medicine
IRT	Item Response Theory
NHMRC	Australian National Health and Medical research Council
NICE	British National Institute of Health and Care Excellence
NSW	New South Wales
OR	Odds Ratio

PE	Pre-eclampsia
PIH	Pregnancy Induced Hypertension
PRECEDE/PROCEED	Predisposing, Reinforcing, and Enabling Constructs in Educational and Environmental Diagnosis and Evaluation / Policy, Regulatory and Organisational Constructs in Educational Environmental Development
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
RCT	Randomised Controlled Trial
RR	Risk Ratio
SAS	Statistical Analysis System
SCT	Social Cognitive Theory
SE	Self-Efficacy
STROBE	Strengthening the Reporting of Observational studies in Epidemiology
UK	United Kingdom
USA	United States of America
WATCH	Woman and Their Children's Health Study
WHO	World Health Organization
WLOC	Weight Locus of Control
WMD	Weighted Mean Difference
WRB-Q	Weight-Related Behaviours Questionnaire
WRPD	Weight Related Psychological Distress

THESIS ABSTRACT

Background

There is no clear guidance on how best to support women to achieve healthy gestational weight gain. The dominant physiological approach of energy in / energy out for weight management, such as diet and exercise interventions, has demonstrated moderate effectiveness at best for optimising gestational weight gain. Increasingly, routine antenatal weighing is being used to monitor women against gestational weight gain targets. However, to optimise pregnancy weight gain, broader socio-ecological approaches to physical and mental health in pregnancy are required.

Objectives

The primary objectives of this thesis are twofold; 1) To investigate the effectiveness of antenatal weight-monitoring as a health promotion strategy for optimising pregnancy weight gain; and 2) To explore the psychosocial factors associated with weight gain in pregnancy.

Methods

A thesis by publication inclusive of a series of six distinct but complementary publications, using a variety of research designs and methodologies were devised to address specific research aims as follows.

Aim 1: Perform a systematic review of the literature to ascertain the effectiveness of routine antenatal weighing as a stand-alone intervention to reduce excessive pregnancy weight gain.

Aim 2: Conduct a narrative review and evidence synthesise in response to the Australian Department of Health, *Pregnancy Care Guidelines,* recommending the re-introduction of routine antenatal weighing.

Aim 3: Perform a revalidation of the Weight-Related Behaviours Questionnaire, originally designed and tested in a pregnancy cohort in the United States, within an Australian pregnancy cohort.

Aim 4: Identify and describe the demographic and psychosocial factors predictive of excessive gestational weight gain, within an Australian pregnancy cohort.

Aim 5: Develop a short-form, psychosocial assessment tool for the detection of women at risk of excessive gestational weight gain.

Aim 6: Perform a qualitative analysis of the experience and perspectives of pregnant women who participated in a pilot weight management randomised controlled trial.

Conclusion

Overall, this program of work concludes existing evidence does not support weight-monitoring as a weight management strategy, with effects on maternal psychology largely unknown. To optimise gestational weight gain, broad socio-ecological approaches to health promotion are required, considering factors like self-efficacy and body image during antenatal care.

CHAPTER 1

INTRODUCTION

1.1 Chapter Overview

This chapter provides an introduction to the thesis topic, providing the necessary background information and context informing all subsequent thesis chapters. Gestational weight gain (GWG) is defined and discussed in **section 1.2**. The problem of excessive gestational weight gain (EGWG) and associated short and long-term adverse health outcomes are explored in **section 1.3**. **Section 1.4** provides an overview of interventions designed to reduce EGWG. This includes a discussion of diet, physical activity and antenatal weight-monitoring interventions, describing their efficacy and limitations. **Section 1.5** provides a definition and discussion of social-ecological factors that may impact women's ability to achieve healthy weight gain in pregnancy. A summary of the thesis aims concludes the chapter (**section 1.6**).

1.2 Gestational Weight Gain

Weight gain is fundamentally characteristic of pregnancy and a well-recognised determinant of fetal growth and pregnancy progression (1). Research conducted by Hytten and colleagues throughout the 1950s and 60s, described the mean gestational weight gain for primiparous women with good pregnancy outcomes to be approximately 12.5 kilograms (kgs) (2). The physiological components that contributed to total GWG were compartmentalised into the following: 1) products of conception; fetus, placenta and amniotic fluid (roughly 6 kgs); 2) maternal tissue accretion; uterine tissue, breast tissue, blood and plasma volume expansion (roughly 3.5 kgs); and 3) fat accumulation (roughly 3 kgs) (2). Fat accumulation was suggested as necessary to support the increased energy demands required for lactation (2, 3).

Since the time of Hytten's research, wide variations in mean GWG with good pregnancy outcomes have been observed, leading to confusion surrounding the definition of what constitutes appropriate GWG (3, 4). In an effort to provide clarity and a definition of "appropriate GWG", the American Institute of Medicine (IOM) undertook a review of the literature, devising reference ranges for weight gain in pregnancy (3). The IOM *Nutrition During Pregnancy* guidelines were first released in 1990. These guidelines had a public health focus on preventing infant mortality

associated with low-birth-weight infants, a health priority at the time (3), prior to the current obesity epidemic and when smoking was more prevalent (3). The weight gain ranges released within the IOM guidelines were largely informed by available published weight gain data from the United States of America (USA). Body Mass Index (BMI) values and categories were derived from American metropolitan lifestyle insurance data (3). The original 1990 IOM weight gain ranges are presented in Table 1.1.

Table 1.1 American Institute of Medicine Gestational Weight Gain Ranges 1990

BMI Category	Recommended Total Gain (kgs)
Underweight (BMI < 19.8)	12.5 – 18.0
Normal (BMI of 19.8 to 26.0)	11.5 – 16.0
Overweight (BMI > 26.0 to 29.0)	7.0 – 11.5
Obese (BMI >29.0)	>6.8
Adapted from the American Institute of Medicine Committee on Nutritional Status During Pregnancy and Lactation. Nutrition During Pregnancy: Part 1 Weight Gain. National Academy of Sciences Institute of Medicine; 1990.	

Since the emergence of the global obesity epidemic during the 1990's, widespread debate and criticism of the IOM 1990 weight gain guidelines has ensued (5, 6). The weight gain targets were argued to be too liberal in the years following their release and were not universally adopted by maternity care practitioners (6). Weight gain targets were argued to not improve infant outcomes but rather lead to poor perinatal outcomes, particularly large for gestational age infants, caesarean section and obese mothers (6). The IOM subsequently undertook a review of the guidelines, releasing updated weight gain targets in 2009 (6).

The revision of the IOM guidelines signified a shift in public health focus, from prevention of low-birth-weight infants and maternal undernutrition, to prevention of adverse outcomes associated with maternal obesity and GWG (6). The revised weight gain guidelines most notably adopted the World Health Organization (WHO) BMI categories (6). Women who are underweight at the beginning of pregnancy are recommended to gain more weight than women who entered pregnancy in the overweight or obese BMI categories, as per Table 1.2 (6).

Gestational weight gain is commonly defined using the IOM 2009 weight gain guidelines, where EGWG is defined as weight gains above the recommended maximum target value; and inadequate gestational weight gain (IGWG) defined as pregnancy weight gains below the minimum target reference value (6).

Table 1.2 American Institute of Medicine Gestational Weight Gain Ranges 2009

BMI Category	Recommended Total Gain (kgs)
Underweight (BMI <18.5)	12.5 – 18.0
Normal (BMI 18.5 – 24.9)	11.5 – 16.0
Overweight (BMI 25.0 – 29.9)	7.0 – 11.5
Obese (BMI ≥ 30.0)	5-9
Adapted from Rasmussen KM, Yaktine AL. Nutrition During Pregnancy: Re-Examining the Guidelines.Washington D.C.: National Academy of Sciences Institute of Medicine; 2009.	

1.3 Excessive Gestational Weight Gain

Weight gain is a normal part of the childbearing experience and in general a positive marker of pregnancy progression and fetal development, except when it is inadequate or excessive. The prevalence of women exceeding the IOM weight gain ranges is a global public health concern (7). A systematic review and meta–analysis of 23 cohort studies (n= 1,309,136) by Goldstein et al. (2017) (7), demonstrated that it is more common for women to gain above the IOM guidelines than within or below. Proportionally, 47% of women (n= 621, 004) were observed to gain weight above the guidelines (n= 621, 004), 23% of women (n=300,723) gained below, with 30% (387,409) gaining within the IOM target ranges, independent of pre pregnancy BMI (7). These statistics are of public health concern as EGWG has been independently associated with both short and long term adverse maternal and infant health outcomes (7, 8).

1.4 Adverse Perinatal Health Outcomes

Gestational weight gain is relevant to pregnancy outcome, including fetal growth. Weight gains above the IOM guidelines are associated with large for gestational infants, while weight gains below the guidelines are associated with small-for-gestational-age infants (7). Excessive gestational weight gain is independently associated with adverse perinatal outcomes including an increased odds for caesarean birth (Odds Ratio (OR) 1.30, 95% Confidence Interval (CI) 1.25, 1.35) (7). Individual studies have found EGWG to be associated with increased risk of pregnancy-specific conditions such as pre-eclampsia or pregnancy induced hypertension (PIH) (9) and gestational diabetes mellitus (GDM) (10). Also of most concern are the long term and intergenerational disease risks of EGWG, proposed by emerging research including the Developmental Origins of Health and Disease (DOHaD) hypothesis and infant “gut” microbiome research (11).

1.4.1 Developmental Origins of Health and Disease (DOHaD)

The Developmental Origins of Health and Disease is a field of research that grew from pivotal work by Professor David Barker (12). Barker proposed that adult diseases including cardiovascular disease and type 2 diabetes, may arise from environmental adaptions made during early life development (12). In particular, Barker hypothesised that early life exposure within the intrauterine environment, may determine fetal physiological development and later life health outcomes (12). Adverse health consequences are proposed to arise when a mismatch occurs between the intrauterine environment and extrauterine environment, post-birth (13). Maternal nutrition is hypothesised to play a large role in the development of adult non-communicable diseases (14). The adaptions the fetus makes to survive within the intrauterine environment is commonly referred to as fetal programming. A maternal intrauterine environment characterised by malnutrition (undernutrition) is suggested to detrimentally alter fetal physiology via epigenetic pathways leading to the development of disease such as cardiovascular disease and diabetes in later life.

Epigenetic functioning is described as being "above genetics" and is explained as the process where endogenous or exogenous stimuli affect gene functioning, without alteration to DNA sequence (15, 16). The exact epigenetic mechanisms involved in maternal over nutrition characterised by maternal EGWG are not well understood (17). During the course of a normal pregnancy, insulin resistance increases to facilitate the transfer of glucose and nutrients from the mother to sustain fetal growth and development. It is proposed that an intrauterine environment characterised by maternal over nutrition could further increase maternal insulin resistance and result in high circulating lipids that could adversely alter fetal physiology (17, 18). An environmental mismatch is proposed to occur after birth increasing the offspring's risk of childhood and adult chronic disease such as obesity, diabetes and non- alcoholic fatty liver disease (13, 14, 18, 19).

1.4.2 Infant gut microbiome and mode of birth

The gastrointestinal "gut" microbiome refers to the diverse populations of micro-organisms that inhabit the human gastrointestinal (GI) tract (20-22). The gut microbiome is a dynamic physiological ecosystem understood to offer the human host protection against pathogens as well as support overall physiological functions such as the processing of nutrients, instigation of angiogenesis and fat regulation (22). The human microbiome is influenced by a vast range of

nutritional and environmental factors such as diet, health status, antibiotic use, geographical area and mode of birth (21). Alterations in the gut microbiome are attributed to the development of a diverse range of diseases such as allergies, auto immune disease and obesity (21).

The establishment of the infant gut microbiome was once thought to only begin following birth. The intrauterine environment was viewed as a "sterile" environment. However, a growing body of evidence has challenged this view, with the uterus evidenced to be colonised by microorganisms (21). This suggests that the establishment of the infant microbiome occurs during early life development (20-22). Although not yet fully understood, maternal microbiota play an important role in the development of the infant gut microbiome (23). Maternal overweight and obesity, early exposure to antibiotics, unbalanced diets and caesarean section have been linked to the development of adult non-communicable disease and obesity (23). A recent small study (86 mother infant pairs) by Garcia-Mantrana et al. (2020) (23), aimed to assess the effects of maternal diet on maternal gut microbiota and evaluate the impacts of maternal microbiota on their infants, from birth to 18 months of life. The results of this study suggest that maternal diet influences maternal gut microbiota, which in turn was statistically associated with infant gut microbiome at birth (23). Maternal microbiota was associated with infant BMI at 18 months, whereby infants born by caesarean section in this study exhibited higher 18-month BMI scores (23).

Mode of birth (vaginal birth or caesarean section) is increasingly being linked to the development of adult and childhood chronic disease with caesarean section being independently associated with increased risk of obesity (24), type 1 diabetes (25) and asthma (26). Important differences in the infant gut microbiome have been found between infants born by vaginal birth and those born by caesarean section (20-22). During vaginal birth the infant passes through the vaginal tract and becomes colonised with maternal perineal and vaginal microbes (21). This event commonly referred to as "seeding", is considered to be a foundational developmental event, responsible for the "priming" and ongoing development of the microbiome (20). Infants born by caesarean section have been found to have very different gut microbiota to that of infants born vaginally (20, 21). Infants born by caesarean section have been found to have microbiota similar to that of the skin and are exposed to microbes from the operating theatre environment and antibiotics (20, 21). When born by caesarean section, infants are thought to miss the foundational seeding event, causing gastrointestinal dysbiosis, leading to chronic disease development (20, 21).

The impacts of maternal diet and mode of birth on the infant gut microbiome are relatively new areas of research with short- and long-term effects being largely unknown. However, the potential

intergenerational disease risk proposed by maternal overnutrition and EGWG, coupled with an associated increased risk of caesarean birth and EGWG is of concern.

1.5 Addressing Excessive Gestational Weight Gain

Pregnancy is often described as an opportune time to address and promote positive health related behaviours such as smoking cessation and the promotion of a healthy diet (27-29). Women are suggested to be emotionally motivated to make positive health behaviour changes during this time for the benefit of their infants (30). Antenatal care in Australia and other high income countries, consisting of between 7-12 pregnancy care visits for low-risk women, presents an opportunity for health promoting interventions to be trialled (31). The regular schedule of visits provides a window of opportunity for positive health promotion (physical and psychologically) and health behaviour modification (28). Health promotion interventions aimed at addressing EGWG have largely employed diet and/ or physical activity interventions and regular maternal weight-monitoring (28, 29).

1.5.1 Diet and/or Physical Activity Interventions

Weight gain in the general population is viewed as a physiological mismatch between energy needs (energy in versus energy out) (32). A poor diet and low physical activity levels are linked to the development of overweight and obesity with some evidence suggesting that diet and physical activity behaviours worsen in pregnancy, perpetuating the problem (32). The physiological (energy in / energy out) approach has been widely adopted as a treatment focus with diet and physical activity interventions being commonly trialled to reduce EGWG within controlled trial studies (32, 33).

A recent systematic review and meta-analysis of interventions inclusive of a nutrition component for the management of GWG and post-partum weight retention, was conducted by Vince et al. (2019). In an analysis of 23 randomised controlled trials (RCTs) (n= 5230), an overall reduction of 1.25 kg in total GWG was observed (Weighted Mean Difference (WMD); -1.25 kg, 95% CI -2.10, -0.40), compared to control groups (32). This review did not report on the effects of interventions on pregnancy or birth outcomes (32). Walker et al. (2018), conducted a similar systematic review of RCTs, identifying 60 diet and/or physical activity trials aimed at reducing EGWG (34). An analysis of 16 diet only intervention trials (n=3681), observed an overall average weight reduction of 3.37kgs (WMD; -3.37kgs, 95% CI -4.96, -1.58) across studies (34). The

analysis of 27 physical activity only intervention studies (n= 5725) revealed a total average weight reduction of 1.02kgs (WMD; 1.02kgs, 95% CI -1.56, - 0.49), with an analysis of 33 combined diet and physical activity intervention studies (n= 9201), reporting an overall average weight reduction of 0.84kgs (WMD; -0.84kgs, 95% CI -1.29, -0.39) (34). Again, this review did not report on the effect of the intervention on pregnancy or birth outcomes or other measures of maternal physical and psychological health (34).

The most recent Cochrane review by Muktabhant et al. (2015), identified 65 RCTs of diet and/or physical activity interventions. In an analysis of 24 included trials (n= 7096) EGWG was reduced on average by 20% (Average Risk Ratio (RR) 0.80, 95% CI: 0.73, 0.87), with no differences observed for selected adverse pregnancy and infant outcomes, including pre-eclampsia, infant macrosomia (birth weight >90th centile), or caesarean birth (35). Rogozińska et al. (2017) also conducted a systematic review of diet and physical activity-based interventions on maternal and infant outcomes including GWG (36). In an analysis of 33 studies (n=9320), diet and physical activity interventions reduced GWG by an average of 0.70kgs (WMD; -0.70kgs 95% CI -9.2, -0.48) (36). A subgroup analysis of 24 studies, found that caesarean section was reduced by 9% (OR 0.91, 95% CI 0.83, 0.99), with no statistically significant differences observed for PIH, GDM, preterm birth, small or large for gestational age infants, between groups (36).

An umbrella review (review of reviews) investigating the effects of diet and physical activity interventions for GWG and post-partum weight retention, identified 15 systematic reviews on the topic (33). Of these, 4 investigated the effects of physical activity interventions during pregnancy, reporting reductions in GWG ranging between -2.22 kgs and -0.61kgs (WMD) across studies (33). Eight reviews investigated the effects of combined diet and physical activity interventions, reporting reductions of between -1.40kgs and -0.63kgs (WMD) (33). Nine of the included reviews reported on maternal and infant outcomes. One physical activity only review, observed reductions in both GDM and large for gestational age infants, with one other review reporting reductions in PIH, caesarean section and macrosomia (33). Two combined diet /physical activity reviews observed reductions in GDM, four reported reductions with PIH, two reported reductions in caesarean section, and two reported reductions in macrosomia. The authors cautioned interpretation of these findings, explaining that maternal and infant outcomes were generally reported as part of subgroup analyses, derived from low quality levels of evidence (33).

1.5.2 Weight-Monitoring

In pregnancy, weight-monitoring is a complex topic (1); further review and discussion of weight-monitoring in pregnancy care is provided in **Chapter 3**. Weight-monitoring in the field of weight management has been found to be successful in aiding non-pregnant adults to achieve weight loss, weight maintenance and prevent weight gain (37-40). Regular weight-monitoring is based on self-regulation, social cognitive theory (SCT), whereby behaviour is influenced by interplay and reciprocity between the person, environment and behaviour (41). Engaging in regular weight-monitoring is proposed to create awareness of an individual's weight in relation to their diet and physical activity patterns (38, 40). Self-awareness serves the function of providing information for goal setting and continual evaluation towards the goal (i.e. target weight) (41). This knowledge can be used to incorporate changes in diet and physical activity behaviours (38, 40, 41). Less is known about the efficacy of weight-monitoring as a self-regulation weight management strategy to reduce EGWG and women's weight-related self-efficacy during pregnancy (1). Therefore, the efficacy of routine antenatal weight-monitoring as a weight management strategy remains inconclusive with research addressing this evidence gap provided in **Chapter 2**.

1.5.3 Limitations of Interventions

Diet and /or physical activity interventions have evidenced moderate effectiveness at best for reducing EGWG (34). These interventions seem to have worked well for some women under research conditions; however, there is no conclusive evidence to support any one intervention for translation into real-world clinical practice. In addition, barriers have been identified with the upscaling of these interventions into clinical practice (1, 28, 29, 42, 43). Professional and organisational / institutional barriers such as lack of health professional knowledge and training, institutional time constraints, lack of specialist staff, funding, and referral pathways present challenges to their translation into real world maternity care (1, 28, 42, 43). In contrast to diet and/or physical activity interventions, antenatal weight-monitoring is reported to be a much less resource intensive intervention (44-46), however its effectiveness as a weight management strategy in pregnancy is inconclusive (47).

A systematic review and meta-synthesis conducted by Vanstone et al. (2017) (48), evaluated the women's experience of weight gain in pregnancy, identifying considerable barriers to achieving GWG targets (48). A synthesis of 42 qualitative studies found that women's personal beliefs, knowledge, emotions, lifestyle, social and organisational factors were barriers to achieving

healthy weight gain. Health professionals were additionally found to influence women's ability to achieve healthy weight gain with women describing weight stigma, humiliation and fear of being judged by their health professionals as barriers. Facilitators to achieving healthy weight gain were high income and high levels of social support (48). Limitations of diet, physical activity and weight-monitoring interventions and women's qualitative experience of achieving healthy GWG, suggest that there are broader factors influencing women's ability to adhere to GWG targets.

1.6 A Social-Ecological Approach to Addressing Gestational Weight Gain

There are no interventions with demonstrated effectiveness in reducing EGWG that are generalisable to large and diverse populations of pregnant women, or able to inform clinical practice guidelines (29). One possible explanation is the need for a greater understanding of women's personal social-ecology and the impact and influence of social-ecological factors on weight gain in pregnancy (35, 49-54). Social-ecological factors are described as being demographic (age, education, income), physical (diet, exercise), psychological (anxiety, depression) or psychosocial (attitudes, beliefs, social support, self-efficacy, body image) (1, 27, 49, 50, 52, 55) in nature. In health behaviour theory, social-ecological factors are considered important predisposing, enabling and reinforcing constructs, that can both directly or indirectly influence capacity for health behaviour change (54, 56). Predisposing factors are considered antecedents to, or motivators for, engagement in particular behaviours (57). Reinforcing factors generally are those that either help or hinder motivation and intention for behaviour change, with enabling factors the direct precursors that help or hinder goal attainment (53, 57).

To date the mechanisms by which social-ecological factors influence weight management outside of, and during pregnancy, are poorly understood (54, 55). Gaining understanding of a population of interest within their own social cultural context is considered an essential element of health behaviour theory, necessary for the development of effective behaviour change strategies (56). Moreover, there has been limited consideration and understanding of the impact of the transition to pregnancy both physically and psychologically. Common pregnancy symptoms such as nausea, vomiting, lethargy and anxiety, can make it difficult for some women to modify (i.e. afford and sustain) their diet and physical activity behaviours (1, 27, 48). A systematic review of health behaviour maintenance theories by Kwasnicka et al. (2016) discussed difficulties arising in the self-regulation of behaviour and the influence of an individual's personal resources such as their

physiological and psychosocial circumstances. When these personal resources are depleted such as through fatigue, stress, and sickness, a person's capacity for behavioural regulation is reduced (58). This is of concern as women are more at risk of experiencing depression and anxiety due to psycho-neurohormonal changes that occur throughout pregnancy (59).

There is an increasing body of evidence exploring social-ecological factors as antecedents to, and moderators (barriers and enablers) of, GWG (49, 51, 52, 56). A systematic review and narrative synthesis by Kapadia et al. (2015) (52) investigating psychological and psychosocial factors as antecedents to EGWG identified levels of cognitive dietary restraint, perceived barriers to healthy eating, negative attitudes towards weight gain, being concerned about weight, high targeted weight gain, and inaccurate body perception, as potential risk factors (52). A similar systematic review and narrative synthesis by Hartley et al. (2015) (49), evaluating the relationship between psychosocial factors and GWG identified depression, body image dissatisfaction, and social support as potential risk factors for EGWG. Both reviews identified significant limitations within and between studies. In particular significant heterogeneity of study designs and psychosocial measurement tools were noted (49, 52). Methodological problems such as this have hindered research progress in this area preventing aggregation of data and estimates of effect using meta-analysis techniques (49, 52). Further research in this area is warranted to identify selected psychosocial factors that are predictive of EGWG and measurement tools for use within large and diverse populations of pregnant women (49, 52).

1.7 Thesis Aims and Structure

The primary aims guiding this thesis are to contribute to the evidence base and improve maternal and infant health by: 1) Investigating the effectiveness of antenatal weight-monitoring as a health promotion strategy for optimising pregnancy weight gain; and 2) To explore the psychosocial factors associated with weight gain in pregnancy. To address these overarching aims, a body of research was undertaken and reported through a series of six, independent but complementary publications. The six research aims guiding the project and linked publications are as follows.

Aim 1: To perform a systematic review and meta-analysis of the literature to ascertain the efficacy of routine antenatal weighing as a stand- alone intervention to reduce pregnancy weight gain, in particular prevent excessive gestational weight gain **(Chapter 2)**.

Aim 2: To conduct a narrative review and synthesise of evidence in response to the Australian Department of Health, *Pregnancy Care Guidelines* recommendation for the re-introduction of routine antenatal weight-monitoring **(Chapter 3)**.

Aim 3: To perform a revalidation of the Weight-Related Behaviours Questionnaire (WRB-Q), originally designed and tested in a pregnancy cohort in the United States of America (USA), within an Australian pregnancy cohort. **(Chapter 4)**.

Aim 4: To identify and describe the demographic and psychosocial factors predictive of excessive gestational weight gain, within an Australian pregnancy cohort **(Chapter 5**).

Aim 5: To develop a short-form, psychosocial assessment tool for the detection of women at risk of excessive gestational weight gain **(Chapter 6)**.

Aim 6: To perform a qualitative analysis of the experience and perspectives of pregnant women who participated in a pilot weight management randomised controlled trial (**Chapter 7)**.

This thesis concludes with a final discussion (**chapter 8**) providing a summary of findings from each individual study chapter **(chapter 2 – 7)** and a discussion of the overall findings taken together. Strengths and limitations of the program of work are recognised with recommendations for clinical practice and research put forward.

CHAPTER 2

WEIGHING AS A STAND -ALONE INTERVENTION DOES NOT REDUCE EXCESSIVE GESTATIONAL WEIGHT GAIN COMPARED TO ROUTINE ANTENATAL CARE: A SYSTEMATIC REVIEW AND META-ANALYSIS

2.1 Chapter Overview

Weighing pregnant women during antenatal care may be a feasible intervention to reduce EGWG however, the risks and benefits of routinely weighing pregnant women are unclear. This chapter presents the first publication undertaken as part of this PhD thesis and addresses Thesis Aim 1; To systematically review the literature and ascertain the effectiveness of routine antenatal weighing as a stand-alone intervention to reduce pregnancy weight gain, in particular, prevent EGWG. A structured systematic review research methodology with fixed effects meta-analysis techniques were employed. The systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). This chapter contains the final version of the article which is published in the open access journal BMC pregnancy and childbirth **(Appendix A1).**

Citation

Fealy, S., Taylor, R.M., Foureur, M., Attia, J., Ebert, L., Bisquera, A., & Hure, A. J. (2017). Weighing as a stand-alone intervention does not reduce excessive gestational weight gain compared to routine antenatal care: a systematic review and meta-analysis of randomised controlled trials. *BMC pregnancy and childbirth, 17*(1), 36. doi.org/10.1186/s12884-016-1207-2

2.2. Abstract

Background

Excessive gestational weight gain is associated with short and long-term adverse maternal and infant health outcomes, independent of pre pregnancy body mass index. Weighing pregnant women as a stand-alone intervention during antenatal visits is suggested to reduce pregnancy weight gain. In the absence of effective interventions to reduce excessive gestational gain within the real-world setting, this study aims to test if routine weighing as a stand-alone intervention can reduce total pregnancy weight gain and, in particular, excessive gestational weight gain.

Methods

A systematic review and meta–analysis of randomised controlled trials (RCTs) was conducted between November 2014 and January 2016 and reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Seven databases were searched. A priori eligibility criteria were applied to published literature by at least two independent reviewers. Studies considered methodologically rigorous, as per the Academy of Nutrition and Dietetics Quality Criteria Checklist for Primary Research, were included. Meta-analysis was conducted using fixed-effects models.

Results

A total of 5223 (non-duplicated) records were screened, resulting in two RCTs that were pooled for meta-analysis (n=1068 randomised participants; n=538 intervention, n=534 control). No difference in total weight gain per week was observed between intervention and control groups (weighted mean difference (WMD) -0.00 kg/week, 95% confidence interval (CI) -0.03 to 0.02). There was also no reduction in excessive gestational weight gain between intervention and control, according to pre-pregnancy body mass index (BMI). However, total weight gain was lower in underweight women (n=23, BMI<18.5kg/m^2) in the intervention compared to control group (-0.12 kg/week, 95% CI -0.23 to -0.01). No significant differences were observed for other pregnancy, birth and infant outcomes.

Conclusion

Weighing as a stand-alone intervention is not worse nor better at reducing excessive gestational weight gain than routine antenatal care.

2.3. Introduction

Obesity has dramatic effects on reproductive health with complications during pregnancy and at birth all the more prevalent in those carrying excess weight (60). Globally obesity is more prevalent than undernutrition (61). The World Health Organization (WHO) estimates that over 1.9 billion adults (≥ 18 years) are overweight and 600 million obese (62). In Australia, 63% of adult women (≥ 18 years) are reported to have a body mass index (BMI) in the overweight (25.0-29.9kg/m^2) or obese (≥30.0kg/m^2) categories (63). For women who gave birth in Australia, the most recent Mothers and Babies report (2013) shows that one-fifth (19%) of pregnant woman were classified as obese at the beginning of pregnancy with one quarter (24%) overweight (64).

The risks of entering pregnancy obese are well documented (60, 65). Excessive gestational weight gain (EGWG) as defined by the American Academy of Sciences Institute of Medicine (IOM) is also an independent predictor of adverse pregnancy and birth outcomes (65, 66).The IOM weight gain guidelines devised in 1990 and revised in 2009 are the most widely cited guidelines for gestational weight gain (GWG) (3, 6). In the absence of Australian-based GWG guidelines, the IOM guidelines have been largely adopted as the standard reference (67, 68). These guidelines recommend that women who are underweight at the beginning of pregnancy gain more weight than women who are overweight or obese (6).

Weight gain in excess of the IOM guidelines has been associated with both short and long term health risks, including pre-eclampsia, gestational diabetes, caesarean section, large for gestational age infants, postpartum weight retention and childhood obesity (8, 69, 70). Evidence suggests that it is more common for women to gain weight above the IOM guidelines than within or below. In a large retrospective cohort study in the United States (n=20,456), Stotland et al. (2006) observed that more women gained above the IOM guidelines (43%) compared to those that gained within (37%) or below (20%) (70). An Australian prospective cohort study of pregnancy weight gain (n= 664) similarly found 38% of women gained in excess of the IOM weight gain ranges (71). Fifty-six percent of women who were overweight and obese (BMI ≥25kg/m^2) had EGWG compared to 30% of women with a BMI <25kg/m^2 (71). Furthermore, in the majority of studies included in a recent systematic review, 47-72% of obese women had EGWG according to the IOM ranges (72).

Addressing EGWG has become a public health priority. Intervention studies have primarily focused on diet and physical activity either alone or in combination (35). The most recent

Cochrane review identified 65 randomised controlled trials (RCTs) of diet and/or exercise interventions. In an analysis of 24 included trials (n=7096) diet, exercise or both in combination reduced EGWG on average by 20% (average risk ratio (RR) 0.80, 95% confidence intervals (CI) 0.73 to 0.87). However no differences were observed for the adverse outcomes of pre-eclampsia, infant macrosomia (birth weight >90th centile) or caesarean birth (35).

In the real world setting there are substantial barriers to upscaling diet and exercise interventions at the population level. These include limited access to specialist staff, time constraints, financial implications and motivation to engage in such interventions as part of clinical practice (42).

One gestational weight gain intervention that is feasible at a population level (i.e. low cost and easy to administer) is weighing during routine antenatal care. The schedule of antenatal care appointments consisting of 7 – 12 regular visits for low-risk women with maternal health care providers, presents an opportunity for health promotion interventions to be trialled. The visits additionally provide a window of opportunity for potential behaviour change and lifestyle modification (73, 74). A recent pilot study evaluating the feasibility of regular weighing in the context of routine antenatal care reported that weighing took on average 1-2 minutes of a midwife's time, was simple to do, and did not significantly add to midwives existing workloads (46). A qualitative analysis of pregnant women's experience of routine weighing reported that weighing during antenatal appointments was an acceptable intervention that when introduced did not cause distress or anxiety (45).

The stand-alone practice of weighing in the field of weight management has been successful in aiding non-pregnant adults achieve weight loss, weight maintenance and prevent weight gain as a self-monitoring/ self-regulation strategy (37, 39, 40). However, this has not been demonstrated in pregnancy. Weighing was originally introduced during the 1940's as a vital sign of pregnancy, considered useful for the detection of low-birth-weight infants and pre-eclampsia (44). Weighing declined in practice during the 1990's and ceased to be recommended as a sign for adverse pregnancy outcomes by the British National Institute of Health and Care Excellence (NICE) in 2003, due to a deficit in evidence that it was an effective screening tool (4, 44, 75, 76).

The practice of weighing is limited to the first antenatal visit in Australia and the United Kingdom for the purposes of calculating an early pregnancy BMI (68, 77). The risks and prevalence of women entering pregnancy obese and exceeding the IOM gestational weight gain guidelines have

caused health care providers necessary concern and led to the development antenatal care pathways, recommending a return to weighing during all antenatal care visits (65, 78).

Therefore, this systematic review aimed to summarise the body of high-quality evidence and determine any effect of routine antenatal weighing as a stand-alone intervention to reduce pregnancy weight gain and, in particular, prevent EGWG.

2.4. Methods

This review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (79) (Appendix. A2).

2.4.1. Search Strategy

An a priori review protocol and eligibility criteria were devised, with consideration given to the research question, study design, population, intervention and outcomes (Appendix. A3).

An electronic search of seven databases was conducted, including Medline, Embase, Maternal and Infant Care (via Ovid; http://www.ovid.com/), Cumulative Index to Nursing and Allied Health Literature (CINAHL) (via EBSCO http://www.ebsco.com/cinahl), Scopus (via http://www.scopus.com), Web of science (http://apps.webofknowledge.com) and the Cochrane library (via http://www.cochranelibrary.com).

The initial search was conducted in November 2014 with the assistance of a research librarian (DB) using the following keywords and Boolean operators: “pregnant” OR “pregnancy” AND “weight gain” OR “weighing” AND “randomised controlled trial” OR “clinical trial” OR “random*” (Appendix. A4). All searches were limited to English language and to human studies. No date limits were applied. The Cochrane Library was searched separately to identify any previously conducted systematic reviews in the area (Appendix. A4). The search was updated in January 2016 to ensure recent evidence was captured (Appendix. A5). The database search results were exported into reference management software.

2.4.2. Study Selection

In the first round, publication titles and abstracts were screened independently by at least two reviewers (SMF, RMT, AJH) according to inclusion and exclusion criteria outlined in Table 2.1

Articles not meeting the eligibility criteria were screened out in the order of (i) study design, (ii) population, (iii) intervention, and (iv) outcome. Articles that met the eligibility criteria were retrieved as full texts and further reviewed by SMF and RMT. Any disagreements in the selection of studies were discussed with consensus achieved. The reference lists of retrieved studies and relevant Cochrane systematic reviews were hand searched for any relevant article not detected by the primary electronic search strategy.

Table 2.1 Inclusion/ Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Randomised control trials with the intervention of any weight measurement, self-recorded or recorded by any health professional	Studies published in languages other than English
Studies that included pregnant women with a singleton pregnancy, of any age, weight, body mass index, without date limits	Studies that are not randomized control trials
Studies that used more than one episode of weight measurement during pregnancy	Studies in animals, Multiple pregnancies
Neutral or good methodological quality studies	Poor methodological quality studies

2.4.3. Quality Assessment

Articles considered eligible for inclusion were assessed for methodological quality using the Academy of Nutrition and Dietetics Quality Criteria Checklist for Primary Research (80). Cochrane suggests, it is preferable to use simple approaches for assessing validity that can be fully reported (i.e. how each trial was rated on each criterion) (81). Similar to the Cochrane Collaboration's tool for assessing risk of bias in each included study, the Academy of Nutrition and Dietetics Quality Criteria Checklist for Primary Research tool requires judgement about risk of bias to be made within each domain and support for the judgement with sufficient detail for potential sources of bias (81). Two independent reviewers (SMF, RMT) undertook the assessments with a third reviewer (AJH) mentoring the reviewers through the process.

The quality checklist for primary research includes ten 'scientific validity' questions; four of which must be satisfactory to gain a positive rating (Q2 - bias, Q3 –comparable groups, Q6 - intervention, Q7 - outcomes) (80). Answers were supplied as either "YES meeting the criteria", "NO not meeting the criteria", or "Unclear" if the criteria were not clearly described. Articles

were rated as positive (+) if the validity questions 2, 3, 6, 7, and at least one additional question were answered as “YES”; negative (-) if “NO” was answered for 6 or more of the validity questions; or neutral (□) if answers to questions 2, 3, 6, or 7 did not indicate that the study was exceptionally strong (80). Quality assessments of included studies are presented in the results.

2.4.4. Data Extraction

Relevant data were extracted by two reviewers (SMF, AJH) and entered into a Microsoft Excel spreadsheet. Data included: authors, year of publication, sample size, population characteristics, intervention and duration of the study, measures of compliance and outcomes. Weight gain outcomes included: total gestational weight gain (kg), gestational weight gain by pre-pregnancy BMI (kg/wk), and EGWG according to IOM guidelines. Pregnancy, infant and birth outcomes included: infant birth weight, macrosomia (>90th centile), intrauterine growth restriction (<10th centile), instrumental birth, caesarean birth, combined pregnancy induced hypertension (PIH) and pre-eclampsia (PE), gestational diabetes mellitus (GDM), infant hypoglycaemia, and Apgar <7 at 5 minutes.

2.4.5. Statistical Analysis

Meta-analysis was conducted using the mean and standard deviation for continuous outcomes and counts for categorical outcomes. A fixed-effects model using inverse variance weights was conducted. Fixed-effect models weight studies according to the amount of information they contribute, whereas random-effects models incorporate an estimate of between-study variation (heterogeneity) in the weighting. The fixed-effect assumption is that the true treatment effect is the same in each study, despite any differences in study protocols (82). We believe a fixed effect model is appropriate as larger studies should be given more weight than smaller ones, and as there are few studies used in our meta-analysis, using a random effects model would provide poor estimates of the distribution of the intervention effects.

Forest plots with unstandardised effect size are reported for continuous variables using weighted mean difference (WMD) and 95% confidence intervals. Categorical outcomes are reported as odds ratios (OR). BMI outcomes were combined across studies to form a single outcome. Test of significance were set at the $p<0.05$ level with all statistical analyses programmed using STATA 14.0 Statistical Software.

2.5. Results

2.5.1. Search Results

A flowchart detailing the screening and selection of studies is shown in Figure 2.1 The broad search identified 6465 articles (n=5223 after removal of duplicates). Initial screening of the title and abstract excluded 4067 articles. Two full text papers were then assessed, and both were eligible for quality checking and meta-analysis. Hand searching did not identify any further articles for assessment.

2.5.2. Study Characteristics

The characteristics of studies included in this review are outlined in Table 2.2. Briefly, both studies were conducted in Australia. The study populations were women of any parity with singleton pregnancies enrolled during early pregnancy. Two types of weighing interventions were trialled. Jefferies et al. (2009) used a self-weighing regime where women were instructed to record and document their own weight at 16, 20, 24, 28, 30, 32 and 36 week's gestation. The control group were weighed at recruitment (≤14 week's gestation) and at 36 week's gestation. Both groups received standard antenatal care (83). The second study by Brownfoot et al. (2016) trialled the intervention of clinician weighing of pregnant women during scheduled antenatal care visits. The control group were weighed at the time of recruitment into the study (<21 weeks gestation) and again at 36 weeks gestation only (84). Both groups received standard antenatal care following the participating hospitals guidelines. Both studies used an intention-to-treat analysis but had low loss to follow-up (< 9%) (84).

Figure 2.1 Study Selection Flow Chart

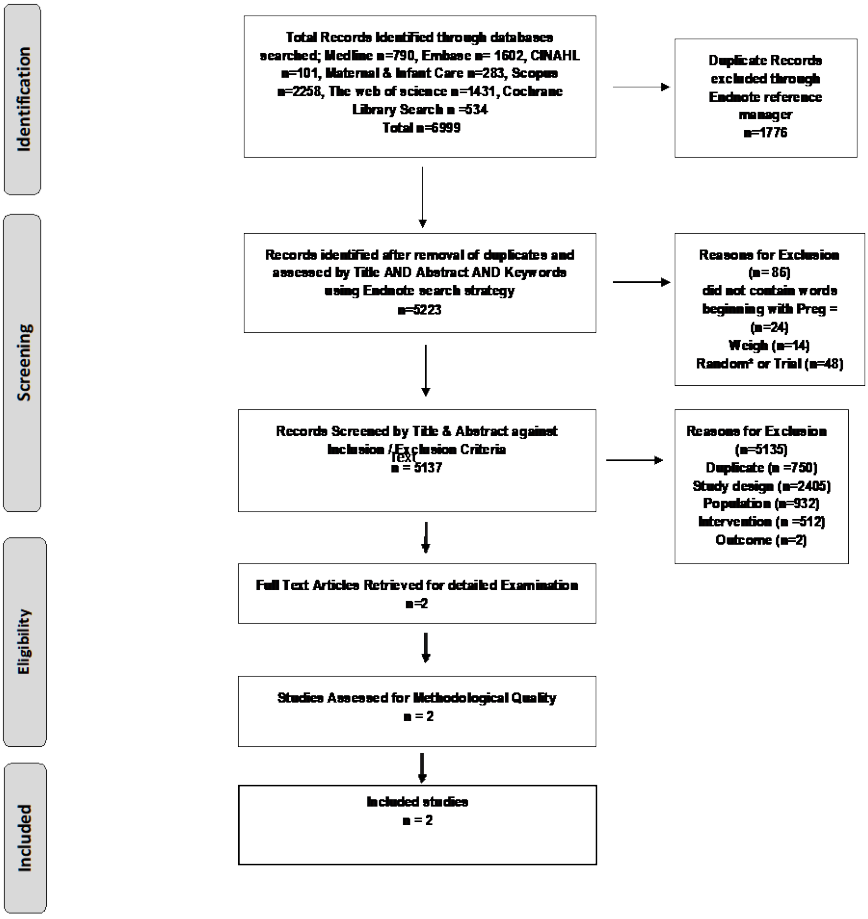


Table 2.2 Characteristics of Included Studies

Author(s), Year Study, Title, Design, & Country	Aim, quality rating	Population characteristics	Intervention, Duration of study	Compliance measure(s)	Outcome(s)	Conclusions	Limitations
Jefferies,K., Shub, A., Walker, SP., Hiscock, R & Permezel, M. 2009, Reducing excessive weight gain in pregnancy: a randomised controlled trial. RCT, Melbourne, Australia.	To assess the effect of regular weight measurements and advice about the recommended (IOM 1990) weight ranges on gestational weight gain (GWG). Neutral (−)	Pregnant women recruited before ≤14 week's gestation. Age >18 years. <45 years., singleton pregnancy. English speaking, no pre-existing Type1 or 2 diabetes Intervention (I_1) *n* = 148 (−23), Control (C) *n* = 138 (−27)	(I_1) Weight measurements + advice compared to standard antenatal care (C). BMI calculated at first antenatal visit and advice on optimal weight gain given as per IOM 1990 guidelines. I_1 self-weighing recorded on participants own antenatal card at first visit, 16, 20, 24, 28, 30, 32, 34 and 36 weeks. (C) Weighed at first visit and at 36 weeks only.	(I_1) Weight self-recorded on personalised measurement card (tabular or graphical), using scales at hospital or participant's home until 34 weeks (I_1) + (C) weighed at recruitment & 36 weeks on hospital scales.	Mean difference in weight gain (Kgs/week) and between BMI subgroups. Total weight gain and proportion gaining in excess of the IOM 1990 weight gain guidelines. Maternal & neonatal pregnancy and birth complications	No difference in total weight gain Kgs/week) between (I1) and (C). A statistically significant reduction in GWG (Kgs/Week.) between (I1) and (C) in overweight BMI subgroup only (mean difference of 0.12 kg/week (95% CI, 0.03 to 0.22), p = 0.01.	Weight measurements were largely self-reported based on home and hospital scales. There was no measure of participation compliance with the (I_1). A small sample size was used with inadequate power to detect differences between groups for weight gain above IOM 1990 guidelines, pregnancy and neonatal complications.
Brownfoot, FC., Davey, M-A. & Kornman, L. 2016 Routine weighing to reduce excessive antenatal weight gain: a randomised controlled trial. RCT Melbourne, Australia.	To assess the effect of clinician weighing at each antenatal visit with advice on appropriate GWG using the IOM 2009 weight gain in pregnancy guidelines. Positive (+)	Pregnant women recruited <21 weeks gestation. Age >18 years <45ys, singleton pregnancy. English speaking, no co morbidities or substance abuse identified. Intervention (I_1) *n* = 386 (−17), Control (C) *n* = 396 (−24)	(I_1) Weight recorded by a clinician at each antenatal appointment and documented in hospital antenatal record. The treating clinician encouraged to discuss weight gain (no scripted responses used). (C) Routine antenatal care including advice of appropriate weight gain within the IOM 2009 ranges. Both groups weighed at recruitment with BMI calculated. The (C) weighed again at ≥36 weeks gestation.	(I_1) Weight documented in hospital antenatal records at appointments by attending clinicians. (C) Weighed at recruitment and ≥ 36 weeks only and documented on hospital antenatal record. Data collected from the antenatal hospital record, mean frequency of weight measurements reported for both groups.	Mean difference in weight gain per week (Kgs/week) and between BMI subgroups. Proportion gaining within, less than and more than the IOM 2009 weigh gain ranges. Maternal & neonatal pregnancy and birth complications	No statistically significant differences reported in mean weight gain per week (I_1) 0.54 kg (±0.28) & (C) 0.53 kg (±0.24) *p* = 0.63 (*p* = 0.05). No difference in proportion of women gaining weight within, less than or more than IOM 2009 guidelines. No differences between groups for all neonatal and maternal complications.	Study not powered to detect a between group differences for all maternal and neonatal pregnancy and birth complications reported.

2.5.3. Study Quality

A summary of the quality assessment is presented below in Table 2.3. Both studies answered "Yes" to all relevance questions. Of the four validity questions, the study by Jefferies et al. (2009) received a "NO" for question 6, with reviewers questioning participant compliance with the intervention and validity of instruments within the intervention group. The corresponding author of the paper was contacted seeking additional information and clarification; however, no further information could be provided. This paper received a neutral quality rating with a score of 9 out of a possible 10.

The second study conducted by Brownfoot et al. (2016) reported sufficient information within their publication receiving a "YES" for all scientific validity questions. The paper gained a total score of 10 and received a positive quality rating.

Table 2.3 Quality Assessment Summary

First author, year of publication (reference)	Jefferies et al. 2009	Brownfoot et al. 2016
VALIDITY QUESTIONS		
1. Was the research question clearly stated?	Y	Y
2. Was the selection of study subjects/patients free from bias?	Y	Y
3. Were study groups comparable?	Y	Y
4. Was method of handling withdrawals described?	Y	Y
5. Was blinding used to prevent introduction of bias?	Y	Y
6. Were intervention /exposure factor or procedure and any comparison(s) described in detail?	N	Y
7. Were outcomes clearly defined and the measurements valid and reliable?	Y	Y
8. Was the statistical analysis appropriate for the study design and type of outcome indicators?	Y	Y
9. Were conclusions supported by results with biases and limitations taken into consideration?	Y	Y
10. Is bias due to study's funding or sponsorship unlikely?	Y	Y
OVERALL QUALITY	N	P
[1] American Dietetic Association Quality Criteria Checklist for Primary Research [2] Y, yes; N, no [3] P, positive rating; N°, neural rating		

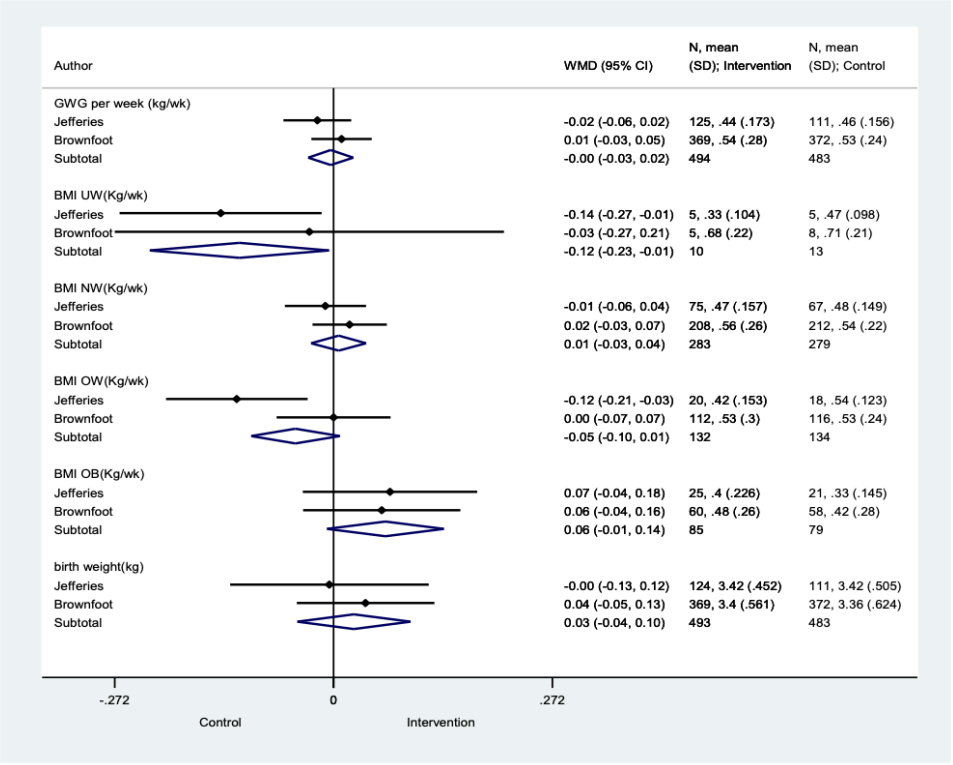
2.5.4. Analysis results

Meta-analysis of continuous outcomes is displayed in Figure 2.2 There was no difference in total GWG between the intervention (n =494) and control groups (n= 483). In the sub-group analysis of weight gain by BMI category a statistically significant difference was found for underweight

women. The amount of weight gained in underweight women was 0.12 kg/week (n=23, p=0.040) less in the intervention group compared to control. There were no differences in the total proportion of women exceeding the IOM weight gain ranges between intervention (n= 290) and control (n= 230): OR 1.10 (95%CI, 0.81 to 1.50). Data on EGWG by BMI category are presented in Figure 2.3 and show no differences in the intervention and control groups. For all secondary pregnancy and birth outcomes (including birth weight on Figure 2.2) no significant differences were found between intervention and control as per Figure 2.4.

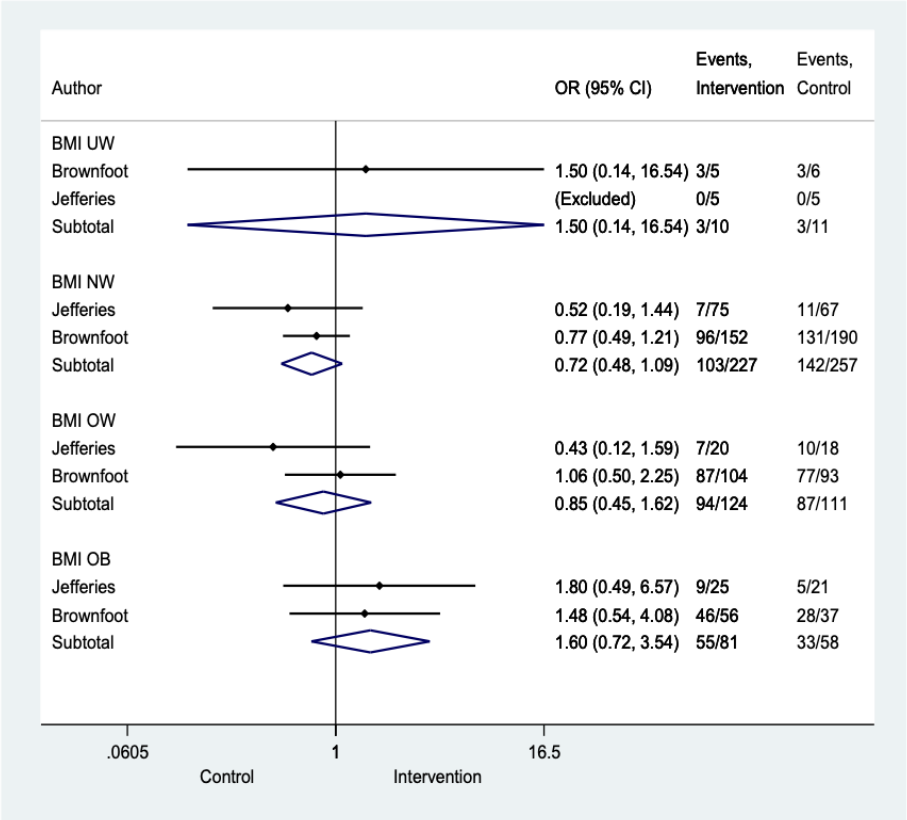
We performed a post-hoc power calculation to determine the minimum detectable difference in total gestational weight gain for the pooled total of 977 participants, distributed approximately evenly between intervention and control groups. The minimum detectable difference was approximately 735g in total gestational weight gain (~20g per week), with 80% power, α=0.05, and SD ± 4.1kg.

Figure 2.2 Results for Continuous Variables and Tests of Significance



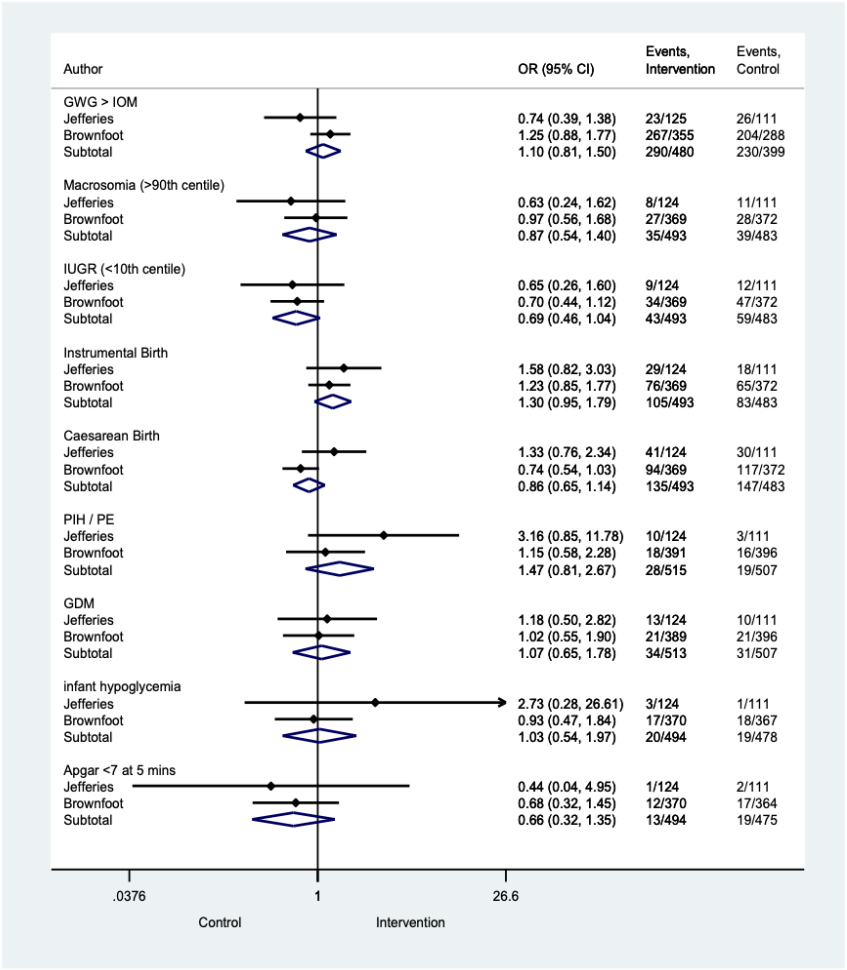
Significance test(s) of Weighted Mean Difference (WMD=0), Gestational Weight Gain (GWG) per week (kg/wk) z= 0.23, p = 0.815; Body Mass Index (BMI) Underweight (UW) (Kg/wk) z= 2.06, p = 0.040; BMI Normal Weight (NW) (Kg/wk) z= 0.36, p = 0.716; BMI Overweight (OW) (Kg/wk) z= 1.68, p = 0.094; BMI Obese (OB) (Kg/wk) z= 1.74, p = 0.081; Birth Weight (kg) z= 0.70, p = 0.481.

Figure 2.3 Proportion of Weight Gain Exceeding the IOM ranges and Tests of Significance



Significance test(s) of Odds Ratio (OR) =1; Body Mass Index (BMI) Underweight (UW) z= 0.33, p = 0.741; BMI Normal Weight (NW) z= 1.55, p = 0.122; BMI Over Weight (OW) z= 0.50, p = 0.617; BMI Obese (OB) z= 1.15, p = 0.250.

Figure 2.4 Pregnancy and Birth Outcomes and Tests of Significance



Significance test(s) of OR=1; GWG > IOM z= 0.63, p = 0.532; Macrosomia (>90th centile) z= 0.58, p = 0.560; Intra Uterine Growth Restriction (IUGR) (<10th centile) z= 1.76, p = 0.079; Instrumental Birth z= 1.62, p = 0.105; Caesarean Birth z= 1.06, p = 0.288; Pregnancy Induced Hypertension (PIH)/ Pre Eclampsia (PE) z= 1.26, p = 0.206; Gestational Diabetes Mellitus (GDM) z= 0.27, p = 0.787; Infant hypoglycemia z= 0.10, p = 0.917; Apgar <7 at 5 mins z= 1.15, p = 0.252.

2.6. Discussion

This systematic review of RCTs aimed to determine the evidence base for weighing as a stand-alone intervention to reduce pregnancy weight gain and prevent EGWG. Two RCTs were retrieved and meta-analysed. Together they suggest that weighing, as a stand-alone intervention during routine antenatal care, is no better at reducing total pregnancy weight gain or preventing weight gain in excess of the IOM weight gain ranges than routine antenatal care.

A statistically significant lower rate of gain (kg/wk) was observed in women in the underweight BMI category between intervention and control. This finding should be interpreted with caution as it was derived from a BMI group that only included 23 women and due to multiple comparisons across BMI sub-groups could be due to random chance alone. However, it is also plausible that underweight women may be more sensitive to weighing and this practice may have an impact on their rate of weight gain. Nohr et al. (2008), in a large Danish birth cohort study (n = 60,892), determined that women who were categorised as underweight at the beginning of pregnancy (BMI <18.5kg/m^2) who had lower rates of GWG (<10kgs) were found to be more at risk of giving birth to small-for-gestational-age infants (OR 1.9, 95%CI 1.7 to 2.1) (85). Based on the existing evidence the IOM in 2009 recommended that underweight women should gain towards the upper limits of the weight gain ranges specifically to prevent small-for-gestational-age infants (6).

It is extremely interesting that only two recent trials contributed data for this review, given the increased prevalence of obesity and EGWG and changes in practice over time. Additionally, weight gain is characteristic of pregnancy progression and a well-recognised determinant of fetal growth. There is convincing evidence that GWG is associated with infant birth weight: lower GWG is associated with low-birth-weight and greater GWG is associated with large for gestational age infants (8). In light of this evidence, it is difficult to reasonably explain why antenatal guidelines restrict the practice of routine antenatal weighing and not consider it as an important predictor of pregnancy outcomes, similar to serial measures of blood pressure.

Restricting routine weighing is in direct contrast to the IOM (2009) weight gain guidelines that specifically advise for pregnant women to be weighed at the initial and all subsequent antenatal visits to detect abnormal patterns of pregnancy weight gain (6). The guidelines recommend that health care providers work in partnership with women to set individual weight gain targets according to their BMI and for weight gains to be graphically documented to enable women to be

aware of their weight gains and educate them on the importance of appropriate pregnancy weight gain (6).

Dimperio et al. (1992) in response to recommendations that routine weighing should be abandoned, argued that weighing was more than just a stand-alone pregnancy intervention and rather presented health care practitioners with the opportunity to counsel women before weight gains became extreme, advocating that weighing is a valuable screening tool rather than a diagnostic tool for adverse pregnancy outcomes (86).

Weighing as a stand-alone intervention may not be effective for reducing pregnancy weight gain and EGWG under controlled conditions however given the prevalence and risks associated with weight gains outside of the IOM guidelines it is negligent of maternity care providers not to address weight gain in pregnancy. Maternity care providers need to be working in partnership with women to achieve the IOM weight gain in pregnancy targets, monitoring their progress and providing feedback on that progress. Therefore, we recommend further research be undertaken into the impacts and acceptability of this intervention within various health care settings and models of pregnancy care, using both experimental and qualitative research methods.

2.6.1. Strengths

We have conducted a methodically rigorous and contemporary search to determine if weighing as a stand-alone intervention can reduce EGWG. All available experimental evidence has been assessed and reported in accordance with the PRISMA guidelines (79) and an appropriate methodological quality checklist (80).

2.6.2. Limitations

Although the included RCTs were deemed good quality, with neutral and positive quality ratings, the following limitations need to be considered. Giving benefit of the doubt, blinding within both studies was rated as adequate, even though neither the participant nor clinicians/researchers (who were also the outcome assessors) were blinded to the intervention. This is because the quality check question is phrased with the qualifier “as appropriate”. Jefferies et al. (2009) reported that participants were blinded to the purpose of the study, however, discussed that researchers conducting the study were not blinded to treatment groups. No participant blinding was used in the study by Brownfoot et al. (2009) because of the nature of the intervention, and this was

acknowledged in their limitations. Reviewers gave consideration to each study's methods and concluded that true blinding would be extremely difficult.

Secondary outcomes within both studies including, proportion of women gaining weight above the IOM recommendations, pregnancy birth and neonatal outcomes were not pre specified within each study's statistical analysis plan. These outcomes were not adequately powered to detect a difference between intervention and control limiting the generalisability of these findings. The decision to exclude studies published in a language other than English was made a priori, for pragmatic reasons. Authors acknowledge that there is potential for this exclusion to have contributed to the low number of included studies.

2.7. Conclusion

This systematic review and meta-analysis conclude that weighing, as a stand-alone intervention is neither worse nor better at reducing excessive gestational weight gain than routine antenatal care alone. In light of the presented evidence, we recommend that where antenatal guidelines advise women to gain weight within the IOM weight gain ranges that they be enacted in their entirety recommending that women be weighed at the first and all subsequent antenatal visits. We additionally recommend that further research studies be conducted to assess the impact and acceptability of weighing in pregnancy.

CHAPTER 3

THE RETURN OF WEIGHING IN PREGNANCY: A DISCUSSION OF EVIDENCE AND PRACTICE

3.1. Chapter Overview

The Australian Department of Health, National Health and Medical Research Council (NHMRC) updated their *Pregnancy Care Guidelines* in 2018. These guidelines recommended a return to the practice of routine antenatal weighing as part of Australian maternity care. This chapter provides further review and context of the practice of weight-monitoring in pregnancy and considers psycho–ecological factors as being potential predictors of GWG. Specifically, this chapter addresses thesis aim 2; To conduct a narrative review and evidence synthesis in response to the Australian Department of Health, *Pregnancy Care Guidelines* recommending the re-introduction of routine antenatal weighing. This chapter contains the final version of the article which is published in the international journal, Women & Birth (**Appendix A6**).

Citation

Fealy, S., Davis, D., Foureur, M., Attia, J., Hazelton, M., & Hure, A. (2020). The return of weighing in pregnancy: A discussion of evidence and practice. *Women & Birth*, 33(2), 119-124. https://doi.org/10.1016/j.wombi.2019.05.014

3.2 Abstract

Background

Inadequate or excessive gestational weight gain is associated with both short and long-term adverse maternal and infant health outcomes. The practice of routine maternal weight-monitoring has been suggested as an effective health promotion intervention, both as a screening tool for adverse maternal and infant outcomes and as a weight management strategy for addressing gestational weight gain.

Discussion

The effectiveness of routine maternal weighing as part of maternity care has been debated for more than 30 years. The National Health and Medical Research Council of Australia have recently revised their pregnancy care clinical practice guidelines recommending maternal weight-monitoring (clinician and/or self-weighing) be reintroduced into clinical practice. This paper presents a timely discussion of the topic that will contribute new insights to the debate.

Conclusion

Weight gain in pregnancy is complex. Evaluation of the translation, implementation, acceptability and uptake of the newly revised guidelines is warranted, given that evidence on the practice remains inconclusive. Future research exploring social-ecological interventions to assist pregnant women achieve optimal gestational weight gains are suggested to expand the evidence base.

3.3 Introduction

Globally there is no consensus regarding the practice of maternal weight-monitoring as a weight management strategy or as a screening tool for the detection of adverse maternal and infant outcomes (34). It is well known that inadequate or excessive gestational weight gain defined as weight gains above or below the American Institute of Medicine weight gain in pregnancy guidelines are associated with both short - and long-term adverse maternal and infant health outcomes (6, 34, 66, 70, 87, 88). These include gestational diabetes, caesarean birth, fetal growth restriction, fetal macrosomia, pre-term birth, nutrient deficiencies, and may contribute to the development of non-communicable diseases into adulthood (6, 87, 89).

In Australia, the National Health and Medical Research Council (NHMRC) have recently revised their pregnancy care clinical practice guidelines, recommending that weighing (clinician and/or self-weighing) be reintroduced as part of antenatal care (31). What is not clear is whether this consensus-based recommendation (i.e. formulated in the absence of quality evidence), is being presented as a weight management strategy, or as a screening tool for adverse pregnancy and infant outcomes (31). The practice of weighing pregnant women has been the subject of a long standing debate within midwifery and obstetrics spanning the last 30 years (44). During this time, evidence has been presented for and against weighing in pregnancy, as a weight management strategy, (44, 46, 47, 65, 83, 84, 90) and as a screening tool for adverse pregnancy outcomes (4, 44, 90, 91) . The most recent recommendations will no doubt reignite debate and require ongoing evaluation of their application within clinical practice. It is thus timely to provide a discussion of evidence on the practice of weighing in pregnancy.

3.3.1 Background

The practice of weighing pregnant women was initially introduced as far back as the 1940s as a composite measure of overall maternal nutrition (44). The practice also became a widely used antenatal screening tool for the detection of pre-eclampsia and low-birth-weight infants in the subsequent decades (44, 90) . The clinical utility of routine maternal weighing as a screening tool was first brought into question during the 1980s when it was revealed that maternal weight-monitoring had little predictive value for the detection of preeclampsia, and ceased to be recommended for this purpose (91).

During the 1990s, the practice of maternal weight-monitoring was subject to further critique following the publication of a seminal, retrospective observational study by Dawes & Grudzinskas conducted in the United Kingdom (UK) (4, 75, 76). The authors presented their findings across two separate publications (4, 76). The first described wide variations in patterns of weight gain in 988 pregnant women with healthy pregnancy outcomes, suggesting that weighing as a screening tool for low-birth-weight infants was not supported (4). Maternal booking weight obtained at first antenatal contact was found to be a more sensitive predictor of low-birth -weight infants, which was a maternal and infant health priority at the time (4).

The usefulness of weighing as a screening tool was further questioned in a second publication from this same study, which revealed that maternal weight-monitoring had little predictive value for adverse pregnancy and birth outcomes (76). A follow up discussion paper by Dawes, Green and Ashurst suggested routine weighing caused unnecessary maternal anxiety, however no evidence was presented to support this claim (75).

This series of publications from the early 1990s essentially initiated the contemporary debate surrounding the practice of weighing pregnant women (44), suggesting that the practice be abandoned (44, 75). A professor of obstetrics and gynaecology (D. Hawkins) published a commentary in response to these suggestions, cautioning that the evidence presented by Dawes and Grudzinkas was not adequate to support the abandonment of weight-monitoring, particularly given the increase in obese women entering pregnancy (92). Dimperio and colleagues also cautioned against the abandonment of maternal weight-monitoring until quality studies could be conducted conclusively showing it was of no value (86). These authors additionally explained that low and high weight gains were a possible predictor of adverse pregnancy outcomes, noting that women who had low weight gain were at risk of pre term birth and intrauterine growth restriction, and those who gained excessively were at risk of birth complications such as caesarean birth (86). Overtime however, and without quality evidence in the form of randomised controlled trials or large prospective observational studies, the practice of weighing declined within the UK and Australia (44).

In the UK, weighing ceased to be recommended as a pregnancy screening tool by the National Institute of Clinical Excellence (NICE) antenatal care guidelines in 2003 (44, 93). In Australia, a decline in weighing was reported by L. Mollart in 1999, who evaluated the impact of weighing cessation in a selected New South Wales antenatal clinic (94). This paper described that ceasing

the long standing practice of routine weighing was well received by women and clinicians, with most supporting the abandonment of the practice (94).

3.4 Routine weighing and gestational weight gain

Weight gain is a well-recognised determinant of fetal growth and pregnancy progression. The physiological components that contribute to total gestational weight gain are compartmentalised into products of conception: fetus, placenta and amniotic fluid; and maternal tissue accretion: uterine tissue, breast tissue, blood and plasma volume expansion, and fat (2). Research conducted by Hytten and colleagues throughout the 1950s and 60s described the mean weight gain for primiparous women with good pregnancy outcomes to be approximately 12.5 kgs, which included roughly 3 kgs of fat accumulation, suggested to support the increased energy demands for lactation (2, 3).

During the early 1990s the American Institute of Medicine, undertook a literature review of maternal weight gain patterns (3). The review included 12 heterogeneous observational studies published between 1934 and 1986, that again revealed wide variations in mean total gestational weight gain with healthy pregnancy outcomes (7kg– 18kgs, 15th and 85th percentile respectively) (3). Given the lack of consensus of what constitutes appropriate gestational weight gain the Institute of Medicine devised the first edition of the nutrition in pregnancy guidelines supporting the continued practice of maternal weight-monitoring as part of routine pregnancy care (3, 76).

The Institute of Medicine guidelines first released in 1990, were primarily focused on addressing maternal undernutrition and the prevention of infant mortality associated with low-birth-weight (3). The original weight gain guidelines are displayed in Table 3.1.

Table 3.1 American Institute of Medicine (1990) weight gain in pregnancy guidelines

BMI Category	Recommended Total Gain (kgs)
Underweight (BMI < 19.8)	12.5 – 18.0
Normal (BMI of 19.8 to 26.0)	11.5 – 16.0
Overweight (BMI > 26.0 to 29.0)	7.0 – 11.5
Obese (BMI >29.0)	>6.8

Adapted from the American Institute of Medicine Committee on Nutritional Status During Pregnancy and Lactation. Nutrition During Pregnancy: Part 1 Weight Gain. National Academy of Sciences Institute of Medicine; 1990.

These guidelines were applied in combination with weight for height or Body Mass Index (BMI) measures. BMI was considered a better measure of overall maternal nutrition than weight alone (3). BMI categories were classified according to weight for height cut-off points from metropolitan lifestyle insurance data widely used within the United States of America (USA) at the time (3).

A systematic review published in the American Journal of Clinical Nutrition (90), expressed concerns at the deficit in research for the continued use of maternal weight-monitoring in obstetric clinical practice 10 years after the release of the Institute of Medicine 1990 guidelines (90). The publication pointed out that no studies (experimental or observational) were available that assessed the predictive value of pregnancy weight gain as a screening tool for maternal or fetal wellbeing (90). In contrast to the UK and Australia, the publication concluded that there was no conclusive evidence to support the discontinuation of maternal weight-monitoring in clinical practice (90).

In the wider public health arena during the 1990s there was a growing concern regarding weight, with the emergence of a global obesity epidemic (6). During the early 2000s the Institute of Medicine felt pressure to review their long-standing guidelines, releasing revised weight gain in pregnancy guidelines in 2009 (5, 6). The new guidelines acknowledged a shift in public health focus from the prevention of maternal undernutrition and low-birth-weight infants, to the prevention of adverse outcomes associated with maternal obesity and excessive gestational weight gain (6). The new weight gain ranges most notably differed from the original version (3), with the adoption of the World Health Organization BMI categories, recommending that women who are underweight (BMI <18.5 kg/m^2) at the beginning of pregnancy gain more weight than women who are overweight (25-29.9 kg/m^2) or obese (≥ 30 kg/m^2) as per Table 3.2 (6).

Table 3.2 American Institute of Medicine (2009) weight gain in pregnancy guidelines

BMI Category	Recommended Total Gain (kgs)
Underweight (BMI <18.5)	12.5 – 18.0
Normal (BMI 18.5 – 24.9)	11.5 – 16.0
Overweight (BMI 25.0 – 29.9)	7.0 – 11.5
Obese (BMI ≥ 30.0)	5-9
Adapted from Rasmussen KM, Yaktine AL. Nutrition During Pregnancy: Re-Examining the Guidelines.Washington D.C.: National Academy of Sciences Institute of Medicine; 2009.	

The guidelines highlighted that weight gain outside the recommended ranges was associated with adverse outcomes compared to women who gained within the weight gain ranges (5, 6). These guidelines have consistently supported the practice of routine maternal weight-monitoring (6).

3.5 Evidence for routine weighing in pregnancy

A recent systematic review published in 2017 conducted by Fealy and colleagues, (47) is the first to evaluate the practice of routine maternal weighing as a stand-alone intervention to reduce pregnancy weight gain and prevent excessive gestational weight gain, compared to routine antenatal care (47). In contrast to diet and exercise interventions, routine maternal weighing is considered a feasible intervention easily incorporated into clinical practice (95). Surprisingly, despite weighing being a long-standing practice the merits of which has been consistently challenged, the review only found two randomised controlled trials, both conducted within Australia, by Brownfoot and colleagues published in 2016 (84) and Jefferies and colleagues published in 2009 (83). The paper authored by Jefferies and colleagues evaluated the effectiveness of maternal self-weighing,(83) with the study conducted by Brownfoot and colleagues evaluating the effectiveness of clinician weighing compared to usual antenatal care (83, 84). The pooling of these studies (n= 977) in a meta-analysis observed no differences in total gestational weight gain (kg/ per week) between intervention and control groups (Weighted Mean Difference, - 0.00 kg 95% Confidence Interval (CI), -0.03 to 0.02) (47). Additionally, no differences were reported in the total proportion of women exceeding the Institute of Medicine weight gain ranges between intervention and control groups (Odds Ratio 1.10, 95% CI, 0.81 to 1.50) (47).

Following the publication of the review by Fealy and colleagues (47), Daley and colleagues (46) published their findings from a small pilot feasibility trial (n= 76) evaluating regular antenatal weighing by community midwives (46). The results were not statistically powered for effectiveness, but add support to the findings of the systematic review, showing no difference in gestational weight gain between intervention and control (95).

The revised Australian pregnancy care guidelines (2018) pooled the results from the Daley publication (46) with the results of the study conducted by Brownfoot (84). From a population of n=711, the analysis again revealed no differences in excessive gestational weight gain (Relative Risk 1.05, 95% CI 0.95 to 1.16) or for mean weekly weight gain (0.01 kg per week, 95%CI –0.03 to 0.05) (31). This evidence reveals that routine maternal weighing as a standalone intervention

is no more effective than routine antenatal care without weighing in supporting adequate gestational weight gain (31).

3.6 Pregnancy weight gain guidelines

The revised Australian National Health and Medical Research Council guidelines now advise health care providers to assess height and weight at the first antenatal appointment for the calculation of a BMI, discuss weight and weight gain in pregnancy, and offer women the opportunity to be weighed and encourage self-monitoring of weight gain at every antenatal visit (31). Health care providers are also advised to discuss weight gain, diet and physical activity (31). In the absence of Australian specific pregnancy weight gain guidelines, the American Institute of Medicine 2009, weight gain in pregnancy ranges have been adopted (31). The revised Australian guidelines however caution maternity care providers, recommending that the ranges are a suggestion only, rather than being goal specific, weight gain targets (31).

The Institute of Medicine nutrition in pregnancy guidelines (6) recommend that women be routinely weighed during antenatal care, not as a stand-alone intervention but as a package of care where health professionals work with women to engage in conversation, provide education and counsel women on the importance of nutrition and appropriate gestational weight gain (6). Weighing essentially becomes part of a health promotion package of care, used within this context as a screening tool to detect abnormal patterns of pregnancy weight gain (6). This is reasonable given that gestational weight gain is associated with infant birth weight; low gestational weight gain is associated with low-birth-weight and, greater gestational weight gain is associated with large for gestational age infants (3, 8, 47, 83).

The revised Australian pregnancy care guidelines are now somewhat more reflective of recommendations from the USA and Canada that support the Institute of Medicine weight gain in pregnancy guidelines as a comprehensive health promoting package of care (6, 96). However, it is unclear if the amendments to weight-monitoring recommendations are moving towards maternal weight-monitoring used as a screening tool for adverse pregnancy outcomes or as a weight management strategy.

3.7 Discussion

The debate for routine weighing in pregnancy has been ongoing for over 30 years. Current evidence suggests that routine maternal weight-monitoring as a stand-alone intervention is ineffective for some women as a weight management strategy for achieving optimal gestational weight gain (46, 47, 83, 84).

Weighing practices within the USA have been consistent overtime, largely due to the widespread adoption of the Institute of Medicine weight gain in pregnancy guidelines (3, 6). This is in contrast to the changing antenatal weighing practices observed within the UK and Australia (6, 31, 68, 77, 93). Regardless of country and independent of routine maternal weight-monitoring practices, women have continued to gain excessive weight during pregnancy (5-8, 70, 97). Excessive gestational weight gain, defined as gains over the Institute of Medicine weight gain in pregnancy guidelines have been associated with increases in maternal and fetal morbidity including higher rates of pre-eclampsia, caesarean birth (66), postpartum weight retention (87), low 5 minute APGAR scores, neonatal hypoglycaemia, seizures (70), and large for gestational age infants (66, 87). Therefore, having information on weight gain in pregnancy is clinically relevant to pregnancy outcome.

Pregnancy is described as an opportune time to intervene with health promoting behaviours (3, 27, 29, 65, 73, 74). Health promotion interventions to reduce excessive gestational weight gain have largely focused on diet and exercise interventions (34, 35). A recent systematic review published in 2018 conducted by Walker and colleagues revealed, in a meta-analysis of 60 trials, that diet and physical activity interventions alone, or in combination, can be effective at reducing gestational weight gain, when compared to usual antenatal care (34). This finding is similar to other published systematic reviews, that also found moderate decreases in gestational weight gain when diet and lifestyle interventions are incorporated as part of antenatal care (35, 36). The review by Walker and colleagues additionally is one of the first systematic reviews to include the available evidence on mobile health (mhealth) interventions, such as smartphone applications (34). Findings from the meta-analysis of mhealth interventions suggest that they are not effective in reducing gestational weight gain, with more studies needed to be conducted in this area (34). These outcomes, while significant and positive in research trial conditions, have substantial barriers in upscaling at the population level. Such barriers include limited access to specialist staff, time constraints placed on clinicians, institutional financial implications, skills and

knowledge and, individual motivation of health providers and consumers to engage in such interventions as part of antenatal care (29, 42).

It has been suggested that the ineffectiveness of interventions at the population level (given the rising trend in excessive gestational weight gain), may be related to a lack of understanding of the broader psychosocial and psychological factors and gap in knowledge of how these impact on weight gain in pregnancy (35, 49-53).

Less is known about a woman's capacity for actual weight-related behaviour change during pregnancy (27, 48). Olander and colleagues (27) discuss that it is largely assumed women are motivated by pregnancy alone to change health related behaviour, and that pregnancy is an opportune time for interventions to be trialled (27). However, weight gain in pregnancy is complex. Diet and exercise modification can be interrupted by physical pregnancy symptoms such as nausea and vomiting, as well as social determinates of health such as socio economic status and social support, making it difficult for women to afford or sustain these types of interventions (27, 48).

A systematic review and qualitative synthesis of the barriers and facilitators to appropriate gestational weight gain found compelling evidence that, the biomedical approach of limiting weight gain using the energy input and output approach, with diet and exercise interventions, is insufficient during pregnancy (48). Women, whilst motivated to achieve healthy weight gain in pregnancy, could not do so due to reported significant barriers. These included personal beliefs, knowledge, emotion, logistics, practice, social and structural factors (48). Facilitators for achieving healthy weight gain were, high income and good social support (48). These findings are similar to a recent umbrella review of the qualitative barriers and enablers to smoking cessation for pregnant smokers (98). This review found that although smoking campaigns have assisted to reduce the overall rates of smoking in pregnancy, women who continued to smoke were generally of low socio economic status, and were aware of the risks of smoking but continued, because they felt it had positive outcomes for their overall lifestyle and mental health (98). Additionally, low socio economic status is a major contributing factor for maternal and fetal undernutrition, underweight, and obesity (89). In low to middle-income countries in Africa and Asia, maternal and neonatal undernutrition account for approximately 3.1 million child deaths annually, pointing to the need for more research in this area (89).

The findings of this discussion indicate that weight gain in pregnancy is a complex phenomenon that has implications that go beyond the debate on routine weighing in pregnancy. Routine maternal weight-monitoring may play a role in assisting women to achieve adequate weight gain, as a package of care, but this needs to be considered within a broader, social-ecological model of woman's health.

3.8 Conclusion

Weight gain in pregnancy is a multifactorial and complex phenomenon. The debate on routine weighing in pregnancy is ongoing. The revision of the Australian pregnancy care guidelines provides scope for differences in clinical practice moving beyond a 'one size fits all' approach, to one that is women focused, opening up conversation and the 'opportunity' for weighing to be integrated into a woman's pregnancy care. It is unclear if the newly revised pregnancy care guidelines have recommended this practice as a screening tool for adverse pregnancy outcomes such as low, or high, infant birth weight, or if it is being employed as a weight management strategy. Ongoing evaluation of these guidelines is needed to assess their clinical translation, acceptability and uptake. Weight gain in pregnancy is determined by more than just diet and exercise. Future research is needed to explore the effect of interventions that embrace a social-ecological view of health.

CHAPTER 4

A REVALIDATION OF THE WEIGHT-RELATED BEHAVIOURS QUESTIONNAIRE WITHIN AN AUSTRALIAN PREGNANCY COHORT

4.1. Chapter Overview

Relationships between broad socio-ecological factors and maternal and infant health outcomes are increasingly being considered within the published literature. In particular, there is a growing body of evidence exploring the associations between psychosocial factors and GWG. One significant limitation hindering research progress in this area is the diversity of psychosocial factors and measurement tools employed throughout studies. There is a need to identify selected psychosocial factors and tools of measurement that may best predict GWG, that allow for pooling of results via meta-analysis techniques. Therefore, the aim of this chapter was to perform a revalidation of the Weight-Related Behaviours Questionnaire (WRB-Q), originally designed and tested in a pregnancy cohort in the United States of America (USA), within an Australian pregnancy cohort. This chapter contains the final version of the article published within the Journal of Midwifery (**Appendix A7**).

Citation

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4.2. Abstract

Problem

Studies investigating the direct and indirect relationships between psychosocial factors (i.e. attitudes, beliefs and values), health related behaviour (diet and physical activity) and gestational weight gain are increasing. To date heterogeneity of psychosocial measurement tools has limited research progress in this area, preventing measurement of effects by meta-analysis techniques.

Aim

To conduct a revalidation analysis of a Weight-Related Behaviours Questionnaire, originally developed by Kendall, Olson and Frangelico within the United States of America and assess its performance for use within the Australian context.

Methods

A revalidation study using Exploratory Factor Analysis was undertaken to assess the factor structure and internal consistency of the six psychosocial scales of the Weight-Related Behaviours Questionnaire, within the Woman and Their Children's Health (WATCH), pregnancy cohort. The questionnaire was self-completed between 18 – 20weeks gestation. Psychosocial factors included; Weight locus of control; Self-efficacy; Attitudes towards weight gain; Body image; Feelings about the motherhood role; and Career orientation.

Findings

Weight locus of control, Self-efficacy and Body image, retained the same factor structure as the original analysis. The remaining psychosocial factors observed a different factor structure in terms of loadings or number of factors. Deleted items modelling suggests the questionnaire could be strengthened and shortened.

Conclusion

Weight Locus of control, Self-efficacy and Body image were observed as consistent, valid and reliable psychosocial measures for use within the Australian context. Further research is needed to confirm the model and investigate the potential for combining these scales into a shorter psychosocial measurement tool.

4.3. Introduction

Weight gain in pregnancy is a complex phenomenon (1). Weight gain in pregnancy is expected and in general is a positive physiological characteristic of fetal growth and pregnancy progression (3). However, since the release of the revised American Academy of Sciences, Institute of Medicine (IOM), nutrition in pregnancy guidelines in 2009, obesity and gestational weight gain (GWG) have become a primary focus of antenatal care, signifying a shift in focus from the management of maternal underweight to overweight and obesity risk management (6, 28).

The Institute of Medicine weight gain in pregnancy guidelines recommend weight gains according to World Health Organisation (WHO) body mass index categories (BMI) (6). Women with a BMI classified as underweight are recommended to gain more than women classified in the overweight and obese categories as follows; Underweight (BMI <18.5) 12.5 kilograms (kgs) - 18kgs, Normal weight (BMI 18.5 -24.9) 11.5 – 16.0kgs, Overweight (BMI 25.0 – 29.9) 7kgs – 11.5 kgs and Obese (BMI ≥ 30.0) 5kgs – 9kgs. Excessive gestational weight gain (EGWG) is therefore defined as total pregnancy weight gain exceeding the IOM weight gain ranges (6). Since the development of the guidelines women have continued to gain in excess of the IOM recommendations (7), increasing their risks of experiencing adverse childbearing outcomes such as large or small-for-gestational-age infants (7, 8), caesarean birth (7, 99), gestational diabetes (10), pre-eclampsia (9) and postpartum weight retention (99). Of concern are the long term and intergenerational disease risks of EGWG proposed by the Developmental Origins of Health and Disease (DOHaD) hypothesis (11). Early life exposure to intrauterine environments characterised by EGWG (over nutrition) have been proposed to increase an infant's susceptibility for childhood overweight, obesity, non-alcoholic fatty liver disease and type 2 diabetes, increasing the global burden of disease (11, 17).

There are no interventions effective at reducing EGWG that are generalisable to large and diverse populations of pregnant women, to inform clinical practice guidelines (29). Intervention studies to date have primarily targeted health behaviour change techniques such as diet and/or physical activity and implementing self-regulation strategies such as routine self-weighing or clinician weighing (32, 34, 35, 47). While healthy eating and physical activity are important for overall maternal and fetal health, diet and physical activity strategies employed during pregnancy have reported moderate effectiveness in decreasing EGWG. These strategies only working for some women, with weight-monitoring during pregnancy no more effective at reducing EGWG than standard antenatal care (32, 34, 35). Additionally, these interventions have reported difficulties

with upscaling at the population level and have demonstrated minimal effectiveness for reducing the adverse maternal and infant outcomes associated with EGWG (1, 28).

Less is known of the complex interactions and relationships of a woman's physical (i.e. nausea and vomiting), psychological (i.e. anxiety and depression) and psychosocial health (i.e. attitudes, beliefs, age, education level), on health-related behaviour (i.e. diet and physical activity) and weight gain during pregnancy (1). There is an increasing body of evidence exploring the myriad of exiting psychosocial factors and their associated direct and indirect relationships with health behaviour and their influence on EGWG (49, 52, 54). Psychosocial factors such as: age, level of education, depression, anxiety, attitudes, beliefs, self-efficacy, body image and social support, are known antecedents to and moderators (barriers and enablers) of health behaviour, potentially influencing (positively or negatively) GWG (49, 52, 56, 100).

A systematic review and narrative synthesis by Kapadia et al. (2015) (52), investigating psychological and psychosocial factors as antecedents to EGWG, identified levels of cognitive dietary restraint, perceived barriers to healthy eating, negative attitudes towards weight gain, being concerned about weight, high targeted weight gain and inaccurate body perception, as potential predictors of EGWG (52). A similar systematic review and narrative synthesis by Hartley et al. (2015) (49), identified depression, body image dissatisfaction and social support as potential predictors of EGWG. While both reviews have examined these important relationships, limitations within and between studies have hindered research progress in this area preventing aggregation of data and estimates of effect using meta-analysis techniques (49, 52). One significant limitation is the current heterogeneity of measurement tools used to examine the relationships between psychosocial factors and EGWG. Further research is warranted to guide the development of pregnancy specific psychosocial measurement tools for use within large and diverse populations of pregnant women and progress research in this area (49, 52).

Kendall, Ohlson and Frangillo (2001) (51), developed the Weight-Related Behaviours Questionnaire (WRB-Q), to assist with the identification of psychosocial factors that influence weight-related behaviour and test their relationships with pregnancy related health behaviour and GWG (51). The development of the WRB-Q was underpinned by the theoretical framework for health promotion by Green and Kreuter (1991) (101), called the Predisposing, Reinforcing, and Enabling Constructs in Educational and Environmental Diagnosis and Evaluation (PRECEDE) / Policy, Regulatory and Organisational Constructs in Educational Environmental Development (PROCEED) model (57, 101). Kendall et al. (2001) additionally applied health behaviour theory

during the development process, primarily social cognitive theory conceptualised by Bandura (1991), to guide the identification of psychosocial factors that may moderate health behaviour during pregnancy (41, 51).

Drawing on measurement tools from the available weight management literature (102-104) and qualitative study findings (105, 106), Kendall et al. (2001) developed the WRB-Q, consisting of 49 individual questionnaire items with 6 psychosocial factors and scales of measurement. Since its development the WRB-Q has been used to explore the potential relationships and interactions between health behaviours (such as diet and physical activity), GWG and postpartum weight retention, primarily within American and Canadian pregnancy cohorts (107-110). To our knowledge the WRB-Q has not been validated for use within an Australian pregnancy cohort. Therefore, to progress research and address current gaps in the evidence base, including heterogeneity of measurement tools, the aim of this study was to conduct a revalidation of the WRB-Q within the Australian Women And Their Children's Health (WATCH) pregnancy cohort and ascertain its performance and suitability as a psychosocial measurement tool for use within the Australian context.

4.4. Methods

4.4.1. The Weight-Related Behaviours Questionnaire

The Weight-Related Behaviours Questionnaire was originally tested and validated within a large (n= 622) prospective cohort study of American pregnant women (Bassett Mothers Health Cohort), recruited between November 1994 and November 1996. The detailed study paper outlining this analysis has been previously published (51).

The entire WRB-Q is comprised of 49 items measuring 6 psychosocial factors. These include: 1) Weight locus of control (WLOC) scale (4 items); 2) Self-efficacy (SE) scale, related to diet, weight control, and exercise (8 items); 3) Attitudes towards weight gain (AtWG) scale (13 items); 4) Body image (BI) scale (4 items); 5) Feelings about the motherhood role (FaMH) scale (7 items); and 6) Career orientation (CO) scale (13 items) (51). Each of the 49 items were measured using Likert scales with responses ranging from 'strongly agree' to 'strongly disagree', from 'very sure' to 'very unsure', from 'too heavy' to 'too light', and from 'very satisfied' to 'not at all satisfied'(51).

The Weight locus of control items measure perceived personal control over weight gain (internal locus of control), or if weight is perceived as outside of personal control (external locus of control) (51).The Self-efficacy items measure perceived confidence for behaviour change in relation to diet, weight control and exercise. The Attitudes towards weight gain items measure positive attitudes towards pregnancy weight gain, or weight gain avoidance during pregnancy (51). The Body image items measure personal satisfaction with own weight and personal perception of body weight. The Feelings about the motherhood role items measure positive and negative perceptions of motherhood and the Career orientation items indicate a preference towards career or family (51).

4.4.2. Population

The Women And Their Children's Health (WATCH) study was a small (n= 180 women and n=182 children) but detailed longitudinal pregnancy cohort study conducted in New South Wales, Australia. Participants were recruited between June 2006 and December 2007 (111). The majority of women in this study (60%) were recruited to participate during early pregnancy (<18weeks) by research midwives at one large tertiary hospital antenatal clinic with a small number of women recruited via word of mouth and local media coverage (111). Women were eligible to participate if they were < 18weeks gestation and planned to birth at the respective tertiary hospital, as outlined in the detailed WATCH study protocol previously published (111).

The first study visit occurred when women were approximately 18–20 weeks pregnant with follow-up visits conducted at 24, 30 and 36 weeks of pregnancy. Postnatal follow-up was conducted at 3, 6, 9 and 12 months and at 2, 3 and 4 year time points (111). The Weight-Related Behaviours Questionnaire was self-completed by participants at the first study visit occurring between 18–20 weeks' gestation (111). Pregnancy and birth data were collected from the health institution's electronic database. Pre-pregnancy weight was self-reported by women on recruitment to the study with all follow up weights measured by researchers. Total GWG was calculated by subtracting the last recorded pregnancy weight reading at approximately 36 weeks, from the self-reported pre-pregnancy weight reference (111).

The research protocol for the WATCH study was approved by the Hunter New England Human Research Ethics Committee (approval number 06/05/24/5.06) and approval was registered with the University of Newcastle (111).

4.4.3. Data Analysis

This was an instrument revalidation study using Exploratory factor analysis (EFA) of the WRB-Q within the WATCH pregnancy cohort. Exploratory Factor Analysis was performed on statistical analysis software (SAS v9.4) using 'proc factor', and varimax rotation. Questionnaire item responses were found to be non-normally distributed so Principal Axis Factoring (PAF) methods, suitable for non-normal distributed data were used. When different questionnaire factor structures were compared to the original validation within the Bassett Mothers Health cohort, the Cronbach's alpha (α) coefficients were calculated according to the original factor structure not the 'new' factor structure, to enable direct comparison between the two cohorts. Cronbach's Alpha (α) coefficients are presented as a value between 0 – 1, with values between 0.70 and 0.90 generally indicating acceptable internal consistency (112, 113). The strength of individual questionnaire items was analysed using Spearman's rank correlation coefficient with two–sided p values (<0.05). All items were further subjected to additional deleted items modelling to assess if the deletion of individual items could improve the internal consistency (α) of each psychosocial scale.

Confirmatory Factor Analysis (CFA) could not be performed to assess the factor structure within the WATCH cohort, as this generally requires larger samples of 200-400 participants (114). As the questionnaire had already been validated within a large population of pregnant women during the original analysis by Kendall et al. (2001) (51), EFA was considered a sound statistical methodology. Exploratory Factor Analysis was applied to each of the 6 psychosocial scales to determine factor structure (in terms of factor number and loading) and Cronbach's alphas (overall and within factor) for comparison with the original analysis performed by Kendall et al. (2001) (51). Factor analysis techniques (i.e., EFA and / or CFA) require complete sets of data, so to ensure as many possible observations were retained, mean substitution was utilised to fill in missing data. However, this was only conducted when the number of missing items within each of the 6 psychosocial scales were fewer than 30%. Ignoring missing items can lead to reduced sample size and loss of power, and so in the absence of specific instructions regarding how to handle missing items within the WRB-Q scales, we utilised person mean imputation for missing items within each scale (115). Bell et al. (2016) (115), explain there are no clear guidelines for handling missing items however, person mean imputation can be performed relatively well when at least 50% of the scale had been answered. For our analysis missing questionnaire items were replaced with the mean of the answered items in the subscale only when there were less than 30% per person, so no values were mean imputed if >30% of scale data was missing, a similar process

to that reported by Hübner et al. (2016) (116). The majority of missing responses were from the career orientation scale (n=19), with 14 values mean imputed and 5 values excluded from the analysis. WATCH cohort characteristics were analysed using descriptive statistics (mean, SD and percentages) using statistical software (SAS v9.4).

4.5. Results

Of the WATCH study participants (n=180), n=159 returned the WRB-Q resulting in an 88% response rate. Of these 73% (n=132) returned complete responses across all 6 psychosocial scales. The total population sample analysed for each of the psychosocial scales were as follows: N = 159 for the WLOC and AtWG scales; N = 158 for the SE scale; N = 157 for the FaMH scale, and n = 154 for both the BI and CO scales.

A comparison of characteristics between the original Bassett Mothers Health cohort (USA) and the WATCH cohort (Australia), are presented in Table 4.1 Participants in the Bassett Mothers Health cohort were recruited between 1994 and 1996. Participants in the WATCH cohort were recruited between 2006 and 2007. The cohorts were similar in terms of age, marital status, parity and mean GWG, however were different in terms of level of education.

Table 4.1 Cohort Characteristics

	Original Bassett Mothers Health cohort (N= 622)	WATCH study cohort (N = 159)
Age *Mean (SD)*	28.8 (nr)	28.9 (5.6) *missing n=12*
Country of birth **Australia** *n (%)*	(nr)	138 (87%)
Other *n (%)*	(nr)	21 (13%)
Education ≥ High School *n (%)*	92.5 %	105 (71%) *missing n=12*
Education ≤ High School *n (%)*	7.5%	42 (29%) *missing n=12*
Married *n (%)*	72.8%	84 (61%)
Unmarried *n (%)*	27.2%	54 (39%) *missing n=22*
Nulliparous *n (%)*	41.3%	66 (45%)
Multiparous *n (%)*	58.3%	80 (55%) *missing n=13*
Total Gestational Weight Gain (kgs) *Mean (SD)*	13.5 (5.3)	13.3 (7.2) *missing n=12*

Demographic data for the Bassett Mothers Health Cohort derived from Kendall, A., Olson, C. M., & Frongillo, E. A., Jr. (2001). Evaluation of psychosocial measures for understanding weight-related behaviours in pregnant women. Annals of behavioural medicine: a publication of the Society of Behavioural Medicine, 23(1), 50-58 & Olson, C. M., & Strawderman, M. S. (2003). Modifiable behavioural factors in a biopsychosocial model predict inadequate and excessive gestational weight gain. Journal of the American Dietetic Association, 103(1), 48-54.

nr = not reported

The entire WRB-Q and results of the EFA are displayed in Table 4.2. Weight locus of control, SE and BI were observed to retain the same item factor structure as the original Bassett Mothers Health cohort analysis, conducted by Kendall et al. (2001) (51). The remaining psychosocial scales exhibited different factor structures, either in terms of loadings or number of item factors.

The analysis within the WATCH pregnancy cohort found the same two-item factor solution across the four WLOC items. Cronbach's alphas were higher in the current analysis for factor 1, but lower for factor 2, and lower overall compared to the Bassett Mothers Health cohort ($\alpha = 0.49$ versus 0.73).

For the SE items, the original Bassett Mothers Health cohort analysis found a three-item factor solution, with the first three items loading on factor 1, the next three items on factor 2, and the final two items on factor 3. The current analysis of WATCH cohort data also found a three-item factor solution with factors 2 and 3 but different item factor loadings to the original analysis for factor 1. Cronbach's alpha coefficients were calculated for the three factors (using the same items as were included in the original Cronbach's calculations) and were higher for factor 2 ($\alpha = 0.82$) and 3 ($\alpha = 0.82$), but lower for factor 1 ($\alpha = 0.65$). The overall Cronbach's alpha was lower for this scale amongst the WATCH cohort compared to the original analysis ($\alpha = 0.76$ versus 0.85).

For the BI items, the original Bassett Mothers Health analysis found a 2-item factor solution across the 4 items, with 2 items loading on each factor. The current WATCH analysis found the same 2-factor solution, with the same items loading on each factors. The overall scale alpha coefficient performed as well in the WATCH cohort as in the original Bassett Mothers Health analysis ($\alpha = 0.91$ versus 0.89, respectively).

The questionnaire item correlations for the WLOC, SE and BI categories are presented in Table 4.3. To summarise these results, item correlations for the WLOC scale were observed to be the strongest for items within the same factor. For the SE scale, item correlations were again strongest for items loading within the same factor with the exception of item Q5 - *"How sure are you that you can fit into your regular clothes,* which did not load strongly on any factor within the WATCH cohort analysis. All BI items were found to be highly correlated.

Table 4.2 Weight-Related Behaviours Questionnaire: Exploratory Factor Analysis and Cohort Comparisons of Factor Structure

	WATCH Cohort Analysis (Australia)			Bassett Mothers Cohort Analysis (USA)		
	Factor 1	**Factor 2**	**Factor 3**	**Factor 1**	**Factor 2**	**Factor 3**
Weight Locus of Control *Circle the number that best represents how you feel* *(Likert scale strongly agree – strongly disagree)*						
1.Whether my weight change is up to me.	**0.69**	-0.03		**0.88**	0.01	
2. If I eat right, get enough exercise and rest, I can control my weight the way I want.	**0.67**	0.11		**0.87**	0.02	
3. Being the right weight is mainly good luck	-0.08	**0.52**		-0.00	**0.88**	
4. No matter what I try to do, if I gain or lose weight, or stay the same, it is just going to happen.	0.17	**0.51**		0.03	**0.86**	
Cronbach's alpha (by factor)	*0.73*	*0.53*		*0.71*	*0.69*	
Overall Cronbach's Alpha		**0.49**			**0.73**	
Self-Efficacy *How sure are you that you can?* *(Likert scale very sure – very unsure)*						
5. Fit into your regular clothes	0.28	-0.01	0.04	**0.96**	-0.05	-0.07
6. Take off any extra weight you gain	**0.79**	0.25	0.02	**0.91**	0.02	-0.01
7. Get back in shape	**0.73**	0.28	0.22	**0.85**	0.05	0.12
8. Eat balanced meals	0.14	**0.69**	0.14	-0.12	**0.90**	-0.06
9. Eat foods that are good for you & avoid foods that are not.	0.09	**0.79**	0.05	0.03	**0.85**	0.03
10. Eat foods that are good for you even when family or social life takes a lot of your time.	0.16	**0.72**	0.21	0.18	**0.76**	0.05
11. Get regular exercise	0.15	0.20	**0.75**	0.00	-0.02	**0.98**
12. Get regular exercise even when family or social life takes a lot of time.	0.10	0.10	**0.77**	0.00	0.01	**0.97**
Cronbach's alpha (by factor)	*0.82*	*0.65*	*0.82*	*0.90*	*0.81*	*0.94*
Overall Cronbach's Alpha		**0.76**			**0.85**	
Attitudes towards weight gain *Circle the number that best represents how you feel* *(Likert scale strongly agree- strongly disagree)*						
13.The weight I gain during my pregnancy makes me feel ugly.	**0.80**	0.25	0.04	**0.83**	-0.09	0.11
14. I worry that I may get fat during this pregnancy.	**0.74**	0.32	-0.09	**0.76**	-0.01	-0.10

15. I am embarrassed at how big I have gotten during this pregnancy.	**0.77**	0.43	0.19	**0.80**	-0.07	0.16
16. I'm embarrassed whenever the nurse weighs me.	**0.70**	0.36	0.24	**0.75**	0.05	0.07
17. I am trying to keep my weight down so I don't look so pregnant.	**0.52**	0.17	0.33	**0.50**	0.18	-0.12
18. I would like to gain between 12.5 and17.5 kilograms during this pregnancy.	0.09	0.30	-0.05	-0.23	**0.78**	0.31
19. I would gain 20kg if it meant a healthier baby.	0.08	**-0.51**	0.21	-0.13	**0.62**	-0.24
20. I will feel badly if I gain more than 20 kilograms during this pregnancy.	**0.61**	-0.15	-0.05	0.37	**0.57**	0.07
21. I like being able to gain weight for a change.	0.41	-0.03	0.04	0.22	**0.54**	0.07
22. As long as I'm eating a well-balanced diet, I don't care how much I gain during this pregnancy.	**0.55**	-0.16	-0.13	0.20	**0.54**	-0.19
23. I'm sure I will be able to fully control the amount of weight I will gain during this pregnancy.	-0.06	-0.19	**0.49**	0.15	0.0	**0.73**
24. You can't totally control the amount of weight you gain when you are pregnant.	0.05	-0.06	**0.52**	-0.01	0.06	**0.66**
25. I feel that women have to be very careful about getting fat during pregnancy.	0.46	0.05	-0.01	0.42	0.17	-0.39
Cronbach's alpha (by factor)	*0.89*	*0.39*	*0.54*	*0.80*	*0.65*	*0.36*
Overall Cronbach's Alpha		**0.75**			**0.78**	
Body Image *Circle the number that best represents how you feel* *(Likert scale very satisfied – very dissatisfied, too heavy, about right, too light)*						
26. How satisfied are you with your current shape?	**0.82**	0.41		**0.95**	0.04	
27. How satisfied are you with your current weight?	**0.82**	0.42		**0.90**	0.10	
28. Do you consider your current weight to be…	0.40	**0.79**		0.02	**0.95**	
29. Do you consider your current body shape to be…	0.40	**0.78**		0.13	**0.87**	
Cronbach's alpha (by factor)	*0.93*	*0.89*		*0.94*	*0.92*	
Overall Cronbach's Alpha		**0.91**			**0.89**	
Feelings about the motherhood role *Circle the number that best represents how you feel* *(Likert scale strongly agree – strongly disagree)*						
30. Having a baby brings a lot of stress into a woman's life.	0.35			**0.84**	-0.28	
31. I am not sure how I will manage after I have the baby.	**0.56**			**0.67**	0.15	
32. I am afraid I will lose my identity after I have the baby.	**0.63**			**0.60**	0.26	

33. After a woman has a baby, she is mainly just somebody's mother.	**0.65**			**0.59**	0.20
34. I am sure I will be a good mother	0.47			**0.41**	0.22
35. I felt proud when I found out I was going to have a baby	0.44			0.01	**0.82**
36. I felt scared when I found out I was going to have a baby.	0.41			0.03	**0.80**
Cronbach's alpha (by factor)	*0.67*	*0.43*		*0.70*	*0.55*
Overall Cronbach's Alpha		**0.71**			**0.74**
Career orientation *Circle the number that best represents how you feel* *(Likert Scale – strongly agree – strongly disagree)*					
37. I want a job that will help me grow.	0.05	0.07	**0.62**	**0.82**	0.14
38. Being able to express myself through a job means a great deal to me.	0.34	0.02	**0.65**	**0.78**	0.01
39. I am determined to achieve my educational and work goals.	0.27	0.07	**0.65**	**0.71**	0.07
40. Success in my work is very important to how I feel about myself.	**0.50**	0.00	0.37	**0.71**	0.10
41. I see myself as working for pay my whole adult life.	**0.57**	0.03	0.15	**0.62**	0.03
42. The responsibilities for home and family should be equally shared when both partners work.	-0.02	0.01	0.16	**0.49**	-0.34
43. I need more in life than what being a wife and mother can give me.	0.47	0.11	0.16	**0.47**	0.26
44. Women who hope to be successful in a job must do so at the expense of home and family.	-0.03	0.26	0.14	**0.46**	0.04
45. Women should seek work that will fit in family needs in terms of work hours, leave time, etc.	0.10	**0.73**	0.03	-0.27	**0.76**
46. Women must make changes in their careers for family needs.	0.17	**0.70**	-0.10	-0.06	**0.70**
47. Women should not work full-time when their children are young.	0.20	**0.67**	0.07	0.22	**0.62**
48. Feeling loved and needed is more important to me than having a career.	**0.56**	0.30	-0.12	0.17	**0.58**
49. I would be very happy staying at home and not working at a job.	**0.73**	0.09	0.02	0.40	**0.46**
Cronbach's alpha (by factor)	*0.66*	*0.73*		*0.75*	*0.67*
Overall Cronbach's Alpha		**0.74**			**0.81**

Table 4.3 Scale Item Correlations

Weight locus of control (n=159)	Q1	Q2	Q3	Q4
Q1	1.00000	**0.57187 <.0001**	-0.09215 0.2480	0.11935 0.1340
Q2		1.00000	0.08097 0.3103	0.19440 0.0141
Q3			1.00000	**0.35759 <.0001**
Q4				1.00000
Spearman's Rho and p-value				

Self–Efficacy (n=158)	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Q5	1.00000	0.28369 0.0003	0.10956 0.1706	-0.00105 0.9896	0.03340 0.6770	0.03006 0.7077	0.09331 0.2436	0.06888 0.3898
Q6		1.00000	**0.72219 <.0001**	0.25270 0.0014	0.23774 0.0026	0.28224 0.0003	0.18259 0.0217	0.08749 0.2744
Q7			1.00000	0.35269 <.0001	0.22362 0.0047	0.29568 0.0002	0.37253 <.0001	0.28994 0.0002
Q8				1.00000	**0.61781 <.0001**	**0.54329 <.0001**	0.30765 <.0001	0.18492 0.0200
Q9					1.00000	**0.63789 <.0001**	0.22461 0.0046	0.11404 0.1537
Q10						1.00000	0.27298 0.0005	0.28683 0.0003
Q11							1.00000	**0.66012 <.0001**
Q12								1.00000
Spearman's Rho and p-value								

Body Image (n=154)	Q26	Q27	Q28	Q29
Q26	1.00000	**0.83114 <.0001**	**0.64231 <.0001**	**0.73707 <.0001**
Q27		1.00000	**0.73954 <.0001**	**0.65370 <.0001**
Q28			1.00000	**0.80674 <.0001**
Q29				1.00000
Spearman's Rho and p-value				

Deleted items modelling carried out on the WLOC, SE and BI scales are presented in Table 4.4. The results of this analysis indicated that the overall Cronbach's alpha coefficient for the WLOC scale improved slightly after deleting item Q3 - *"Being the right weight is mainly good luck*" (α = 0.56 verses α = 0.49), suggesting that this scale may be improved with the removal of this item. When applied to the SE scale, modelling indicated that the removal of item Q5 - *"Fit into your regular clothes*", could improve the Cronbach's alpha coefficient of this scale (α = 0.79 verses α = 0.76). For the BI items all Cronbach's alphas decreased with the deletion of each item indicating that no items need omitting.

Table 4.4 Deleted Items Modelling

Weight locus of control	**Raw Variables**		**Standardized Variables**	
Deleted Items Cronbach's α	**Correlation with Total**	**Alpha**	**Correlation with Total**	**Alpha**
Q1	0.294495	0.420017	0.282067	0.415460
Q2	0.427261	0.294319	0.406368	0.293217
Q3	**0.127560**	**0.546547**	**0.120824**	**0.556712**
Q4	0.321052	0.393549	0.339803	0.360182
Self- efficacy				
Deleted Items Cronbach's α	**Correlation with Total**	**Alpha**	**Correlation with Total**	**Alpha**
Q5	**0.154773**	**0.784592**	**0.146079**	**0.790219**
Q6	0.514318	0.695857	0.507454	0.729234
Q7	0.578706	0.686513	0.576343	0.716582
Q8	0.500599	0.704142	0.523386	0.726338
Q9	0.470355	0.705975	0.502686	0.730097
Q10	0.566190	0.689647	0.591691	0.713717
Q11	0.477347	0.705046	0.483284	0.733593
Q12	0.369311	0.725216	0.380391	0.751690
Body image				
Deleted Items Cronbach's α	**Correlation with Total**	**Alpha**	**Correlation with Total**	**Alpha**
Q26	0.831215	0.855278	0.807888	0.879599
Q27	0.838792	0.850219	0.815148	0.877021
Q28	0.759369	0.884108	0.779625	0.889544
Q29	0.762119	0.882908	0.781955	0.888729

4.6. Discussion

This analysis has retested the validity and reliability of the WRB-Q within an Australian pregnancy cohort. The main findings indicate that the WRB-Q as being partly suitable for measuring psychosocial factors in the Australian context. Of the 6 psychosocial scales we observed that the WLOC, SE and BI scales retain the same factor structure as the original Bassett Mothers Cohort analysis conducted by Kendall et al. (2001) (51). The shared factor structure of these 3 psychosocial scales indicates consistent construct validity across time. These results additionally suggest that there is potential for the combination of these 3 scales into a shortened psychosocial measurement tool. The Attitudes towards weight gain, FaMH, and CO scales returned a different factor structure to the original Bassett Mothers Cohort analysis. These results suggest that they may not be suitable as psychosocial measures for use within the Australian context. The scales however demonstrated acceptable internal consistency suggesting that they may be useful as stand-alone, single psychosocial scales.

Moreover, all 6 psychosocial scales were observed to have acceptable internal consistency when retested within the WATCH cohort with the exception of the WLOC scale, demonstrating a lower overall internal consistency in comparison to the original analysis. Explanations for the lower reliability of this scale (α <0.50) could be due to the lower number of items within the scale or due to poor correlation between scale items (112, 113, 117). The results of the current analysis suggest that poor correlation between scale items as the most likely explanation. Item correlations for the WLOC scale were higher for the items loading on the same factor and lower for items loading across the different factors (i.e. items Q1 and Q3, Q1 and Q4). Tavakol and Denick (2011) (117), explain that when the internal consistency is due to poor item correlation, that this may indicate the presence of redundant items, advising revision of items to see if any can be discarded. In the current WATCH analysis novel deleted items modelling was performed for each of the 6 psychosocial scales. For the WLOC scale deleted items modelling indicated that the internal consistency can be strengthen to an acceptable level (>0.50) by the removal of item Q3 - *"Being the right weight is mainly good luck*". When applied to the SE scale deleted items modelling indicted that the internal consistency of this scale can be improved by the deletion of item Q5 - "*How sure are you that you can fit into your regular clothes?".* The internal consistency of the BI items tested within the WATCH cohort, performed better overall and better in comparison to the original Bassett Mothers cohort analysis. All BI items in the WATCH analysis were observed to be highly correlated with deleted items modelling suggesting that no items should be removed from this scale.

Possible explanations for the inconsistency of the factor structure for the AtWG, FaMH, and CO scales could be due to difference in, and changes to public health messages regarding weight gain in pregnancy experienced between the cohorts over time (1). Most notable is the shift in public health focus (mostly within high income countries) over the last two decades, from the prevention of undernutrition and low-birth-weight, to obesity prevention, GWG and diabetes management (1, 3, 6). The differing factor structure for the FaMH and CO scales may also be explained by changing social roles experienced overtime and may not reflect the cultural attitudes of participants within this Australian pregnancy cohort (118).

The Feelings about the motherhood role items, were originally derived from previously published works by Devine and colleagues, suggesting that first time mothers anxious about taking on the motherhood role were more likely to retain weight after birth, with women found to have a strong career orientation more likely to return to work early and lose their pregnancy weight (105, 106). It is possible that these items were more oriented towards first time mothers and may explain some of the missing responses and differing factor loadings, as 55% (n=80) of the WATCH population were identified as multiparous. The Career orientation items were adopted from previously published works by Hemmelgarn (1990) (119), for use amongst employed mothers. It is possible that WATCH participants not in active employment may have perceived some of the items as not applicable to their circumstances, choosing to omit their responses. One other explanation could be attributed to the difference in education levels with 71% of WATCH participants indicating that they were high school educated or above compared to 92% of participants in the Bassett Mothers Health Cohort. Given that lower education levels are associated with unemployment this may also assist in explaining why these particular scale items recorded the majority of missing responses (120). Future research investigating the direct and indirect relationship between psychosocial and demographic factors (i.e. education level) in combination with GWG would be useful to provide further insight into the complex mechanisms of EGWG.

This revalidation analysis has identified that the WLOC, SE and BI scales from the WRB-Q as valid and reliable psychosocial measures for use within Australian context. Investigating the relationships between these psychosocial scales as predictors of EGWG within larger diverse cohorts of Australian pregnant women is warranted. Further research such as conducting instrument short-form analysis, may be useful to confirm if these scales and individual questionnaire items can be developed into a short pregnancy specific, psychosocial measurement tool.

4.6.1. Strengths

To our knowledge this is the first time the entire WRB-Q has been tested within an Australian population of pregnant women. We additionally performed novel deleted item modelling to identify potential redundant items for removal and overall scale improvement. The results suggest that these scales (WLOC, SE and BI) may be candidates for combining into a short-form questionnaire, potentially reducing participant burden and increasing the questionnaire's appeal for broader clinical research application.

4.6.2. Limitations

Due to the small sample size, the current analysis was an EFA rather than a CFA and as such interpretation of findings needs caution. For instance, changes in Cronbach's alpha values for each of the psychosocial scales may represent natural variation in the behaviour of the scale, or actual improvement in the performance of the scale. Therefore, further analysis using CFA on a larger sample of pregnant women is needed to confirm the factor structure of the WRB-Q as proposed by the current EFA. Further investigation into the external validity of the performance of the factors is also required to determine whether the improvement in alpha scores correlated to improved prediction of the psychosocial construct being measured. The large number of items mean imputed for the CO scale may distort the observed results. While increasing the sample size for this analysis, the mean imputation of values is not reflective of the actual participant responses further undermining the validity of this scale.

4.7. Conclusion

The revalidation of the WRB-Q within an Australian pregnancy cohort suggests that the WLOC, SE and BI scales are consistent, valid and reliable psychosocial measures for use within the Australian context. Findings additionally suggest these scales may be candidates for combining into a short-form questionnaire. Further research is required to confirm the factor structure and internal consistency of these measures on a more diverse and larger sample of Australian pregnant women. Additional testing of these scales as predictors of EGWG is required.

CHAPTER 5

DEMOGRAPHIC AND SOCIAL COGNITIVE FACTORS ASSOCIATED WITH GESTATIONAL WEIGHT GAIN IN AN AUSTRALIAN PREGNANCY COHORT

5.1 Chapter Overview

Psychosocial factors are considered important mediators (barriers and enablers) of health behaviour change. However, less is known about the relationships between psychosocial factors weight-related behaviour and GWG. Therefore, to contribute to the evidence base the aim of this chapter was to identify and describe the demographic and psychosocial factors predictive of EGWG, within an Australian pregnancy cohort. This chapter contains the final version of the article published in the Journal of Eating Behaviors (**Appendix A8**). Of note is that the journal editors preferred the term social–cognitive factors to psychosocial factors, with the term social-cognitive factors used in place of psychosocial factors within this chapter.

Citation

Fealy, S., Attia, J., Leigh, L., Oldmeadow, C., Hazelton, M., Foureur, M., Collins, C.E., Smith, R., Hure, A. (2020). Demographic and social-cognitive factors associated with gestational weight gain in an Australian pregnancy cohort. *Eating Behaviors*, (39). https://doi.org/10.1016/j.eatbeh.2020.101430

5.2 Abstract

Aim

To identify and describe the demographic and social-cognitive factors associated with excessive gestational weight gain using the Weight-Related Behaviours Questionnaire, within an Australian pregnancy cohort.

Background

Supporting women to achieve optimal weight gain in pregnancy is complex. Social-cognitive factors are recognised antecedents to, and mediators of, weight-related behaviour change. Less is known about their role during pregnancy.

Methods

159 women enrolled in a pregnancy cohort study completed the Weight-Related Behaviours Questionnaire (WRB-Q) at approximately 19 weeks gestation, and total gestational weight gain was later measured at 36 weeks. Summary scores were reported descriptively. Multivariable logistic regression was used to test demographic (maternal age, pre pregnancy body mass index, parity, smoking status, marital status, education) and social-cognitive factors (weight locus of control, self-efficacy, attitudes towards weight gain, body image, feelings about motherhood, career orientation) as predictors of excessive gestational weight gain.

Findings

Maternal age was the sole demographic factor predictive of excessive gestational weight gain. Older participants (34-41yrs) were less likely to gain excessive weight when compare to younger participants (18-24 yrs): Odds Ratio 0.20, 95% Confidence Interval 0.05, 0.82. Body image (measured as personal satisfaction and perception of own weight) was the sole social-cognitive factor associated with excessive gestational weight gain. For every one unit improvement in body image score, there was a 33% decreased odds of excessive gestational weight gain (OR 0.67, 95% CI 0.53, 0.85).

Conclusion

This study suggests that younger maternal age and lower perceived body image are predictive of excessive gestational weight gain.

5.3 Introduction

Supporting women to achieve healthy weight gain in pregnancy is complex (1, 54). Weight gain is a normal part of the childbearing experience and in general a positive marker of fetal growth and pregnancy progression (3, 6). In contrast, the global prevalence of women experiencing excessive gestational weight gain (EGWG), defined as weight gains above the American Institute of Medicine (IOM) Weight Gain in Pregnancy Guidelines (2009) (6), is a public health concern. A systematic review of 23 cohort studies (n= 1, 309 136) by Goldstein et al. (2017) (7) has demonstrated that it is more common for women to gain weight above the IOM guidelines (47%, n= 621 004), compared to those gaining below (23%, n=300, 723) or within (30%, 387, 409), independent of pre pregnancy body mass index (BMI) (7).

Excessive gestational weight gain is associated with adverse perinatal and intergenerational health outcomes. These include, an increased odds of having a large for gestational age infant (birth weight >90th centile) (Odds Ratio (OR) 1.85, 95% Confidence Interval (CI) 1.76, 1.95), and an increased odds for caesarean birth (OR 1.30, 95% CI 1.25, 1.35) (7). Individual studies have found EGWG to be associated with increased risk of pregnancy- specific disease such as hypertensive disorders and gestational diabetes (8, 66, 69, 70). Long term and intergenerational health impacts of gestational weight gain (GWG) are explained by the Developmental Origins of Health and Disease (DOHaD) hypothesis, whereby fetal programming occurs via epigenetic pathways, increasing the offspring's risk of non-communicable diseases over the lifespan (14). An in-utero environment characterised by maternal malnutrition, causing maternal overweight, is further suggested to lead to childhood chronic disease risk such as obesity, diabetes and non-alcoholic fatty liver disease (13, 14, 18, 19).

The experience of weight gain during pregnancy is multifactorial, influenced by a multitude of social-ecological factors. These are described as demographic (age, education, income), physical (diet, exercise), psychological (anxiety, depression) and social-cognitive factors (attitudes, beliefs, social support, self-efficacy, body image) (1, 27, 49, 50, 52, 55). These social-ecological factors are considered important predisposing, enabling and reinforcing constructs within health behaviour theory, that can directly or indirectly influence personal health related behaviours such as diet and exercise (54, 56). To date however, the mechanisms by which social-ecological factors influence weight management outside of, and during pregnancy, is poorly understood (54, 55).

Social-ecological factors have largely been neglected in the design of health promoting interventions aimed at reducing EGWG. Individual studies have primarily focused on modifying the nutrition and physical activity behaviours of pregnant women (32, 34, 35). Collectively, these interventions have been found to be moderately successful for some women, with significant barriers identified in the upscaling and translating of these interventions into real world maternity care settings (29, 42, 47). Moreover, there is limited consideration and understanding of a pregnant woman's capacity for diet and exercise behaviour modification outside of research conditions (27, 32, 34, 35). Common pregnancy symptoms such as nausea, vomiting, lethargy and anxiety, as well as social determinates of health, including socioeconomic status and social support, can make it difficult for some women to modify (i.e. afford and sustain) their diet and physical activity behaviours (1, 27, 48).

Demographic and social-cognitive factors such as age, educational attainment, attitudes, beliefs, self-efficacy, body image and social support are recognised antecedents to, and mediators (barriers and enablers) of, health behaviour change (49, 52, 121). A systematic review and narrative synthesis of thirty-five studies (25 cohort, 8 cross-sectional and 2 case–control) by Kapadia et al. (2015) (52), investigating psychosocial and psychological factors as antecedents of EGWG, considered levels of cognitive dietary restraint, perceived barriers to healthy eating, negative attitudes towards weight gain, negative body image, being concerned about weight gain, high targeted weight gain and inaccurate body perceptions, as potential risk factors for EGWG (52). Hartley et al. (2015) (49) conducted a similar systematic review and narrative synthesis exploring psychosocial risk factors associated with EGWG. In a synthesis of twelve studies (2 randomised controlled trials, 8 longitudinal, 2 cross-sectional), this review identified depression, body image dissatisfaction, and social support, as potential psychosocial factors associated with EGWG. Of the 47 studies reported in these two systematic reviews, 9 were identified as being duplicated across both review articles. Both studies highlight the need for further research, specifically research that is replicable using valid and reliable measurement tools, to reduce between study heterogeneity and work towards a consensus of social-cognitive factors that influence weight gain during pregnancy (49, 52).

To better understand the influence of social-cognitive factors on weight gain in pregnancy, Kendall, Olson and Frongillo (2001) (51) developed the Weight-Related Behaviours Questionnaire (WRB-Q), to assist with identifying and understanding the mechanisms by which, social-cognitive factors mediate GWG amongst populations of pregnant women (51). Due to the multitude of social-cognitive factors evidenced to exhibit relationships with GWG, the WRB-Q

provides a valid and reliable consensus of factors for investigation (49, 51, 52). Therefore, the purpose of this study was to identify and describe the demographic and social-cognitive factors predictive of EGWG, within the Australian Women and Their Children's Health (WATCH) cohort study.

5.4 Methods

5.4.1 Weight-Related Behaviours Questionnaire

The Weight-Related Behaviours Questionnaire measures 6 social-cognitive factors across 49 individual question items. The social-cognitive factor categories included within the WRB-Q are: 1) *Weight locus of control* (WLOC) (4 questions), measuring the degree to which a person feels that behaviour change is within personal control (internal locus of control), or outside of personal control (external locus of control) (51, 104); 2) *Self-efficacy* (SE) (8 questions), measuring confidence for behaviour change related to diet, weight control and exercise; 3) *Attitudes towards weight gain* (AtWG) (13 questions), measuring attitudes towards gaining weight or weight gain avoidance; 4) *Body image* (BI) (4 questions, 2 measured as personal satisfaction with own weight and 2 measured as personal perception of own weight); 5) *Feelings about the motherhood role* (FaMH) (7 questions), measuring positive and negative aspects of motherhood; 6) *Career orientation* (CO) (13 questions), measuring preference towards career or family orientation (51). Each social-cognitive factor was measured using a Likert scale with responses ranging from strongly agree to strongly disagree (factors 1,3,5,6), from very sure to very unsure (factor 2), from too heavy to too light (factor 4), and from very satisfied to not at all satisfied (factor 4) (51).

The questionnaire was originally tested for reliability and validity amongst a large cohort of pregnant women (n= 622) in the United States of America (USA), between March 1995 and December 1996, as reported in the Kendall et al. (2001) study paper (51). The questionnaire has been used in seminal works, mainly within USA, to examine factors that influence GWG and postpartum weight retention (107-110). The internal consistency for each of the 6 social cognitive factor scales, demonstrated acceptable internal consistency when retested within the WATCH pregnancy cohort, with the exception of the weight locus of control scale as follows; 1) *Weight locus of control* (α 0.49); 2) *Self-efficacy* (α 0.76); 3) *Attitudes towards weight gain* (α 0.75); 4) *Body image* (α 0.91); 5) *Feelings about the motherhood role* (α 0.71); 6) *Career orientation* (α 0.74).

5.4.2 Population

The Women And Their Children's Health (WATCH) study was a detailed prospective Australian longitudinal cohort study. Women were recruited (between June 2006 and December 2007) to participate in the study during early pregnancy (<18weeks), with follow up to 4 years post birth (n= 180 women and n=182 children) (111). The detailed WATCH study protocol has been previously published (111). Demographic and birth data were extracted from electronic hospital birth records. The Weight-Related Behaviours Questionnaire was administered to participants at the first study visit occurring between 18–20 weeks gestation. The research protocol for the WATCH study was ethically approved (approval number 06/05/24/5.06) (111).

5.4.3 Weight and height measures

Maternal weight and height measurements were obtained at each study visit using the same set of annually calibrated scales and wall mounted stadiometer, by an accredited practising dietitian with level 1 anthropometry training (111). Maternal height and weight were taken in clothing with no shoes. Height was measured on two consecutive appointments to the nearest 1mm, with an average of the two measures used. Where both height measures varied more than 1.5% a third measure was taken, and the median used as the maternal height reference (111). Maternal pre-pregnancy weight (kilograms) was self-reported at the first study visit, with all subsequent weights measured by researchers at study visits. Pre-pregnancy BMI was calculated using pre-pregnancy weight and the recorded maternal height reference. Total GWG was calculated by subtracting the last recorded pregnancy weight reading at approximately 36 weeks from the self-reported pre-pregnancy weight reference (111).

Pre-pregnancy BMI was classified into World Health Organization (WHO) categories. Guidelines for GWG were based on the American IOM 2009 Nutrition in Pregnancy Guidelines (6). The outcome of interest, EGWG was defined as weight gain greater than the maximum recommended weight gain, according to pre-pregnancy BMI category recorded at the last pregnancy appointment at approximately 36 weeks gestation.

5.4.4 Statistical analysis

Demographic, pregnancy and birth characteristics of the WATCH cohort were analysed using descriptive statistics (mean, SD, numbers and percentages). Individual questionnaire items were additionally analysed using descriptive statistics (numbers and percentages). The participant

questionnaire scores were summarised (trichotomised or dichotomised) for presentation purposes as per (**Appendix A10**).

Multivariable logistic regression modelling was then performed to test the association between demographic and social-cognitive variables and EGWG. Prior to this analysis, 29 items were reverse coded so that higher scale scores were representative of a higher level of social-cognitive factor being measured.

Multivariable logistic regression model diagnostics indicated that leaving maternal age as a continuous predictor violated the assumption of linearity, and as a result maternal age was categorised into quintiles. A further six logistic regression models were then performed for each of the 6 social-cognitive factors. Each model was subject to covariate adjustment (Area Under the Curve - AUC) for each of the listed demographic factors, and each was compared to determine whether the addition of these factors improved the accuracy of the model. Assessment of model diagnostics for this analysis again indicated that the linearity assumption was violated for all social-cognitive factors except for body image, and these were categorised into quintiles. The criterion for statistical significance was set at $p<0.05$ (two tailed). Demographic and multivariable logistic regression were programmed using SAS v9.4 (SAS Institute, Cary, North Carolina, USA). Descriptive questionnaire data were calculated using STATA/IC v13.0 (StataCorp, Texas, USA) and Microsoft Excel v16.24.

5.5 Results

Of the WATCH study participants 88% (n=159) returned the WRB-Q, with 73% (n= 132) returning complete responses across all six social-cognitive factor categories. The entire WRB-Q, social-cognitive factors and missing data are presented in **Appendix 10**. The Weight locus of control and AtWG categories returned the highest range of complete responses, with the CO category returning the most incomplete responses (3-5% missing responses across all 13 items). Population demographics of the WATCH sample are summarised in Table 5.1.

The majority of participants were born in Australia, identified as being married, were high school and above educated, non-smokers and experiencing a subsequent pregnancy (i.e. multiparous). Birth data indicated that the majority of participants experienced a vaginal birth, with only 20% experiencing a caesarean birth. The proportion of participants diagnosed with gestational diabetes, gestational hypertension / pre-eclampsia were representative of wider state based

maternal and infant data trends, for the years in which pregnancy and birth data were collected for the WATCH study (122). Maternal weight characteristics are shown in Table 5.2, with the mean pre-pregnancy weight and the stratification of participants by pre-pregnancy BMI category.

Table 5.1 WATCH cohort demographic, pregnancy and birth characteristics

WATCH Cohort (N=159)	
Age ***(Mean / SD)*** *Missing 12*	**28.9 (5.64)**
Country of birth Australia ***n (%)***	**138 (94%)**
Other ***n (%)***	**9 (6.1%)**
Education ≥ Year 12 (high school) ***n (%)***	**105 (71%)**
Education ≤ Year 12 (high school) ***n(%*** *Missing 12*	**42 (29%)**
Married ***n (%)***	**84 (61%)**
Unmarried n ***(%)*** *Missing 22*	**54 (39%)**
Parity- Primiparous ***n (%)***	**66 (45%)**
Party- Multiparous ***n (%)*** *Missing 13*	**80 (55%)**
Smoker n (%)	**15 (10%)**
Developed gestational diabetes n (%) *Missing 14*	**6 (4.1%)**
Developed hypertension in pregnancy n (%) *(pre-eclampsia / gestational hypertension* *Missing 13*	**9 (6.1%)**
Mode of birth n (%)	
Vaginal birth	**104 (66%)**
Instrumental birth	**22 (14%)**
Caesarean birth	**32 (20%)**
Missing 1	
Infant Birth Weight (grams) **Mean (SD)** *n=144*	**3495.0 (557.02)**
Breastfeeding n (%)	
(at approx. 3-months post-partum n=140)	**94 (67%)**
(at approx. 6 months post-partum n= 120)	**68 (57%)**

Table 5.2 WATCH maternal weight characteristics

WATCH cohort (N = 159)	
Pre-pregnancy weight (kg) *Mean (SD)*	**69.63 (16.97)**
Pre-pregnancy BMI by Category *(n, %)*	
Underweight ***(<18.5 kg/m²)***	**8 (5.4%)**
Normal ***(≥18.5 – 24.9 kg/m²)***	**75 (51%)**
Overweight ***(≥25 – 29.9 kg/m²)***	**34 (23%)**
Obese ***(Obese ≥ 30 kg/m²)***	**30 (20%)**
Missing 12	
Excess weight gain by pre-pregnancy BMI *(n, %)*	
Underweight ***(<18.5 kg/m²)***	**5 (62.5%)**
Normal ***(≥18.5 – 24.9 kg/m²)***	**24 (32.0%)**
Overweight ***(≥25 – 29.9 kg/m²)***	**20 (58.8%)**
Obese ***(Obese ≥ 30 kg/m²)***	**11 (36.7%)**
Total sample gaining excess weight *(n, %)*	**60 (41%)**

In total, 41% of participants had already exhibited EGWG by approximately 36 weeks gestation, independent of pre-pregnancy BMI. When stratified by BMI, participants in the underweight and overweight categories proportionally exhibited greater gains than those in the normal weight or obese BMI categories.

To summarise the descriptive results presented in **Appendix A10**, the cohort generally possessed high internal levels of *Weight locus of control* and *Self-efficacy*. Most women had positive *Attitudes towards gaining weight during pregnancy* and were satisfied with their *Body image*. There were generally positive *Feelings towards the role of motherhood* and the women were oriented to family rather than *Career orientated*. Of these social-cognitive factors, there was a proportion of women whose item responses indicated that weight gain as outside personal control, low levels of *Self- efficacy*, preference towards weight gain avoidance, dissatisfaction with /or negative *Body image* and negative *Feelings towards the role of motherhood*. It is these women that we hypothesise require better linkage with health services and greater support to optimise weight gain in pregnancy.

The results of the multivariate logistic regression on cohort demographic factors are presented in Table 5.3. Maternal age was found to be the single demographic factor inversely associated with EGWG. When compared to the youngest participants in quintile 1 (18–24 yrs), older participants in the fifth quintile (34–41yrs) were less likely to experience EGWG (OR 0.20, 95% CI 0.05, 0.82, p 0.0146). When the 6 social-cognitive factors from the WRB-Q were tested as predictors of EGWG (Table 5.4), *Body image* was the only social-cognitive factor found to be statistically associated with EGWG. For every one unit increase in *Body image* score (i.e. more positive about their body), there was 33% decreased odds of experiencing EGWG (OR 0.67, 95% CI 0.53, 0.85, p 0.0008).

The AUC (adjusted for maternal age, pre-pregnancy BMI category, parity, smoking status, marital status, and education) improved to the greatest extent after the addition of Body image but did not improve significantly with the addition of the other social-cognitive factors (FaMH, CO, AtWG, and WLOC or SE).

Table 5.3 Multivariable logistic regression of demographic factors

Variable (n = 138)	*Odds Ratio (95% Confidence Interval CI)*	*P-value*	*AUC*
***Maternal Age (years)** *(ref = Quintile 1) (age18 – 24 yrs)*			
Quintile 2 (age 24.2-26.9)	*1.15 (0.32, 4.10)*	**0.0146**	**0.732**
Quintile 3 (age 27.3-30.2)	*0.32 (0.09, 1.18)*		
Quintile 4 (age 30.3-33.8)	*1.23 (0.34, 4.44)*		
Quintile 5 (age 34.0-41.2)	*0.20 (0.05, 0.82)*		
Pre-pregnancy BMI *(ref = "Normal")*			
Obese	*1.49 (0.53, 4.18)*	0.1025	
Overweight	*3.31 (1.23, 8.86)*		
Underweight	*2.91 (0.52,16.29)*		
Parity *(ref = 0 primiparas)*			
1	*0.89 (0.35, 2.31)*	0.9687	
2+	*0.91 (0.34, 2.45)*		
Smoking *(ref = No)*			
Yes	*0.88 (0.22, 3.50)*	0.8582	
Married *(ref = No)*			
Yes	*0.60 (0.25, 1.43)*	0.2467	
Education >= year 12 *(ref = No)*			
Yes	1.54 (0.61, 3.86)	0.3600	

**Model diagnostics indicated that leaving maternal age as a continuous predictor violated the assumption of linearity, and as a result maternal age was categorised into quintiles*

Table 5.4 Multivariable logistic regression of social-cognitive factors

Social-Cognitive Categories	*Odds Ratio (95% Confidence Interval CI)*	*P-value*	**AUC*
Body Image			
(n = 137)	*0.67 (0.53, 0.85)*	**0.0008**	0.794
Career Orientation *(n = 135)*			
(ref = quintile 1) Score range (22-29)			
Quintile 2 - Score Range (30-32)	*0.35 (0.09, 1.32)*	0.4854	0.762
Quintile 3 - Score Range (32-33)	*0.39 (0.10, 1.53)*		
Quintile 4 - Score Range (34-35)	*0.84 (0.25, 2.74)*		
Quintile 5 - Score Range (36-47)	*0.64 (0.19, 2.21)*		
Feelings about motherhood *(n = 137)*			
(ref = quintile 1) Score range (18-23)			
Quintile 2- Score Range (24-25)	*3.07 (0.77,12.27)*	0.3678	0.763
Quintile 3- Score Range (26-27)	*1.95 (0.53, 7.23)*		
Quintile 4- Score Range (28-30)	*3.80 (1.00,14.53)*		
Quintile 5- Score Range (31-35)	*2.81 (0.71,11.13)*		
Locus of control *(n= 138)*			
(ref = quintile 1) Score range (7-11)			
Quintile 2- Score Range (12-13)	*0.73 (0.24, 2.21)*	0.7824	0.728
Quintile 3- Score Range (4-14)	*0.40 (0.10, 1.58)*		
Quintile 4- Score Range (15-15)	*0.83 (0.18, 3.70)*		
Quintile 5- Score Range (16-20)	*0.75 (0.25, 2.24)*		
Self-efficacy *(n= 138)*			
(ref = quintile 1) Score Range (3-23)			
Quintile 2- Score Range (24-27)	*1.43 (0.45, 4.54)*	0.9057	0.727
Quintile 3- Score Range (28-29)	*1.11 (0.32, 3.80)*		
Quintile 4- Score Range (30-31)	*0.78 (0.21, 2.94)*		
Quintile 5- Score Range (32-38)	*1.25 (0.36, 4.32)*		
Attitudes towards weight gain *(n = 138)*			
(ref = quintile 1) Score Range (17-27)			
Quintile 2- Score Range (28-30)	*0.58 (0.16, 2.08)*	0.3865	0.747
Quintile 3- Score Range (31-33)	*1.25 (0.34, 4.56)*		
Quintile 4- Score Range (34-38)	*1.02 (0.32, 3.27)*		
Quintile 5- Score Range (39-52)	*2.17 (0.66, 7.18)*		

*Adjusted under the curve (AUC) *Adjusted for maternal age, pre-pregnancy BMI category, parity, smoking status, marital status, and education Assessment of model diagnostics for this analysis indicated that the linearity assumption was violated for all social-cognitive factors with the exception of body image, and these were categorised into quintiles.*

5.6 Discussion

The current study has explored the associated relationships between selected demographic and social-cognitive factors and EGWG, in a cohort of Australian pregnant women. The results suggest a temporal relationship exists between age and body image and EGWG within this cohort.

Age is a known predictor of GWG, however the relationship between these variables has been inconsistent. The original IOM (1990) guidelines, in a review of 9 studies (published between 1977 – 1989), reported that women of a younger age were more susceptible to lower GWG. The revised IOM guidelines (2009) in an updated review (14 studies, published between 1977 – 2006), suggested that older women (≥34ys) were entering pregnancy with higher BMI's, but exhibiting lower GWG compared to younger childbearing women (<25ys) (6). A large Danish cohort study (n= 60,892 pregnancies) conducted by Nohr et al. (2008) (85), similarly observed that older women (≥34ys) exhibited lower GWG (15.2% gaining >20kgs) compared to younger women (<25ys, 31% gaining >20kgs. In this study older women (≥34ys, 6.9%) were less likely to be classified as obese according to pre-pregnancy BMI compared to younger women (<25years 10.1%) (85). A more recent cross-sectional study investigating dietary patterns, socio demographic factors and GWG in a cohort of Polish women (n=458), did not find age to be associated with GWG. Within this study, a higher pregnancy BMI (>25.0kg/m^2, OR 6.44, 95% CI 2.87, 14.42) and smoking cessation after conception (OR 9.01, 95% CI 1.20, 41.23) were associated with EGWG (≥ IOM weight gain in pregnancy guidelines) (123).

The current WATCH analysis did not identify a relationship between any other demographic factors and EGWG. This analysis observed that women most at risk of EGWG were of a younger age with a negative body image, identified by mid-pregnancy.

Body image refers to the internal representation a person has towards their external appearance and is often separated into two measures: body satisfaction and body attitudes (thoughts and beliefs) (124-127). In non-pregnant populations body image dissatisfaction is reported as a constant norm across the lifespan (128, 129). Runfola et al. (2013) (129) combined data from two cross-sectional studies of American women (n=5868) aged between 25–89 years and observed that 91% of participants were dissatisfied with their body image. In this study age was found to mediate body dissatisfaction, with women aged 35–44 years reporting the highest levels of body dissatisfaction. Women aged 65–74 years recorded the lowest levels of body dissatisfaction, with women in the 25–34-year age group also reporting high body dissatisfaction scores (129). These

findings outside of pregnancy, are in contrast to the body image scores observed within the WATCH pregnancy cohort. The majority of women in the WATCH study indicated overall satisfaction with their body image when assessed during mid pregnancy.

Consistent with our findings, systematic reviews by Kapadia et al. (2015) (52) and Hartley et al. (2015) (49), exploring the relationships between psychological and social-cognitive factors as predicators of EGWG, collectively identified 7 individual studies investigating body image dissatisfaction in pregnant women. Of these studies, 4 observed significant associations between body dissatisfaction and EGWG (49, 52). A recent study by Roomruangwong et al. (2017) (126), investigated the relationships between body dissatisfaction, anxiety, depression, BMI and GWG, in a small population (n=126) of Thai pregnant women. Findings indicated that body image dissatisfaction was increased in women with a mean age of 27.3 years and was lower in women with a mean age of 30.3 years. Participants reporting body image dissatisfaction were of a higher pre-pregnancy BMI (mean 23.8 SD 4.1) and exhibited higher GWG (mean 13.8 kgs SD 4.9), compared to those who were satisfied with their body image (126). In addition body image dissatisfaction during the perinatal period was found to be associated with increased depression and anxiety scores (Hamilton Depression Rating Scale, Edinburgh Postnatal Depression Scale, Beck depression Inventory), antenatal depression diagnosis, depression, mood disorders and postnatal depression (126).

There is a growing body of evidence exploring the potential direct and indirect relationships between maternal psychology (depression and anxiety) body image and EGWG (124-127). Hill et al. (2013) (50), presented a conceptual model to theoretically explain the potential relationship and pathways between psychosocial, psychological, demographic factors and GWG. This model theorised that maternal psychological, psychosocial and demographic factors as preceding mediators of body image and self-efficacy. Satisfaction with body image and self-efficacy are suggested to indirectly influence (positively or negatively) motivation for behaviour change (i.e. diet and physical activity), affecting GWG outcomes (50).

Indirectly, consistent temporal relationships have been demonstrated between body image dissatisfaction and maternal depressed mood, with depression preceding body image dissatisfaction (130). A recent prospective cohort study (n=253) by Riquin et al. (2019) (131), found a significant relationship between body image dissatisfaction and perinatal depression. The risk of perinatal depression was found to be 3 times greater in women with body image dissatisfaction (OR 3.7, 95% CI 1.9 – 7.2) compared with women who were satisfied with their

body image (131). These studies suggest the existence of a bidirectional relationship between body image dissatisfaction and depression (i.e. body image dissatisfaction increases the risks of depression and depression increasing the risks of body dissatisfaction) (131).

A more recent review and discussion of maternal body image dissatisfaction by Bergmeier et al. (2020) (121), suggests direct theoretical relationships may exist between body image dissatisfaction, the development of antenatal depression and anxiety affecting eating behaviour and EGWG (121).

While further research is needed to model these relationships, it is possible that the interrelationship between body image dissatisfaction and maternal depressive symptoms are both directly and indirectly associated with EGWG. Analysis techniques such as mediation analysis may be a pragmatic next step in the research process (132) and intervention studies trialling support strategies could also help in determining causation.

The remaining social-cognitive factors, WLOC, SE, AtWG, FaMH and CO, were not associated with EGWG in this cohort. A similar study conducted by De Jersey et al. (2017) (54), investigating the relationship between psychosocial heath cognitions and EGWG (at 36 weeks), found a relationship between healthy weight women (BMI <25.0) and weight locus of control, assessed in early pregnancy. In this study a higher perceived weight locus of control was associated with lower risk (adjusted odds ratio 0.6) for EGWG (54). Similar to our findings and using a larger population sample, the study did not find a statistical relationship between self-efficacy and EGWG (54). This is in contrast to findings outside of pregnancy that have consistently associated self-efficacy with weight loss and weight maintenance success (51, 54).

The current WATCH analysis provides further insight into the complex nature of GWG and contributes to the accumulating evidence suggesting a shift in focus from diet and exercise interventions for optimising GWG, to acknowledging the moderating role of social-cognitive and demographic factors, on weight gain in pregnancy. We have highlighted that “one size fits all” approaches such as addressing the physiological components of diet and exercise, whilst working for some women, are not enough to address the complexities of weight gain in pregnancy. This is consistent with findings outside of pregnancy (133). We suggest, future research work towards developing a consensus of social-cognitive factors that are predictive of EGWG, with greater consideration given to demographic factors such as age and social-cognitive factors, such as body image, when designing interventions to improve adherence to GWG targets.

5.6.1 Strengths

To our knowledge this is the first description of the WRB-Q in an Australian cohort of pregnant women. This study has been conducted using a previously validated questionnaire for the identification of social-cognitive factors amongst pregnant women and a combination of self-reported (pre-pregnancy) and objectively measured weight.

5.6.2 Limitations

We are not able to determine from our analyses whether the observed association is causal, non-causal association or consequence. However, in our prospective cohort study the relationship is temporal in that the WRB-Q was administered at roughly 19 weeks gestation, it is possible that early pregnancy weight gain had already affected body image by the time the questionnaire was administered. Prospective studies that assess body image prior to pregnancy would help elucidate this role. The measurement for total GWG was taken at approximately 36 weeks and may not reflect the total weight gain prior to giving birth. While the sample size for this study was limited, we were able to detect significant associations for those predictors with a particularly large effect size. We have not undertaken a post-hoc power analysis as it is generally accepted as inappropriate and misleading (134, 135). The low internal consistency observed for the WLOC scale (α 0.49) does undermine the reliability of results observed for this scale and suggest that these findings be interpreted with caution. The majority of participants within this study were born in Australia, high school educated and above and married or partnered. Therefore, this cohort is not representative of vulnerable populations, for example migrant women, those with lower education, or women with limited social support.

5.7 Conclusion

This study provides further insight into the complex nature of GWG. This study suggests that a temporal relationship exists between body image dissatisfaction in mid pregnancy and EGWG. Future research is needed to ascertain the causal pathways between social-cognitive factors particularly age and body image, when assessing a woman's capacity for weight-related behaviour change during pregnancy amongst large and diverse cohorts of pregnant women.

CHAPTER 6

TRANSLATION OF THE WEIGHT-RELATED BEHAVIOURS QUESTIONNAIRE INTO A SHORT-FORM PSYCHOSOCIAL ASSESSMENT TOOL FOR THE DETECTION OF WOMEN AT RISK OF EXCESSIVE GESTATIONAL WEIGHT GAIN

6.1. Chapter Overview

Methodological limitations including a wide variety of psychosocial factors and measurement tools, have been identified as hindering the progress of research exploring the relationships between psychosocial factors and GWG. There is an increasing need to develop pregnancy specific psychosocial measurement tools that are predictive of GWG with broad research relevance and with possible clinical practice applications. Informed by the studies conducted within **Chapters 4** and **5**, the specific aim of this chapter was to develop a short-form, psychosocial assessment tool for the detection of women at risk of EGWG. This chapter contains the final version of the manuscript currently under review with the journal Appetite.

Citation (under peer review)

Fealy, S., Leigh, L., Hazelton, M., Attia, J., Foureur, M., Oldmeadow, C., Collins, C.E., Smith, R., Hure, A. (submitted to *Appetite* journal 4th February 2021). Translation of the Weight-Related Behaviours Questionnaire into a short-form psychosocial assessment tool for the detection of women at risk of excessive gestational weight gain.

6.2. Abstract

Background

The identification and measurement of psychosocial factors that are specific to pregnancy and relevant to gestational weight gain is a challenging task. Given the general lack of availability of pregnancy specific psychosocial assessment instruments, the aim of this study was to develop a short-form psychosocial assessment tool for the detection of women at risk of excessive gestational weight gain with research and clinical practice applications.

Methods

A staged scale reduction analysis of the weight-related behaviours questionnaire was conducted amongst a sample of 159 Australian pregnant women participating in the Women And Their Children's Health (WATCH) pregnancy cohort study. Exploratory factor analysis, univariate logistic regression, and item response theory techniques were used to derive the minimum and most predictive questions for inclusion in the short-form assessment tool.

Results

11 questionnaire items from the body image, attitudes towards weight gain and self-efficacy psychosocial scales were the strongest predictors of excessive gestational weight gain, deemed suitable for combination into the short-form.

Conclusion

The short-form questionnaire may assist with the development of tailored health promotion interventions that support women psychologically and physiologically to optimise their pregnancy weight gain and address methodological limitations currently hindering research progress in this area.

6.3. Introduction

Globally there has been a renewed focus on prioritising and promoting a healthy start to life, including appropriate weight gain in pregnancy (136). In Australia, the revised Australian Department of Health Pregnancy Care Guidelines, released in 2018, have expanded their clinical assessment recommendations beyond overweight and obesity management (i.e. calculation of body mass index (BMI) and diet and physical activity advice), to highlighting the risks of excessive gestational weight gain (EGWG) at any pre-pregnancy BMI (31). The revised guidelines now include consensus based recommendations advising pregnant women to gain weight within the American Institute of Medicine (IOM) 2009 weight gain in pregnancy ranges, combined with routine antenatal weighing (1, 6, 31). While the antenatal period provides a window of opportunity to promote positive heath behaviours, such as a nutritious diet that meets pregnancy nutrient reference values (137), and being physically active (28), less is known about women's psychosocial capacity for weight-related behaviour change during pregnancy (1).

The pregnancy experience, including weight gain, is highly variable, and influenced by a complex interplay between physiological, psychological, and sociological factors (138). Psychosocial factors include body image, self-efficacy, locus of control, attitudes, beliefs, values, social support, depression and anxiety (49, 52). There is a growing body of research exploring the direct and indirect relationships between these psychosocial factors and heath behaviours (121, 139), including their role in gestational weight gain (GWG) (49, 52, 54). Although no cause and effect relationships have been established, cohort studies to date suggest that temporal relationships exist between psychosocial factors such as body image dissatisfaction, depression, weight gain attitudes, social support and EGWG (49, 52, 130, 138). The majority of studies to date have employed observational designs such as cohort and cross-sectional (49, 52). Across studies, a variety of psychosocial constructs and measurement tools have been identified and evaluated for their relationships with EGWG (49, 52). A systematic review and narrative synthesis of 35 studies evaluating psychosocial and psychological antecedents of EGWG by Kapadia et al. (2015) (52) identified 20 different constructs as exposure variables. The number of identified constructs and variety of measurement tools was a limitation of the review, with authors unable to pool studies using meta–analysis techniques (52).

There is a need to develop a consensus in regard to psychosocial factors and scales of measurement that are predictive of EGWG (49, 52). A single tool that is quick to complete and relevant to clinical outcomes, similar to the Edinburgh Postnatal Depression Scale, may help with

knowledge gains about weight gain in pregnancy (140). The current focus for preventing EGWG is on lifestyle behaviours including diet and physical activity (32, 35). However, these targets for health behaviour change have yielded modest results at best (32, 35), questioning their role. Therefore, there is a need to develop pregnancy specific psychosocial measurement tools with broad research relevance and potential clinical application. A single psychosocial assessment tool may offer new opportunities for health promotion and research during pregnancy.

6.3.1. The Weight-Related Behaviours Questionnaire

Kendall et al. (2001) (51), developed and validated the Weight-Related Behaviours Questionnaire (WRB-Q), to assist with the identification of pregnancy specific psychosocial factors affecting GWG and postpartum weight retention. The authors further sought to explain the mechanisms by which psychosocial factors affect weight-related health behaviours (i.e. diet and physical activity) over the childbearing continuum. The complete WRB-Q consists of 49 individual items measuring 6 psychosocial factors (subscales), using Likert scale responses (51). The WRB-Q was developed without a global score or subscale scoring system.

The original WRB-Q was designed by combining existing psychosocial measurement tools from the available health behaviour literature (102-104) with qualitative study findings (105, 106). The WRB-Q was then tested and validated within the Bassett Mothers Health Cohort, a large (n= 622) prospective pregnant cohort study in the United States of America (51). The WRB-Q subscales have been used to examine the relationships between psychosocial factors and outcomes such as GWG (excessive or inadequate) (141-143). Hinton and Olson (2001) (107, 144) have explored the WRB-Q as a predictor of pregnancy and postpartum health behaviour including food intake and exercise frequency (107, 144) and post-partum weight retention (108), primarily within one large American pregnancy cohort (Bassett mothers cohort, n=622). Other studies utilising the WRB-Q subscales have been cross-sectional in nature conducted within Canadian (n=330) (142) and Dutch samples of pregnant women (n=258) (143). It is unclear why the entire pregnancy specific WRB-Q has not been used for research purposes more broadly. However, the exclusive use of individual subscales suggests that length of the complete questionnaire may not be practical for use even in a research setting, with further time-constraints, as perceived by maternity care providers, potential barriers to implementation in real-world clinical practice (145). A study conducted by Ockenden et al. (2016) (146) additionally suggested that psychosocial measurement tools developed prior to the release of the updated IOM 2009 nutrition in pregnancy guidelines such as the WRB-Q could be perceived as outdated, limiting its use within the published literature.

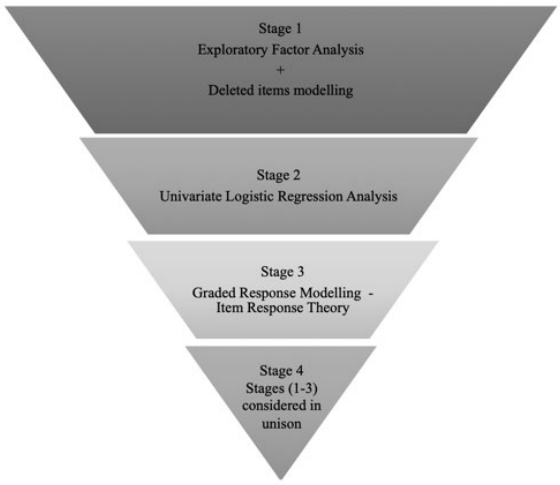
Therefore, the primary aim of the present study was to determine which of the WRB-Q items are most suited for inclusion into a short-form pregnancy-specific psychosocial assessment tool.

6.4. Materials and Methods

6.4.1. Study design

This was a scale reduction analysis using exploratory factor analysis (EFA), univariate logistic regression and item response theory (IRT) techniques. Weight gain and WRB-Q data were collected from participants within the Women And Their Children's Health (WATCH) pregnancy cohort study (111). A pragmatic staged-design approach was undertaken as displayed in Figure 6.1. The scale reduction process was guided by the pragmatic research paradigm applied widely within social science research, whereby practical problem-solving techniques are employed (147). All analyses were performed using STATA 14.0 and SAS V9.4, by a statistician who was blinded to the original data collection.

Figure 6.1 Scale reduction study design for a short-form questionnaire



6.4.2. Population sample and data collection

The sample for the analysis was drawn from the WATCH study. The WATCH study was a small (n= 180 women and n=182 children) Australian prospective longitudinal study, where women were recruited during early pregnancy (<18weeks), with follow-up occurring until 4 years post birth (111). Women were recruited to the cohort between June 2006 and December 2007. Pregnancy and weight data were collected during antenatal care visits by researchers at

approximately 19, 24, 30 and 36 weeks gestation. The 49 item WRB-Q was self-administered to participants at the first study visit where participants were approximately 19 weeks gestation. The questionnaire response rate was 88%, completed by n=159 WATCH participants. Maternal pre-pregnancy weight (kilograms) was self-reported at the first study visit only. All subsequent weight measurements were conducted by researchers, who held Level I anthropometry qualifications (111). Total GWG was calculated by subtracting the last recorded pregnancy weight at approximately 36 weeks gestation, from the self-reported pre-pregnancy weight measurement as per the detailed study paper (111). The research protocol for the WATCH study was approved by the Hunter New England health human research ethics committee (approval number 06/05/24/5.06).

6.4.3. WRB-Q items and scales of measurement

The 6 psychosocial subscales are:

1) Weight locus of control (WLOC) - (4 questionnaire items, Likert scale 'strongly agree to strongly disagree') indicating whether a woman feels she has control over her body weight (internal WLOC) or if body weight is something a woman feels she has little control over (external WLOC);

2) Self-efficacy (SE) - 8 questionnaire items, Likert scale 'very sure to very unsure', indicating levels of confidence for diet, exercise and post-partum weight loss behaviour change;

3) Attitudes towards weight gain (AtWG) - 13 questionnaire items, Likert scale 'strongly agree to strongly disagree', indicating personal attitudes towards gaining weight during pregnancy or weight gain avoidance;

4) Body image (BI) - 4 questionnaire items, Likert scale too heavy to too light, indicating personal satisfaction with body weight and shape and perception of body weight and shape;

5) Feelings about the motherhood role (FaMR) - 7 questionnaire items, Likert scale 'strongly agree to strongly disagree', indicating positive and negative perceptions of motherhood; and

6) Career orientation - 13 questionnaire items, Likert scale 'strongly agree to strongly disagree', indicating preference towards career or family (51).

6.4.4. Scale reduction analysis

Stage 1

Exploratory factor analysis with principal axis factoring and varimax rotation was performed for all WRB-Q items listed under the 6 psychosocial subscales, to examine their overall performance (i.e. construct validity and internal consistency) within the WATCH cohort. Results from this analysis have been reported elsewhere (148). Briefly, the EFA conducted amongst the WATCH sample indicated that the *weight locus of control*, *self-efficacy* and *body image* subscales demonstrated consistent construct validity, retaining the same item factor structure to the original analysis conducted by Kendall et al. (2001) (51). All 6 psychosocial subscales demonstrated acceptable internal consistency (Cronbach's alphas $\alpha > 0.70$), when tested amongst the WATCH cohort with the exception of the *weight locus of control* scale (Cronbach's α 0.49) (148).

In the current analysis EFA was a necessary step in the scale reduction process, accounting for the assumption of unidimensionality (i.e. checking that the data is appropriate for the model), for the application of further analysis techniques such as IRT (149). During the EFA, strength of scale item correlations were examined using Spearman's rho coefficient and p values (<0.05), indicating the presence of probable redundant items (117). To detect these redundant items, further deleted items modelling analysis was performed on each of the 6 psychosocial scales (148). Where the deletion of scale items improved the internal consistency (Cronbach's alphas α) of each individual scale, these were considered as redundant items as displayed in figure 6.2. These results were the precursor for reducing the WRB-Q into a short-form.

Stage 2

Univariate logistic regression was conducted to examine the relationship between each of the individual WRB-Q items and EGWG (measured at approximately 36 weeks gestation). The strength of associations was assessed via the magnitude of the Odds Ratios (OR) and statistical significance (p-values <0.05). Four individual questionnaire items (items 7, 8, 9, 10 and 36) violated the assumption of linearity (between the predictor and outcome) and were examined and reported using categorical analysis techniques. Due to multiple hypothesis testing, Hochberg False Discovery Rate (FDR) procedures was applied to account for type 1 error (150).

Stage 3

Item response theory (IRT) is a collection of techniques that is increasingly being applied to the development of questionnaire instruments or shortening of existing instruments as part of scale reduction (149). Item response theory can evaluate the relationship between a person's response to a particular questionnaire item and the level of construct being measured (149). In this analysis, IRT was used for the purpose of scale reduction to test the strength of associations between the WATCH cohort questionnaire responses (measured by Likert scales) and the respective psychosocial subscale (latent trait).

Of the available models of IRT, the graded response model (GRM), suitable for polytomous responses rather than dichotomous, was deemed the most appropriate due to all WRB-Q items being ordered, categorical Likert scale items (149). The GRM utilises cumulative logistic regression to relate each questionnaire item to its respective psychosocial scale, essentially modelling the probability of a lower item response versus a higher item response (e.g. scoring a 1 versus a 2, 3, 4, or 5 or scoring 1 or 2 versus a 3, 4 or 5, or scoring a 1, 2 or 3 versus a 4 or 5, etc). A participant's response to each item depends on both their 'ability' (i.e. their level of psychosocial construct - specific to each person), as well as the difficulty (*b* parameter) and discrimination (*a* parameter) of the item.

The model produces a trace line called the item characteristic curve (ICC) defined by the location (*a* parameter) and the slope (*b* parameter) and provides a visual representation and value statistic (denoted as θ) (149). Generally, more discriminating items (steeper slope and higher value statistic) are considered better items whereas non discriminating items exhibit flatter curves and lower item information function (IIF) value statistics (149). Item information functions for each of the 6 psychosocial subscales were produced. Item information function value statistics are a function of theta (θ) providing a statistic of how much information a questionnaire item provides to the respective psychosocial subscale; higher values are considered better, more discriminating items (149).

The standard GRM (in which a unique discrimination parameter is estimated for each item) did not converge for the Body Image scale. To address this, an alternative constrained GRM was performed in which the discrimination parameters of items 26 and 27 were constrained to be equal, and items 28 and 29 were constrained to be equal. This was performed in SAS rather than STATA (due to the absence of 'constraint' options in STATA v 14.0).

Stage 4

In this stage, all analyses were considered in unison, with only the best performing items, that performed well across all analyses, considered as candidates for inclusion within the GWG psychosocial assessment tool.

6.5. Results

Demographic characteristics of the WATCH sample have been previously published (138, 148). Briefly, the mean age of participants was 28.9 years (SD 5.64), 71% had an education level at or above completing high school, 61% were married, and 55% were multiparous. The majority of participants (51%) recorded a pre-pregnancy BMI in the normal range (≥18.5 – 24.9 kg/m^2), with 41% of participants gaining excessive weight by 36 weeks gestation. Proportionally, women in the underweight pre-pregnancy BMI category (<18.5 kg/m^2) gained excessively compared to women classified as obese (obese ≥ 30 kg/m^2), 62.5 % versus 36.7% respectively.

6.5.1. Stage 1

Results of the deleted items modelling (Cronbach's alpha (α)) conducted as part of the EFA are presented in Figure 6.2. Deleted items modelling revealed that the internal consistency of the psychosocial scales could be improved with the deletion of selected items. Where the deletion of items strengthened the internal consistency of a psychosocial subscale these were labelled as *"DROP"* items, with all other well performing items labelled as *"KEEP"* items.

6.5.2. Stage 2

Univariate regression identified 13 individual items across four psychosocial subscales as predictors of EGWG ($p<0.05$) as displayed in Figure 6.2. These include all *Body image* scale items (items 26 – 29, p. <0.01); four *Self-efficacy* items (Items 8,9,10, and 12, $p<0.05$); four items from the *Attitudes towards weight gain* scale (items 13-16, $p<0.05$); and one item from the *Career orientation* scale (Item 44, $p<0.05$). Following false discovery rate adjustments none of the questionnaire items demonstrated a statistically significant relationship with EGWG. As the determination of this relationship was not the primary objective of the study, the unadjusted univariate results were used to guide item selection. Only items exhibiting high probability relationships with EGWG ($p<0.05$) were considered for inclusion in the assessment tool.

6.5.3. Stage 3

The graphical item information function results are presented in **Appendix A9**. Item information function value statistics (θ), for all WRB-Q items ranged between -0.11 to 8.80, as displayed in Figure 6.2. A description of the IIFs for each psychosocial scale are as follows. For the *weight locus of control* scale, item 2 contributed the greatest amount of information having the highest estimated discrimination value statistic (4.12). Item 1 provided some information (1.72), with items 3 and 4 contributing very little information (exhibiting flat curves) with low value statistics. Of the *self-efficacy* scale, item 10 contributed the most information exhibiting the highest value statistic (2.77), followed by item 9 (2.49) and item 8 (2.38). For the *attitudes towards weight gain* scale, item 13 contributed the most information (3.44), followed by items 15 (3.17), 14 (3.08) and 16 (2.84). All *body image* scale items exhibited high discrimination values, with the highest value observed for items 26 and 27 (8.80), followed by items 28 and 29 (3.31). As the discrimination was constrained to be equal, the IIF plots for items 26 and 27 and items 28 and 29 are identical as per **Appendix A9**. For the *feelings about the motherhood role* scale*,* item 33 (2.46) exhibited the highest discrimination value followed by item 32 (2.34) and item 31 (1.43). For the *career orientation scale,* item 38 exhibited the highest discrimination value (1.87) followed by item 40 (1.60) and item 39 (1.56).

6.5.4. Stage 4

As per Figure 6.2, when the EFA, univariate analysis and IRT were taken together a total of 11 items across three psychosocial subscales (*self-efficacy, attitudes towards weight gain, body image*) were determined as best candidates (i.e. performing well across all stages of analysis) for inclusion in a short-form assessment tool. As displayed in Table 6.1, three *self-efficacy* items (items 8, 9,10), exhibited high probability for predicting EGWG ($p<0.05$). These same items were all highly correlated with each other (i.e. loading on the same factor) and contributed the most information to the scale (i.e. high IIF value statistics). Four items from the *Attitudes towards weight gain* scale (items 13, 14, 15, 16), exhibited high probability for predicting EGWG ($p<0.05$). These same items were again highly correlated with each other and had high discrimination value statistics. All *body image* scale items were predictive of EGWG ($p<0.01$), highly correlated with each other and exhibited high IIF value statistics.

Figure 6.2 Full model of results from the scale reduction analysis

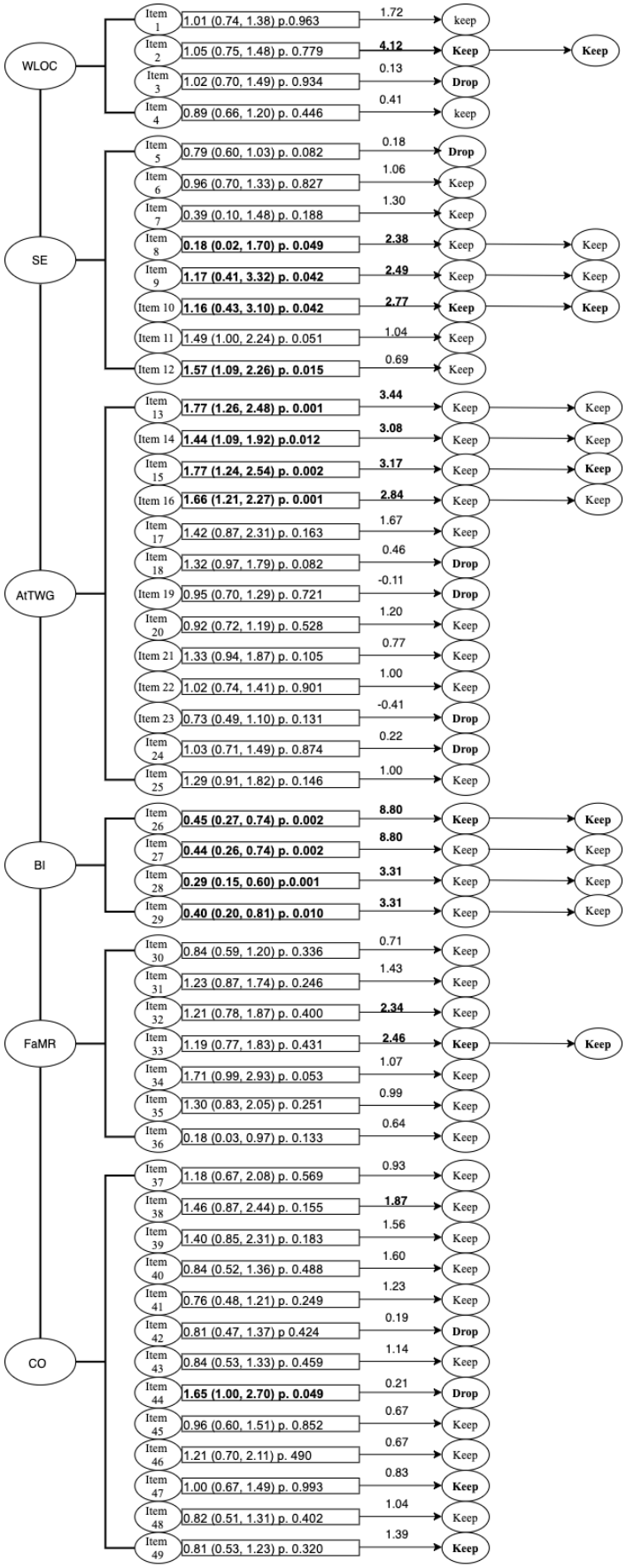


Table 6.1 Gestational Weight Gain Psychosocial Risk Assessment Tool

Self- Efficacy ***How sure are you that you can?***	**Very Sure**	**Sure**	**Neither Sure nor Unsure**	**Unsure**	**Very Unsure**
Eat balanced meals	**1**	**2**	**3**	**4**	**5**
Eat foods that are good for you & avoid foods that are not.	**1**	**2**	**3**	**4**	**5**
Eat foods that are good for you even when family or social life takes a lot of your time…	**1**	**2**	**3**	**4**	**5**
Attitudes towards weight gain ***Circle the response that best represents how you feel:***	**Strongly agree**	**Agree**	**Neither Agree nor Disagree**	**Disagree**	**Strongly Disagree**
The weight I gain during my pregnancy makes me feel ugly	**1**	**2**	**3**	**4**	**5**
I worry that I may get fat during this pregnancy.	**1**	**2**	**3**	**4**	**5**
I am embarrassed at how big I have gotton during this pregnancy.	**1**	**2**	**3**	**4**	**5**
I'm embarrassed whenever the nurse weighs me.	**1**	**2**	**3**	**4**	**5**
Body Image ***Circle the response that best represents how you feel:***	**Very satisfied**	**Satisfied**	**Dissatisfied**	**Very dissatisfied**	
How satisfied are you with your current shape?	**0**	**1**	**2**	**3**	
How satisfied are you with your current weight?	**0**	**1**	**2**	**3**	
	Too heavy	**About right**	**Too light**		
Do you consider your current weight to be…	**0**	**1**	**2**		
Do you consider your current body shape to be…	**0**	**1**	**2**		

6.6. Discussion

The current study evaluated results of a scale reduction analysis of the WRB-Q originally developed by Kendell et al. (2001) (51). Our analysis has furthered this body of work identifying 11 questionnaire items as best candidates for combination into a short-form assessment tool to predict EGWG. Shortening the WRB-Q from 49 items across six psychosocial subscales to 11 items across three subscales with high predictive value for EGWG, may increase the questionnaire's utility for both research and clinical application. This new analysis was conducted within a contemporary Australian pregnancy cohort (111), using the IOM 2009 weight gain ranges, ensuring that only those psychosocial factors relevant to current public health guidance have been identified.

Of the 11 questionnaire items selected out from the full WRB-Q, 8 items were specifically related to weight stigma and/or body image dissatisfaction. The unadjusted univariate analysis results indicated that higher body image scores, indicating greater satisfaction with body image, were associated with a decreased odds of experiencing EGWG. The questions related to weight stigma (items 13-16), indicating attitudes towards weight gain avoidance, were also associated with greater odds of EGWG. These results suggest that some women might benefit from tailored care approaches that seek to reduce weight stigma and embarrassment and improve body image satisfaction during pregnancy.

The remaining questionnaire items with high probability for predicting EGWG were derived from the self-efficacy scale (items 8–10). These items specifically addressed perceived confidence towards diet and food intake, with higher perceived self-efficacy scores towards eating food that is 'good for you' and avoiding foods that are not good for you, associated with a lower odds of EGWG. These results suggest that some women may need and benefit from more support in eating a more balanced diet, particularly those with a busy family / work life, with further research needed to evaluate the outcomes of a psychosocial risk-based approach to diet. These findings are of particular interest given that current weight management guidance in Australia aims to prevent EGWG with a physiological focus, through healthy eating and physical activity advice and weight-monitoring (31), without much emphasis on the cause of EGWG.

Body image dissatisfaction among women is highly prevalent across the lifespan (128, 129). A recent review and discussion of maternal body image dissatisfaction in childbearing and early childhood suggests, that body image is an important but often overlooked psychosocial factor that

mediates (barrier/enabler) weight gain in pregnancy (121). Dryer et al. (2020) (59), assert that given the rapid physiological changes to body shape, weight and size that occur during pregnancy, health professionals need to evaluate body image to increase their awareness and responsiveness to women's psychosocial needs, so as to not exacerbate or contribute to the development of pregnancy specific anxiety, depression or disordered eating, particularly given that weight stigma is still prevalent amongst health professionals (59, 151).

Pregnant women have described their experiences of gestational weight gain with health care professionals as stressful, confusing and judgmental (48, 152). This, coupled with a lack of clinical guidance, appropriately qualified health professionals and focus on diet, exercise, and weight gain, may contribute to negative health behaviours such as disordered eating, low self-esteem and social exclusion (33, 151). A systematic review and qualitative synthesis by Vanstone et al. (2017) (48), discussed that when women received nutritional and physical activity advice from health care providers, it rarely considered their individual circumstances. Women consistently reported significant social and economic disadvantage as barriers to healthy eating/ and physical activity, with authors arguing that it is unethical to directly target the physiological aspects of weight gain alone (48).

By evaluating the psychosocial factors from this WRB-Q short-form, like body image and attitudes towards weight gain, early in pregnancy, researchers and health care professionals may better understand the motivation, readiness and capacity for health behaviour change (153). Health promotion approaches delivered by appropriately qualified health professionals, that are considerate of a woman's psychosocial factors, that aim to reduce weight stigma, improve body image satisfaction and improve eating habits, could increase adherence to GWG targets, improve health professional engagement and increase women's satisfaction with this aspect of maternity care.

Confirmatory factor analysis amongst a large independent pregnancy cohort is now needed to assess the construct validity and internal constancy of the short-form assessment tool. It is hoped that by reducing the WRB-Q into a short-form, specifically for the detection of women at risk of EGWG, may increase research in this area and allow for the eventual pooling of results by meta-analysis techniques to confirm these relationships; the eventual translation of the assessment tool into real world maternity care practice could genuinely support women to achieve healthy weight gain during pregnancy.

6.6.1. Strengths

This paper proposes a short-form WRB-Q to assess psychosocial factors that may be useful in predicting EGWG. Further testing is now needed to confirm the performance (reliability and validly) of the short-form within larger and diverse cohorts of pregnant women. The short-form WRB-Q may go some way to reduce the burden of time for participants and researchers and may be more practical for use in both clinical research and practice settings than the original WRB-Q.

6.6.2. Limitations

Due to the small sample size, multi-dimensional IRT, which would also take into account the multi-factor structure within each subscale, was not performed. IRT generally requires large sample sizes (n=100s to 1000s) for adequate analysis. However, Edelen et al. (2007) (149) argue that parameters can be adequately tested within samples of between 200 – 500 subjects, and that questionnaire properties can be assessed with sample sizes as small as <100 subjects. Given these limitations we have attempted to reduce the potential bias due to the smaller sample by using three sets of results (EFA, individual item regressions, and IRT).

6.7. Conclusion

These analyses have produced a short-form psychosocial assessment tool that may be used to screen for and detect women at risk of experiencing EGWG. Collectively assessing these psychosocial factors using the newly developed assessment tool, may go some way to assist with the design and development of tailored health promotion interventions that support women psychologically and physiologically to optimise their pregnancy weight gain. Further testing of the short-form questionnaire by confirmatory factor analysis is now needed to progress research in this area.

CHAPTER 7

PREGNANCY WEIGHT A BALANCING ACT: THE EXPERIENCE AND PERSPECTIVES OF WOMEN PARTICIPATING IN A PILOT RANDOMISED CONTROLLED TRIAL

7.1. Chapter Overview

Weight gain in pregnancy is directly and indirectly affected by a woman's individual pregnancy experience and her wider psychosocial context. Pregnant women are additionally the recipients of health promotion strategies, resulting from guideline developments, and as such it is important to monitor current practice and ascertain if current health promotion guidance is meeting the needs of pregnant women. Therefore, the aim of this chapter was to perform a qualitative analysis of the experience and perspectives of pregnant women who participated in a pilot weight management randomised control trial. This chapter includes the final version of the manuscript currently under peer review with The Qualitative Report journal.

Citation (under peer review)

Fealy, S., Jones, D., Davis, D., Hazelton, M., Foureur, M., Attia, J., Hure, A. (submitted to *The Qualitative Report*, 22nd January 2020). Pregnancy weight a balancing act: The experience and perspectives of women participating in a pilot randomised controlled trial.

7.2. Abstract

Aim

Supporting women to achieve healthy gestational weight gain is a global health challenge. Less is known of the perceptions and experience of women motivated to participate in pregnancy weight management intervention trials. The aim of this study was to describe the experience and perspectives of gestational weight gain of women participating in an Australian pilot weight management randomised controlled trial.

Methods

A qualitative descriptive methodology and inductive thematic analysis was applied. Five women from regional New South Wales, enrolled in the Eating 4 Two trial, participated in semi-structured interviews during the post-natal period. Interviews were conducted during the trial period between July 2017 – February 2019.

Results

Two main themes emerged: 1) Addressing weight gain in pregnancy; and 2) Pregnancy weight the balancing act. Women identified weight gain as an important topic, the need for improvements within maternity services, responsive feedback and realistic support strategies. Women identified pregnancy symptoms, occurring during early and late pregnancy as barriers to achieving healthy weight gain.

Conclusion

Further investigation into the effects of pregnancy symptoms on eating and physical activity patterns across pregnancy is warranted. Both qualitative and quantitative research is needed to monitor the translation of guideline recommendations into clinical practice.

7.3. Introduction

Optimising gestational weight gain (GWG) in maternity care is a global health challenge (28, 43, 154). Pregnancy weight gains, over (excessive) and under (inadequate) the American Institute of Medicine (IOM) gestational weight gain targets (6) are independently associated with short and long term adverse maternal and infant health outcomes. These include small and large for gestational age infants (7), gestational diabetes, and caesarean section (7, 8). Inadequate and excessive gestational weight gain (EGWG) is increasingly attributed to the development of adult and childhood non communicable diseases, such as type 2 diabetes and cardiovascular disease as explained by the developmental origins of health and adult disease (DOHaD) hypothesis (14). This is of concern as more women currently gain weight above the IOM ranges than fall within the recommendations, thereby, increasing the intergenerational risk of obesity and associated diseases (14, 18).

In Australia there has been a renewed response towards optimising weight gain in pregnancy (1). The Australian Department of Health *Pregnancy Care Guidelines* updated in 2018, broadened their scope from targeting "at risk women", defined as those with a body mass index (BMI) >25kg/m^2 (31). One strategy to achieve this was a recommendation to return to the practice of routine antenatal weighing in addition to the provision of diet and exercise information (31). It is unclear due to a lack of evidence, if this consensus-based recommendation has been employed as a weight management strategy or as a screening tool for adverse pregnancy outcomes (i.e. for the detection of large or small-for-gestational-age infants) (1). Given that pregnancy weight gain is relevant to pregnancy outcome, women who do exhibit weight changes either above or below the IOM guidelines are recommended to be referred for specialist care by allied health professionals such as dietitians (31).

Recommendations such as these have been proven to be difficult to scale at the population level (1). Institutional and professional barriers including a lack of health professional knowledge and training as well as institutional time constraints, lack of specialist staff, funding and referral pathways present challenges to the translation of such recommendations into real world clinical practice, requiring broad institutional and professional reorganisation to be effective (1, 28, 42, 43).

To date evidence suggests that for women, pregnancy symptoms and psychosocial factors directly and indirectly influence weight gain in pregnancy (27, 48, 155). Symptoms such as nausea and

fatigue as well as psychosocial factors such as body image dissatisfaction, depression, socioeconomic status, attitudes beliefs and values, have been suggested as barriers to initiating and sustaining positive weight-related behaviour change, such as diet and physical activity changes (1, 49, 52, 138). There has been a growing body of evidence suggesting a need to identify and address a woman's individual psychosocial capacity for weight-related behaviour change during pregnancy, working towards the development of tailored health promotion strategies (49, 52, 138).

Gaining an understanding of a population of interest within their own social cultural context is considered an essential element of health behaviour theory, necessary for the development of effective behaviour change strategies (56). Qualitative studies to date, aiming to ascertain the women's experience of GWG have been conducted primarily amongst populations of overweight or obese women (155). A systematic review and qualitative synthesis of 42 studies (n= 1339), evaluating women's experience of GWG (48), have found that although women were motivated to achieve weight gains within the recommended range, however there were significant barriers to achieving weight gain targets (48). Barriers included symptoms of pregnancy, health professional attitudes towards weight gain, lack of clear guidance, personal knowledge and beliefs, lack of support, weight stigma, and lack of time and money (48). All studies were conducted on populations of women from high income countries however, interestingly the majority of included studies were conducted amongst women of low socio-economic status (n=13), or amongst populations of overweight or obese women (n=11) (48).

Less is known about women's perceptions and experience of GWG within normal BMI categories (155), with even less known about the characteristics, perspectives and experience of women motivated to participate in pregnancy weight management intervention trials (156). Women participating in research trials are considered to be motivated by the potential therapeutic health benefits offered by the particular interventions (157). Given the complexity of factors directly and indirectly influencing GWG, further insight into women's experience and perspectives of managing pregnancy weight gain is needed.

The aim of this study was to describe the experience and perspectives of women participating in an Australian based weight management randomised controlled trial. Investigating the experience of women motivated to participate in research trials may be useful for understanding the main issues for achieving healthy weight gain in pregnancy.

7.4. Methods

7.4.1. Study design

This is a secondary analysis of qualitative data from one arm of an Australian multicentre randomised controlled trial (158). The Eating 4 Two trial was a pregnancy weight management trial aimed at testing the effectiveness of a mobile health (mhealth), smartphone/tablet application (app). The Eating 4 Two application was designed to assist pregnant women (any BMI) to achieve a healthy GWG, in comparison to a control group receiving usual antenatal care (158). The Eating 4 Two application was designed by experts in the field of midwifery, nutrition and dietetics, and obstetrics, in conjunction with pregnant women. The app was available for trial participants on both Apple iOS and Android platforms.

The within app content provided women within the intervention group with diet and nutrition information, according to the Australian National Health and Medical Research Council's (NHMRC), nutrition in pregnancy reference values (159). This information was combined with a weight tracking tool whereby participants were encouraged to plot and track their GWG. The app additionally provided women with suggested meal plans and general pregnancy information such as common pregnancy symptoms. The control group received standard antenatal care at the participating trial sites as per the detailed study protocol paper (158). The trial was registered with the Australian and New Zealand Clinical Trials Registry (ACTRN12617000169347).

7.4.2. Participants

A purposive sample of consenting women from the regional New South Wales (NSW) arm of the Eating 4 Two trial (Region 3), provided individual interviews were included for the current analysis (158). Women were recruited by maternity care providers within one regional hospital antenatal clinic and via social media advertisement.

7.4.3. Data Collection

Qualitative data were collected via semi-structured telephone interviews with consenting trial participants during the postpartum period (between 5 – 13 weeks post birth). A date and time were negotiated with each woman to ensure that interviews were conducted at a time that suited their individual circumstances. Interviews were conducted by the lead author and Eating 4 Two site research midwife (SF).

The semi-structured interview questions are displayed in Table 7.1 Interviews were audio recorded and then transcribed verbatim by a research transcriber not associated with the trial.

Table 7.1 Semi Structured Interview Questions

Q1. What do you know about weight gain in pregnancy?
Q2. What was your experience of managing your pregnancy weight gain?
Q3. What role did your maternity care provider play?
Q4. How should maternity caregivers approach the issue of weight with you?
Q5. What things helped you to manage your weight in pregnancy
Q6. What were the barriers?
Q7. What is your experience of using the Eating 4 Two app? (intervention group only)
Q8. What would you advise other women about weight gain in pregnancy?

7.4.4. Data Analysis

All women participating within the trial provided written informed consent. Ethics approval was granted for all participating trial sites by their respective Human Research Ethics Committees with approvals additionally registered with participating higher education institutions (H-2017-0074, HREC/17/ACT/1, SSA/17/NCC/13).

Qualitative analysis was undertaken using a qualitative descriptive methodology. The qualitative descriptive methodology was chosen for its ability to provide factual responses to questions about a phenomenon of interest within real world contexts (160). Qualitative descriptive methods follow traditional qualitative methods employing purposive sampling techniques, gathering of interviews or focus groups data, with analysis performed by an inductive thematic and/or content analysis of the data (160, 161).

In the current analysis transcribed interview data were deidentified and checked for quality against the interview recordings using a unique participant identifier, by authors SF and DJ. An inductive thematic analysis was applied where data were coded and categorised into themes (160). Interview transcripts were imported into qualitative analysis software NVivo12 for coding.

The analysis was conducted adhering to the Consolidated criteria for Reporting Qualitative research (COREQ) checklist (162). To increase validity and reduce researcher bias, initial coding and thematic analysis was completed independently by authors SF, and DJ whom was not involved with the Eating 4 Two trial. Following the independent coding of themes, authors (SF &DJ) met to compare and discuss their coding and then developed agreeable themes and

subthemes. Saturation was considered to have been achieved once no new codes or themes emerged from the data (163). A third author (MH) not associated with the Eating 4 Two trial, reviewed the coding of themes, to further enhance accuracy and objectivity of interpretation.

7.5. Results

Twelve women enrolled in the regional NSW arm of the Eating 4 Two trial during the recruitment period. Of these, five women (41%) consented and provided individual interviews. All women interviewed were multiparous and aged between 26 – 38 years. All women received antenatal care through one hospital based antenatal clinic where care was provided by midwives and obstetricians or via a GP shared care clinic model. No midwifery continuity of care models were available to women at this trial site. Four women had a pre-pregnancy BMI in the normal weight category with one woman having a BMI classified as overweight. Two women were representative of the intervention 'app' group with three women representative of the control (usual care) group.

Qualitative data were arranged into two distinct main themes, each represented through a series of relevant subthemes. Main Theme 1. *Addressing weight gain in pregnancy*, describes the experience and perspectives of women, derived from their encounters with their maternity care providers, in relation to the provision of information, guidance and support with GWG. These are expressed through the following subthemes: *'A moot point', 'a really important topic', 'feedback and support'*. Main Theme 2. *Pregnancy weight the balancing act*, describes the women's experience of pregnancy related symptoms and associated impact on personal health behaviour and management of pregnancy weight gain. These are expressed through two subthemes '*early and late pregnancy symptoms'* and *'a sensitive topic'*. Women's attitudes and perspectives towards weight gain are also considered within this theme. Due to the small sample size (n=5), quotes from all participants were chosen and presented where possible, to ensure a balanced narrative.

7.5.1. Main Theme 1. Addressing weight gain in pregnancy

'A moot point'

Women identified that weight gain in pregnancy was not a topic that was openly approached or discussed by maternity care providers. Women reported having to initiate these conversations themselves. Women described their previous pregnancy experiences of GWG and post-partum

weight loss, as the main reasons for initiating these conversations with their care providers. Women identified that when weight gain was addressed by care providers, the information tended to be brief with no clear direction or guidance provided:

"I raised it initially, because with my other two I put on a fair bit of weight. And then I had to lose it all. And you know, I did that with my first one (gain a fair bit of weight) and I did it with my second one and I just knew that the same thing would happen with the third one; that I would put on a lot of weight. So, I raised it with them, and they directed me to your study and that was pretty much the extent of it" (participant #1).

"So, I did bring it up, I didn't want to gain as much weight. I gained 19 kilos with my first pregnancy and I didn't want to gain that much weight again. And so, we kind of talked about it because we talked about the trial and just sort of spoke of usual weight gain in pregnancy" (participant #2).

"In general, yes. They didn't say I had an issue about only gaining a certain amount of weight, it was just be mindful, don't go crazy just because you're…you know, some people get that mindset eating for two" (participant #3).

"Yeah, it was, admittedly it wasn't something I was really worried about. They showed me the healthy weight ranges and I was falling in them, so I was very lucky" (participant #4).

"They did in the first one (appointment) and that's when they enrolled me into this study and then that's the last, I sort of heard from it" (participant #5).

'A really important topic'

Women identified addressing weight gain in pregnancy as important topic applicable to all pregnant women. Drawing once again from their previous pregnancy experiences of GWG and postpartum weight loss, women perceived information to be addressed on an ad hoc basis, with the information perceived to be largely aimed at women entering pregnancy overweight or obese. Women additionally described a lack of clarity with GWG and the nutritional information being presented.

"I think it's really important to address because it can really…like it just sneaks up on you……So yeah, I think it's something that should definitely be brought up…And also, you know my eldest

is in kindergarten and there's quite a few quite obese mums and they have 2 or 3 kids. So even if it's not addressed the first time maybe… maybe it wasn't addressed with them I don't know, but the second time you know, I think it's really important to be …like healthy" (participant #1).

"I think maybe making it part of something that's addressed routinely rather than just adhoc, for someone that needs it …I had a really big baby with my first pregnancy, and I was actually on an eating trial similar to this one where I saw a dietitian every other week and kept food diaries and things. And I still had a really big baby! So, the second pregnancy I actually treated myself as a diabetic and I checked my sugars frequently and I really watched my carbohydrate intake and so my second baby was smaller and my third pregnancy I kind of didn't watch everything as closely, I was mindful of it, I probably didn't watch my carbohydrates as much and it was smaller still, so I don't really know how it all works" (participant #2).

"I think so for every woman, even the women who are small or any in that healthy weight range. I feel like they maybe don't get it as much. But it's usually women going in already with a high BMI that really get that talk given to them. Everyone just needs to have that talk" (participant #3).

"Yeah, absolutely without a doubt. I know that I was lucky and that I stayed in the nice healthy weight ranges, but I just think it's really important because the complications that can come with gestational diabetes or labour itself or whatever, people just need to be aware of it….I did weigh myself probably every two or so weeks out of interest. I was more interested to see that there was weight gain happening because that was kind of like my check to know the baby was putting on weight. I thought well if I'm putting on weight hopefully, they're putting on weight so this is a good thing" (participant #4).

"Yes, and I think that's one of the parts that is skipped over when it comes to their appointments and things like that, because there's so much other things that they need to talk about and that sort of thing, that when it comes to the diet, they kind of just do the flick and go…..A lot of the girl's sort of get stuck with what they can and can't eat and then you know eating, unhealthier things, the deep-fried stuff they know is safe to eat, whereas some of the other things, they get scared. The rock melon thing, having listeria and therefore they don't eat fresh fruit and vegetables and stuff like that" (participant #5).

'Feedback and support'

Women identified that they required realistic support strategies to assist to manage their GWG. They identified a need for responsive feedback on their GWG progress from their maternity care providers beyond weight-monitoring, identifying the need for collaboration with specialist health professionals such as exercise physiologists and dietitians.

"I think it would have been better if I had like additional support. So, if the GP would say 'oh you know, you're probably putting on a little bit too much weight.' Instead of just weighing me and recording the number. Or you know, 'you probably need to put on a bit more weight' whatever the case was, getting a bit of feedback from the number on the scale" (participant #1).

"I just kind of stopped weighing myself. One I didn't really want to know and two it probably just wasn't something that I thought to do. It wasn't motivating it was a bit frightening, Oh God! Look how big am I getting!" (participant #2).

"*Refer to a dietitian. I know that they do but it's usually not for women already in a healthy weight range. It's sort of if they have the risk factors. You never know what can happen when you fall pregnant and get cravings for things. ..... Because people do have that mindset you know, I'm going to fit into these jeans two weeks after I give birth and then they don't because they put on you know, three extra kilos than what they were expecting, that needs to be spoken about because your body's changing and everyone's body is different, reacts differently"* (participant #3).

"So maybe suggesting ways when they talk about weight gain and or healthy weight and what you're eating, maybe ways that consider swimming, consider this consider that. Because that was never presented to me. And I knew it anyway, but it was never presented, and I thought, if people don't know or if it's their first kid and they have no idea (which was me with my first kid), maybe just those suggestions you know, go to the pool, go and walk. Just those little suggestions and people might actually go, I can do that, just make it more realistic" (participant #4).

"I find it's (weighing) a good starting point for a conversation. If that makes sense? I don't feel that it's a great reflection because it doesn't take into account their whole lifestyle, exercise and what's actually going in their mouth…..And I think that's just as negative as if they were putting on weight but eating a really healthy diet…. Um…look… they don't …they didn't even weigh me…like I had to prompt…yeah, they didn't weigh me at all through the pregnancy" (participant #5).

7.5.2. Theme 2. Pregnancy weight the balancing act

'Early and late pregnancy symptoms'

Women identified that symptoms of pregnancy, during the early and late stages of pregnancy, required changes in diet and physical activity patterns. Women indicated that they had knowledge about maintaining a healthy lifestyle, however symptoms such as nausea and fatigue, impaired physical mobility and pelvic discomfort were identified as barriers to maintaining diet and physical activity behaviours. Women additionally identified personal lifestyle factors such as family commitments as factors influencing their dietary habits.

"Well, my biggest problem was that I felt sick throughout pregnancy. So, I wasn't, walking, I wasn't going to the pool for a swim, I wasn't doing any of those things that if I wasn't feeling sick I would….with me, like I was just… you know, toast every morning for breakfast, big pasta meals for tea like it's definitely the food and not being able to exercise 'cos I wasn't feeling up to it….Yeah So, I think that's the biggest challenge, if you can't do the exercising you've really got to watch what you eat. .... I thought 'oh, I'm definitely going to go to the gym, I'm 7 months pregnant and all this type of thing but I felt so sick that I can't maintain that" (participant #1).

"I had usual aches and pains and I think I was more tired than I had been in my other pregnancies that's probably because I'm a bit older than I was and a bit busier. I'm more time poor this time around having two young children already and I tend to just eat snacks or leftovers and eat whatever's left on their plate because, I'm hungry and eat whatever is going and I'm probably not having regular meals ...I'm probably having regular meals as well as snacking in between. So yeah, I probably ate more than I probably wanted to. Just mindless eating" (participant #2).

"Tiredness so you're not as motivated to go the gym or go for a walk and even prepare a healthy meal, especially in that first trimester when you're just exhausted. And then towards then end when you can't really move around as much if you don't keep up with your fitness" (participant #3).

"I was sick for the first 15 weeks, quite sick. So that's probably something even with the research project to take into consideration because my diet changed, changed dramatically, then I got better. So, for the first 15 weeks I just ate whatever would stay in. So, I ended up not exercising because it just wasn't comfortable. And so, for the first 15 weeks I did nothing because I just felt so sick and I know you're meant to when you're sick, but I was like, I cannot deal with going out

right now and then I was really good and then probably during the last 6 or 7 weeks I did nothing, because I was just really big and uncomfortable in that groin area, I had a lot of pressure in that area" (participant #4).

"The biggest problem I had was that I had ligament issues and I had a lot of pelvic girdle pain. So, I couldn't exercise, I had to manage what was going in and my hunger and my nausea, because I wasn't exercising, there wasn't a lot of energy being expended either" (participant #5).

'A sensitive topic'

Women identified weight gain as a sensitive topic, one that can be difficult to address, and that may be perceived as unpleasant. Women identified that well-considered respectful approaches were necessary when discussing the topic of GWG with pregnant women.

"I guess it's a very sensitive issue. A lot of people get very sensitive about their weight I don't know if it is avoidance of that or what" (participant #1).

"Talking amongst my friends, when we talk about weight gain… I've got another friend who's pregnant at the moment and she thinks there's too much emphasis placed on weight gain. Whereas my experiences, I don't know that there is too much emphasis and she feels that the BMI is quite outdated, and it probably isn't a good indicator of someone's general health, the BMI, but it can be a bit of a guide. And it is an older way of looking at health but it's something that we all know, and we can use. So, I think it's difficult" (participant #2).

"I think it's a pretty sensitive topic. Like I know women know they're going to gain some weight during pregnancy, but you know, it's just got to be talked about respectfully, respectful? ……So, I think you just need to be a bit careful" (participant #3).

"So, she (the midwife) approached it in a really, I thought caring, professional way. So that if you were a bigger person you wouldn't be like, you wouldn't leave the appointment and go, 'oh man! She just called me fat … She did it in a really good way that wouldn't make me feel bad if I did end up putting on 20 kilos" (participant #4).

"Look I don't think it's a very good indicator because you can carry a lot of fluid, which will obviously reflect on the scales …and it's not a pleasant experience I suppose" (participant #5).

7.6. Discussion

This study has described the unique experience and perspectives of weight gain in pregnancy, from a small sample of regional Australian women participating in a weight management randomised controlled trial. In this analysis all women were multiparous and identified weight gain as an important topic applicable to all pregnant women. Women identified the need for improvements with service delivery and dissemination of GWG information, requiring responsive feedback on weight gain and clarity of purpose of weight-monitoring, as well as the need for realistic support strategies and referrals to specialist health care professionals. Of significance is that all women identified pregnancy symptoms, occurring during early and late pregnancy, as barriers for healthy lifestyle behaviours in pregnancy.

Pregnancy is often presented as an opportune time to address and promote positive health related behaviours such as smoking cessation and a healthy diet (28, 34). Women are suggested to be emotionally motivated to make positive health behaviour change during this time for the benefit of their infants (30); however, when it comes to GWG the physiological transition to pregnancy and onset of early and late pregnancy symptoms seem to directly impede good intentions. A recent and similar qualitative study conducted by White and Davis (2020) (155) amongst a population of 15 normal weight pregnant women, participating in an Australian pilot weight management randomised controlled trial, identified symptoms of pregnancy as barriers to achieving healthy GWG. Women in this study identified that nausea, vomiting, food cravings, food aversions, fatigue and physical discomforts, required changes from their usual dietary habits and limited their ability to exercise (155).

Flannery et al. (2020) (30) conducted a thematic analysis of obese and overweight women's (n=30) perceptions of dietary behaviours and weight management. This study identified that physiological changes of pregnancy and associated symptoms such as nausea, vomiting and food aversion to impacted on their dietary behaviour (30). A systematic review and qualitative synthesis of 47 studies (n=7655), investigating pregnant women's attitudes and barriers to physical activity, revealed that the most frequent barriers to physical activity in pregnancy were fatigue, lack of time, physical discomforts and pregnancy symptoms including nausea (164). These findings are also reflective of a systematic review and meta synthesis of pregnant women's perceptions of gestational weight gain (42 studies, n= 1339) conducted by Vanstone et al. (2017) (48). In this meta-synthesis women reported nausea, food aversions and cravings as physical barriers to health eating (48).

One quantitative study investigating the maternal dietary intake of women in their third trimester (mean 31.4 weeks) attending one Australian tertiary hospital antenatal clinic (n=534), found that no women met the Australian Guide to Healthy Eating recommendations for pregnancy (137). The highest daily dietary adherence was found for the fruit food group with 38% of women indicating that they had an intake of 2 serves of fruit per day (137). This is of concern as pregnant women were found to be not meeting the minimal nutritional requirements in pregnancy with authors further discussing that pregnancy symptoms could further contribute to nutritional deficits (137).

A study by Sui et al. (2013) (165), investigating the physical activity patterns of Australian overweight and obese pregnant women (n=305), observed a statistically significant decline ($p<0.001$) in women's physical activity across pregnancy (165). Physical activity was observed to be greatest on study entry when women were between 10–20 weeks gestation. Activity levels then declined at the 28-week time point from trial entry, with the lowest recorded activity noted at the 36 week time point (165). Women were observed to increase their activity at 4 months post-partum but at lower levels than observed at trial entry (165). Further investigation into the effects of pregnancy symptoms on eating and physical activity patterns across pregnancy is warranted.

Qualitative evidence suggests that early and late pregnancy symptoms are major factors impairing women's ability to continue with pre-pregnancy diet and exercise regimes. Given this information, women who experience early pregnancy symptoms may require early referral to specialists such as dietitians for nutritional support throughout the duration of pregnancy. Women who experience late pregnancy symptoms such as fatigue and decreased mobility may also need specialist nutritional and allied health support (i.e. physiotherapist or exercise physiologists) during late pregnancy that continues into the post-partum period. These suggestions are consistent with health behaviour theory and behavioural regulation (56, 58).

A systematic review of health behaviour maintenance theories by Kwasnicka et al. (2016) (58) discussed, that self-regulation of behaviour is difficult, being influenced by an individual's personal resources such as their physiological and psychosocial circumstances. When these personal resources are depleted such as through fatigue, stress and sickness, a person's ability for behavioural regulation becomes limited (58). Therefore, targeting women who have good intentions for weight-related behaviour change, i.e. motivated by pregnancy and the health of their babies, and designing interventions that support them through early and late pregnancy symptoms, where personal capacity for diet and activity behaviour regulation is being tested, may assist

women to meet both nutritional and GWG targets. Further research is needed to test this hypothesis.

In terms of clinical service delivery, women in the current analysis identified the need for service improvements in relation to addressing GWG. Although this is taken from one regional maternity service provider, the women's experience is consistent with findings from the wider qualitative literature (30, 48, 155). White and Davis (2020) (155) discussed that women from their study identified a lack of access to reliable information about nutrition and GWG. Some women reported having the topic dismissed by their care providers, with others reporting being provided with inconsistent information on the topic or no information at all (155). Women in this study additionally reported wanting practical information such as meal plans and ideas to assist them to optimise their GWG (155). Vanstone et al. (2016) (48), reported that women across studies consistently reported that health providers were unlikely to discuss GWG and reported a lack of inconsistent information as barriers to achieving healthy GWG. Flannery et al. (2020) (30), in their thematic analysis conducted in a population of overweight and obese women, reported that women felt they were not provided with adequate information and described their encounters with health professionals when discussing diet and healthy weight gain as brief.

The evidence is clear, women who gain within the IOM ranges are at a lower risk of experiencing adverse maternal, infant and intergenerational health outcomes (7, 8, 14, 34). However, despite current evidence and guidance this is not translating into real world clinical practice. Women have consistently identified GWG as an important topic acceptable to be addressed during pregnancy requiring a respectful approach (48, 155). Women are asking to be provided with support to achieve healthy weight gain targets however, are seemingly being let down due to professional and institutional barriers (30, 48, 155). Clear guidance, respectful care, including a tailored approach for those who may not want to be weighed, and support strategies are suggested to overcome current systemic challenges and may go some way to assist women to achieve GWG targets. Further qualitative and quantitative research is needed to monitor the progress and uptake of current guideline recommendations and their translation into practice.

7.6.1. Strengths

This analysis has been conducted amongst a purposive sample of regionally based Australian women participating in a weight management randomised controlled trial. Women in this study were all multiparous and mostly of a BMI in the normal weight range, contributing unique

population perspectives on GWG to the evidence base. The perspectives of these women were found to be consistent with findings from the wider published literature (30, 48, 155, 164).

7.6.2. Limitations

This analysis has been taken from a small sample of women, who were homogenous in terms of parity, maternity care and BMI. Although this was intentional, we acknowledge that this is a limitation with these findings not being representative of wider more diverse populations. Most women from this analysis were from the control group. This may explain why discussion of the Eating 4 Two mobile phone application did not come through within the themes. The analysis of all qualitative data from all participating Eating 4 Two trial sites may provide broader insight into Australian women's experience and perspective of GWG services, the impact of pregnancy symptoms and usability and acceptability of the eating 4 Two smartphone application.

7.7. Conclusion

Assisting women to achieve health gestational weight gain remains a global health challenge. In this analysis, a small sample of women from regional Australia identified the need for improvements in clinical practice and support services when addressing gestational weight gain. Of most significance is that women identified pregnancy symptoms, occurring during early and late pregnancy as factors necessitating modifications from their pre pregnancy diet and exercise regimes. These findings are consistent with qualitative research on this topic opening up areas for future research to assist women to achieve healthy weight gain targets.

CHAPTER 8

THESIS DISCUSSION & CONCLUSIONS

8.1. Chapter Overview

This chapter provides a final discussion and synthesis of studies presented within **Chapters 2-7**. A series of six independent but linked papers incorporating various research aims, designs, and methodologies have been presented to address the overarching thesis aims: 1) To investigate the effectiveness of antenatal weight-monitoring as a health promotion strategy for optimising pregnancy weight gain; and 2) To explore the psychosocial factors associated with weight gain in pregnancy. **Section 8.2** of the chapter provides a summary of findings from each individual study inclusive of a discussion of recent evidence, study strengths and limitations. A synthesis of overall thesis findings is presented in **section 8.3.** Overall strengths and limitations are presented in **section 8.4** with recommendations for future research presented in **section 8.5**. Concluding thesis remarks are presented in **section 8.6**.

8.2. Summary of Findings

8.2.1. Weighing as a stand-alone intervention does not reduce excessive gestational weight gain compared to routine antenatal care: a systematic review and meta-analysis of randomised controlled trials.

The specific aim of **Chapter 2** of this thesis was to systematically review the literature and ascertain the effectiveness of routine antenatal weighing as a stand-alone intervention to reduce pregnancy weight gain, in particular, prevent excessive gestational weight gain (EGWG) (47). Systematic reviews and meta-analyses of randomised controlled trials are considered the highest levels of evidence (level 1) needed to appropriately inform clinical practice guidelines and the provision of evidence-based practice (166). The practice of routine maternal weight-monitoring has been long standing in some western countries such as the United States of America (USA) and Canada. However, this is not been the case in other countries such as the United Kingdom (UK), Ireland and Australia (1, 167). Routine maternal weight-monitoring was not universally adopted within these countries largely due to a paucity of evidence to support its efficacy as a weight management strategy or as a screening tool for adverse pregnancy outcomes (1). Weighing was additionally suggested to cause unnecessary maternal distress resulting in the practice not being widely adopted (1, 76, 167).

Following an extensive search of 7 databases between November 2014 and January 2016 only two randomised controlled trials, both conducted within Australia (n= 977), were found. Both studies were published from 2009 onwards, suggests that this is a relatively new area of experimental research, particularly within Australia. Within the included studies, weighing interventions varied slightly (47). The study conducted by Jefferies et al. (2009) (83) employed routine "self-weighing" during pregnancy, while the study by Brownfoot et al. (2016) (84), tested the effectiveness of routine "clinician weighing". As displayed in Figure 2.2, when the included studies were pooled and meta-analysed, there were no statistical differences observed between intervention and control groups for weekly GWG, or GWG above the IOM 2009 weight gain ranges. No statistical differences were observed for maternal and infant outcomes between groups as per Figure 2.4. A subgroup analysis of GWG by BMI categories revealed a statistically significant difference in weight gains for underweight weight women only (Figure 2.3). Underweight women (BMI <18.5) in the intervention group were found to have lower gains (0.12 kgs/week) compared to those receiving usual care (WMD -0.12, 95% CI -0.23, -0.01). Due to the small sample (n=23) informing this outcome the significance of this finding is questionable and could be attributed to chance alone; caution is thus required when interpreting this finding (47).

Since the publication of the review presented in **Chapter 2**, Daley et al. (2016) (95) published their findings from a small pilot/ feasibility RCT (n=76), evaluating the effectiveness of routine weighing by community midwives in the UK. Although not powered to test for effectiveness, pilot results indicated a slight difference in the proportion of women experiencing EGWG between groups (29.4% usual care, n=36 vs 23.5 % intervention, n=40) (95). A meta-analysis conducted as part of the revised Australian National Health and Medical Research Council (NHMRC) *Pregnancy Care Guidelines* (31), pooled the results of the Daley et al. (2016) (95) feasibility trial with the trial conducted by Brownfoot et al. (2016) (84). Presumably, the rationale for this pooling was to establish the effectiveness of clinician weighing. Findings from this analysis (n=711) revealed no differences in weekly GWG (0.01 kg, 95% CI, -0.03, 0.05) or EGWG (Relative risk 1.05, 95% CI 0.95 – 1.16) between intervention and control groups (31).

A more recent publication conducted in the UK by Daley et al. (2019) (167) reported findings from a large randomised controlled trial (n= 656) investigating routine antenatal weighing by clinicians and informed by self-regulation theory. In this study in addition to weighing, clinicians tracked participant's weight, gave feedback on weight and set weight gain goals for subsequent antenatal care visits (167). The authors hypothesised that weighing when informed by self-regulation theory (similar to the use of weighing outside of pregnancy), may increase the effectiveness of the intervention in pregnancy (167). However, this trial also observed no difference in the proportion of women exceeding the IOM 2009 weight gain targets between intervention and control groups (27.6% vs 28.9%, OR 0.84, 95% CI 0.53, 1.33). Subgroup analysis of EGWG by BMI category, did not reveal any statistical differences between intervention or control groups (167).

The most recent RCT by Arthur et al. (2020) (168), evaluated daily weighing as an intervention to control GWG within a cohort of Australian pregnant women (n=326). Findings from this trial revealed no statistically significant difference in weight measures or pregnancy and birth outcomes between groups however, the intervention group was found to exhibit lower percentage weight gains compared to the control group (mean difference 5.8%, 95% CI-5.4 – 17.0, p 0.31) (168). No statistical differences were reported in weekly GWG, weight gain by BMI category, gestational diabetes, gestational hypertension, gestational age at birth, mode of birth, blood loss at birth, infant birth weight or infant APGAR scores (168). One large limitation of the study was that adherence to the daily weighing intervention was not assessed, with no data reporting on daily weighing compliance amongst trial participants. The study additionally recorded a 17% loss to follow up (168).

The systematic review featured within **Chapter 2** was the first to combine RCTs to test the effectiveness of weighing as a stand-alone intervention to optimise GWG. The review followed the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines and was informed by completion of the Joanna Briggs Institute systematic review training program, ensuring research competence, rigor, transparency of reporting and replicability of results (47, 79). In addition to the limitations reported in **Chapter 2**, the included studies were both conducted using homogenous samples of pregnant women receiving antenatal care in Australia. Therefore, the results are not representative of other populations and need to be interpreted with caution (47).

8.2.2. The return of weighing in pregnancy: A discussion of evidence and practice

A narrative review and synthesis of evidence on the topic of routine antenatal weighing within Australia was presented in **Chapter 3.** Following the publication of the systematic review in **Chapter 2,** the Australian Department of Health, National Health and Medical Research Council, reviewed and updated the National *Pregnancy Care Guidelines* in 2018, recommending a return to the practice of routine antenatal weighing as part of maternity care (1). Therefore, the aim of this chapter was to provide a review of the evidence in response to the Australian Department of Health *Pregnancy Care Guidelines* and discuss the broader social-ecological factors that may impact on women's ability to achieve GWG targets. Moreover, **Chapter 3** signified a change in research focus from investigating the efficacy of antenatal weighing to considering the potential relationships between psychosocial and pregnancy factors as antecedents to, and moderators of, EGWG.

The most recent Australian *Pregnancy Care Guidelines* (31) recommended women be offered the opportunity to be weighed and for clinicians to encourage self-monitoring of weight gain at every antenatal appointment, regardless of BMI. It was unclear if the consensus-based recommendation (i.e. formulated in the absence of quality evidence) was included as a weight management strategy, pregnancy screening tool, or to facilitate the collection of country-specific GWG data, in the absence of Australian GWG guidelines (1, 155). In addition to weighing, women were recommended to gain weight within the IOM 2009 weight gain reference ranges. Maternity care providers were urged to exercise caution, with recommendations to use the IOM 2009 weight gain ranges as suggestions only, rather than absolute weight gain targets (31) because the IOM guidelines were derived from American population data, limiting overt generalisability to Australian populations (6).

The re-initiation of routine maternal weight-monitoring into Australian pregnancy care is worth questioning. In contrast to diet and physical activity interventions, weighing is relatively easy to implement at the population level requiring minimal resources and time (43, 95, 154). However, there is no evidence to support its efficacy as a weight management strategy (1, 47) or as an intervention that improves pregnancy or birth outcomes (47). In the absence of effective interventions to address EGWG, there has been increasing evidence to suggest that GWG is influenced by more than the traditional physiological energy in / energy out approaches to weight management (49, 52-54). Psychosocial factors are known antecedents to, and mediators of health behaviour change outside of pregnancy, with less being known of their influence on women's ability to initiate or sustain positive weight-related behaviours such as diet and physical activity interventions during pregnancy (49, 50, 52). Additionally, qualitative studies suggest that pregnancy itself may also affect weight-related health behaviour (1, 27, 48, 155). Therefore, a line of inquiry addressing the relationships between selected psychosocial factors and pregnancy factors as potential predictors of EGWG were presented within thesis **Chapters 4-7**.

The narrative review presented in **Chapter 3** was methodologically unstructured. Unlike systematic reviews, narrative reviews have broad contextualisation, are based on informed opinion, and are particularly open to author bias in terms of inclusion of articles, interpretation of evidence, and conclusions (169). One advantage of narrative reviews though is that they allow for expert opinion and understanding of a particular topic within its context (169). For example, antenatal weighing was once a long-standing practice, abandoned during the late 1990's due to a paucity of evidence to support its continuation within Australian maternity care. However, with the backdrop of the obesity epidemic, increasing incidence of women experiencing EGWG, and ease of implementation at the population level, there has been increasing support for weighing to be reintroduced as part of standard Australian pregnancy care. This raises concerns given the benefits and risks of the practice are relatively unknown (1). Having experiential knowledge of the practice ensures that contemporary results, such as those presented in **Chapter 2**, are interpreted broadly, in light of contemporary evidence whilst taking into account the historical context (169).

8.2.3. A revalidation of the weight-related behaviours questionnaire within an Australian pregnancy cohort

Systematic review literature has evidenced a myriad of psychosocial factors to exhibit relationships with EGWG (49, 52). The Weight-Related Behaviours Questionnaire (WRB-Q)

originally developed by Kendall et al. (2001) (51), was an instrument designed to assist with the identification of pregnancy-specific psychosocial factors that influence GWG, and postpartum weight retention amongst women from the USA. To date the WRB-Q has been used amongst populations of American, Canadian and Danish pregnant women with no published record of its use in Australia (138, 142, 143). The WRB-Q was designed prior to the release of the updated IOM 2009 nutrition in pregnancy guidelines, when the public health focus was on inadequate gestational weight gain (IGWG) and low-birth-weight infants. This is a potential limitation of the instrument, as it may be viewed as outdated for use within the current public health context (146). Therefore, the aim of the research reported in **Chapter 4** was to perform a revalidation of the WRB-Q within a more contemporary pregnancy cohort and to assist with identification of psychosocial factors that may be used to predict EGWG amongst Australian pregnant women.

Classical test theory (CTT) methods, using exploratory factor analysis (EFA) techniques were employed to retest the construct validity and internal consistency of the instrument amongst a small (n= 159) cross-section of women participating in the WATCH prospective longitudinal cohort study. Findings from the EFA suggested that the WRB-Q remained a valid and reliable tool for measurement of psychosocial factors amongst this cohort of Australian pregnant women. Specifically, the Weight Locus of Control (WLOC), Self-efficacy (SE) and Body Image (BI) scales retained the same instrument factor structure when compared to the original validation analysis performed by Kendall, Olson and Frongillo (51), indicating consistent construct validity. The Attitudes towards Weight Gain (AtWG), Feelings about the Motherhood Role (FaMH) and Career Orientation (CO) scales did not demonstrate the same factor structure as the original analysis, however, overall and within scale Cronbach's alpha coefficients (α) suggested that these remained reliable, individual psychosocial factor scales of measurement amongst this population and should not be discounted. Furthermore, scale item correlations (spearman's rho coefficient) and deleted items modelling suggested that the WRB-Q should be further refined and possibly shortened to accurately reflect current public health guidance, potentially expanding the research and clinical relevance of the instrument **(Chapter 3)**.

The identification and measurement of psychosocial factors that are specific to pregnancy and relevant to GWG is a challenging task (51, 170). Valid and reliable measurements of psychosocial factors that are predictive of EGWG are needed to address current research limitations and inform future research such as enabling cross cultural comparisons between variables and eventual estimates of effect by meta-analysis techniques (171). Studies evaluating instrument measurement properties should be of high methodological quality to ensure accuracy of outcome reporting

(172). This study was guided by the Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) guidelines, aimed at improving the reporting and selection of measurement instruments (172). Statistical design and analysis were conducted by statisticians not involved with the WATCH study, limiting confirmation bias. Missing data were reviewed and managed by mean imputation. The analysis of results was then compared to the original validation analysis conducted by Kendall et al. (2001) (51) to ensure transparency with the reporting of results.

Statistically, the BI scale performed the best overall, retaining the same factor structure and exhibiting better reliability in comparison to the original analysis reported by Kendall et al. (2001) (51). In contrast, the large number of missing values and mean imputed items for the CO scale suggests that this was a poor psychosocial construct and unreliable scale of measure for use within this pregnancy cohort. The study was additionally taken from a small cross section of homogenous Australian pregnant women and thus the results are not representative of more culturally diverse Australian populations, requiring caution with interpretation of results.

8.2.4. Demographic and social cognitive factors associated with gestational weight gain in an Australian pregnancy cohort

Demographic factors such as age and educational status have been associated with weight gain outside of, and during, pregnancy. However, relationships have been demonstrated between certain demographic factors and GWG in the study population over time (6, 138). The WRB-Q provides a valid and reliable combination of psychosocial factors to be tested as predictors of EGWG. Informed by the study reported in **Chapter 4**, the study presented in **Chapter 5** aimed to identify and describe the demographic and psychosocial factors predictive of EGWG, within an Australian pregnancy cohort.

The results from **Chapter 5** suggest that women in this cohort exhibited high levels of WLOC and SE, as well as positive AtWG and FaMH. Women indicated that they were generally satisfied with their BI and were slightly more family oriented than career oriented (138). However, a proportion of women indicated low levels of WLOC and SE, negative AtWG and FaMH, as well as dissatisfaction with BI. It was hypothesised that these women may require increased support to achieve weight gain targets. Findings from the multivariate logistic regression on demographic factors revealed maternal age to be inversely associated with EGWG (Table 5.3). Participants aged between 34 – 41 years, were less likely to experience EGWG than younger participants aged

18 – 24 years (OR 0.20, 95% CI 0.05, 0.82, p 0.0146). Analysis of the 6 WRB-Q psychosocial factors (Table 5.4) found BI to be the only psychosocial factor predictive of EGWG. For every one unit increase in BI score there was a 33% decreased odds of EGWG (OR 0.67, 95% CI 0.53, 0.85, p 0.0008) (138).

The study presented in **Chapter 5** observed a temporal relationship between BI dissatisfaction and EGWG, meaning the women reported BI dissatisfaction prior to their EGWG. Moreover, younger women indicating dissatisfaction with their BI were more likely to experience EGWG. These findings have been supported by a recent study conducted by Dryer et al. (2020) (59) who observed similar associations between age and BI in a larger population of Australian pregnant women (n=408). In this study, advancing maternal age was found to be modestly associated with increasing BI satisfaction (Spearman's rho 0.14, $p < 0.05$)(59). Body image dissatisfaction has been found to be highly prevalent amongst women of all age ranges outside of pregnancy, largely attributed to societal stereotypes and pressures to meet beauty standards (128, 129). The rapid physiological changes that occur to body shape, weight and size during pregnancy and an evident bi-directional relationship between BI and depression (i.e., BI dissatisfaction increases the risks of depression and depression increases the risks of BI dissatisfaction), suggests the need to broaden current psychosocial screening to include satisfaction with BI (59, 121). Moreover, the results presented in **Chapters 4** and **5** combined suggest that the WRB-Q BI scale (consisting of questionnaire 4 items), is a valid and reliable instrument predictive of EGWG. The simplicity of the scale may afford broad application for future research and clinical assessment purposes, thus addressing a limitation identified within the current literature (59, 121, 131, 138).

Observational studies are inherently limited by design, and the inability to detect true cause and effect relationships between variables (173). Cross-sectional studies are, however, useful for detecting prevalence and testing associations between selected variables that can be used to inform the design of randomised controlled trials (i.e. hypothesis generating) (173). Whilst not explicitly stated in **Chapter 5**, this study was guided by the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines for the reporting of cross-sectional studies (174). Following these reporting guidelines ensures the transparent collection, analysis and reporting of data (174). This study was derived from a small homogenous sample of pregnant women and therefore results are not generalisable or representative of more culturally diverse populations of pregnant women. While the sample size was limited, the analysis was able to detect significant associations between variables with a large effect size (138).

8.2.5. Translation of the Weight Related Behaviours Questionnaire into a short-form psychosocial assessment tool for the detection of women at risk of excessive gestational weight gain.

Methodological limitations including significant heterogeneity of psychosocial factors, measurement instruments, as well as a general lack of availability of pregnancy-specific psychosocial measurement tools have hindered the progress of research investigating the relationships between psychosocial factors and GWG (49, 52, 146). The results of the study presented in **Chapter 4** suggested that the WRB-Q should be refined and could possibly be shortened. **Chapter 5** observed a statistically significant relationship between the WRB-Q, BI scale and EGWG. Informed by the results reported in these chapters, the aim of the study presented in **Chapter 6** was to develop a short-form psychosocial assessment tool for the detection of women at risk of EGWG, with research and clinical practice applications.

A staged instrument scale reduction study for the WRB-Q was designed using the following statistical methods: Stage 1) utilised the results of the EFA presented in **Chapter 4,** to satisfy the assumption of unidimensionality needed for the application of Item Response Theory (IRT) techniques and for the detection of redundant questionnaire items; Stage 2) employed univariate logistic regression techniques to detect the strength of associations between all 49 WRB-Q items and EGWG; and Stage 3) applied IRT techniques, specifically graded response modelling (GRM), to test the strength of associations between the 6 WRB-Q, psychosocial factor scales, and responses to scale items gathered from women participating in the WATCH pregnancy cohort study. In Stage 4, all of the above analyses were considered in unison with only the best performing items (i.e. performed well across all analyses) included within the short-form questionnaire **(Chapter 6)**. When all results were taken together (stage 4, Figure 6.2) the WRB-Q could be refined and shortened from 49 items measuring 6 psychosocial factors, to 11 items measuring 3 psychosocial factors. Best performing items were derived from the SE scale (3 items), AtWG scale (4 items) and BI scale (all items). These items were highly correlated with each other, exhibiting high probability for predicting EGWG with high item information function (IIF) value statistics **(Chapter 6)**.

The results presented within **Chapters 4, 5, and 6,** have consistently identified BI as a psychosocial construct predictive of GWG within the WATCH cohort. Interestingly, the 4 questionnaire items from the AtWG scale identified for inclusion in the short-form were also related to BI. This provides further support for the need to assess for BI dissatisfaction as a risk

for EGWG, and as a possible measure of weight-related psychological distress (WRPD) (121, 131). The remaining 3 items identified for inclusion in the short-form were derived from the SE scale, with all items measuring confidence in relation to diet related behaviour change. In Australia, psychosocial screening is a long standing and acceptable practice recommended as part of routine antenatal care, for detection and early intervention in women at risk of anxiety and depression (31). The findings presented in **Chapter 6** provide further support for the need to broaden the scope of psychosocial screening for the detection of women at risk of EGWG. Collectively assessing these psychosocial factors using the newly developed WRB-Q short-form may go some way to assist with the design and development of tailored health promotion interventions that support women psychologically and physiologically to optimise their pregnancy weight gain, as described in **section 8.3.3** of this chapter.

The short-form was developed in consultation with statisticians and guided by the Consensus-based Standards for the selection of health Measurement Instruments (COSMIN), recommendations (172). As this analysis was completed within one small pregnancy cohort results are not overtly generalisable. Confirmatory factor analysis (CFA) techniques need to be employed amongst a large, independent, and more culturally diverse Australian pregnancy cohort, to confirm the construct validity and internal constancy of the instrument and provide confidence for its generalisability as a pregnancy-specific psychosocial assessment tool **(Chapter 6).**

8.2.6. Pregnancy weight gain a balancing act: The experience and perspectives of women participating in a pilot randomised controlled trial

Gaining an understanding of a population of interest within their own social and cultural context is considered an essential element of health behaviour theory, necessary for the development of effective health promotion strategies (56). The qualitative systematic review literature has reported significant barriers for women in achieving weight gain targets, including symptoms of pregnancy, health professional attitudes, lack of clear guidance, personal knowledge and beliefs, lack of support, weight stigma, and lack of time and money (48). Therefore, the aim of **Chapter 7** was to evaluate the experiences and perspectives of regionally located pregnant women who participated in one arm of an Australian multisite weight management trial and gain better understanding of the mechanisms by which pregnancy and psychosocial factors influence GWG.

The study presented in **Chapter 7** was designed using a qualitative descriptive methodology including inductive thematic analysis techniques. Qualitative descriptive methods follow

traditional qualitative methodologies, employing purposive sampling techniques, gathering of interview or focus group data, with analysis performed by an inductive thematic and /or content analysis (160, 161). The qualitative descriptive methodology was additionally chosen for its ability to provide factual responses to questions about a phenomenon of interest within real world contexts (160). Five women consented to participate and provided individual interviews.

Two main themes were derived from the interview data: 1) Addressing weight in pregnancy, described the participants' experiences and perspectives of maternity care in relation to GWG; and 2) Pregnancy weight the balancing act, described the women's experience and perspectives of pregnancy-related symptoms and general experience of GWG. Both main themes were described through a series of sub-themes as follows: Theme 1 - Addressing weight gain in pregnancy: 'A moot point', 'a really important topic' and 'feedback and support'; and Theme 2 - Pregnancy weight the balancing act: 'early and late pregnancy symptoms' and 'a sensitive topic'. Overall, the analysis identified weight gain as an important topic that was of relevance and interest to pregnant women. The need for improvements with maternity care service delivery and dissemination of GWG information were evident. Responsive feedback on weight gain, clarity of purpose of routine weight-monitoring, the need for realistic support strategies, and referrals to specialist health care professionals were also identified **(Chapter 7)**.

Importantly, all women identified pregnancy symptoms occurring during early and late pregnancy as barriers to maintaining or initiating positive diet and physical activity weight-related behaviours. These findings are consistent with current literature on the topic (30, 48, 155) and indicate the need to broaden the scope of psychosocial screening for the detection of women at risk of EGWG. As suggested in **sections 8.2.5** and **8.2.6**, broadening the scope of psychosocial screening to include assessment for diet related self-efficacy (i.e. confidence in ability for diet related behaviour change), could further assist with the development of tailored health promotions strategies and referrals to specialist staff such as dietitians to provide meaningful support for women to achieve GWG targets and maintain health, whilst experiencing early and late symptoms of pregnancy. This suggestion is consistent with health behaviour maintenance theory that suggests when personal resources are depleted through fatigue, stress and sickness, a person's ability for behavioural regulation becomes limited (58). Moreover, women identified GWG as a sensitive topic requiring respectful care with the practice of routine weight-monitoring viewed by some participants as unhelpful and frightening. These results, coupled with the results presented in **Chapter 5,** further suggest that routine weight-monitoring may cause weight-related distress for some women.

The study presented in **Chapter 7,** followed the Consolidated criteria for Reporting Qualitative research (COREQ) guidelines (162). These guidelines specifically aim to improve the quality and transparency of reporting of qualitative studies that are derived from interview and/or focus group data (162). As this was derived from a small sample of pregnant women (n=5) findings are unable to be generalised, however these findings are consistent with the wider published qualitative literature. Future research should consider involving pregnant women with the co-design of interventions ensuring research meets the needs of the end users.

8.3. Overall Thesis Discussion

The following section provides an overall discussion of results presented within **Chapters 2 – 7**, in relation to addressing the overarching thesis aims: 1) To investigate the effectiveness of antenatal weight-monitoring as a health promotion strategy for optimising pregnancy weight gain; and 2) investigate the impact and influence of selected psychosocial factors on weight gain in pregnancy.

8.3.1. The effectiveness of antenatal weight-monitoring as a health promotion strategy for optimising pregnancy weight gain

The studies presented within **Chapters 2 and 3** and discussion of evidence presented within **section 8.2** of this chapter, have evidenced a paucity of studies investigating routine antenatal weighing (clinician or self-weighing) as a stand-alone intervention or as a behavioural (self-regulation) intervention, for the management of EGWG (1, 47). The available published studies when considered individually and when pooled together, have shown no statistical difference in EGWG between groups and no difference in associated adverse maternal and infant outcomes (1, 47, 167). Whilst routine maternal weight-monitoring is a feasible intervention scalable at the population level, requiring less time and resources compared to diet and physical activity interventions, its efficacy as a weight management strategy has not been established (1, 47). Of concern is the widespread re-introduction of the practice without consideration of the wider effects on maternal psychology.

The impact of routine antenatal weighing on maternal psychology is certainly not well understood. Dawes and Grudzinskas (1991) (76) have raised the prospect of antenatal weighing causing unnecessary distress for women without providing evidence to support this assertion. Brownfoot et al. (2016)(45) have attempted to quantify women's experience of weighing within

their RCT. Using separate purposive satisfaction surveys for the control (n=288) and interventions groups (n=298), findings indicated that less than half of women in the control group preferred not to be weighed in pregnancy with 73% of women in the intervention group indicating satisfaction with routine weighing (45). Daley et al. (2016) (95) reported qualitative findings from their pilot RCT evaluating routine weight-monitoring. Twelve women provided qualitative feedback on the intervention; of these 9 women commented that weighing was helpful for monitoring their weight gain with 8 participants indicating that they did not feel anxious about being weighed (95). A qualitative study of 10 women ascertaining the lived experience of weighing and weight management in pregnancy conducted by Allen -Walker et al.(2017) (175), reported that women thought routine weighing should be offered and is beneficial to all women. These authors discussed that their findings were supportive of results presented by Brownfoot et al. (2016) (45) and Daley et al. (2016) (95), suggesting that claims regarding weight-monitoring causing unnecessary maternal distress are unfounded (175).

A more recent feasibility study evaluating clinician weighing in a sample of 38 pregnant women receiving hospital or community midwifery care in Ireland, retrieved weight records for 26 participants (154). Of these, 3 (11.5%) had no weights recorded, 17 (65.4%) had between one and three weights recorded and six (23.1%) had more than four weights recorded between study commencement (approx. 18 – 20 weeks) and up to 40 weeks gestation. Five participants consented to providing individual interviews. Qualitative findings from this study suggested that women felt weighing was mostly positive and could be integrated into antenatal care; however no participants reported receiving information on GWG as a result of being weighed, bringing the application of the practice further into question (154).

To date assumptions that routine weighing is a benign practice with no negative effects are largely untested (45, 95, 154, 175). Qualitative findings presented in **Chapter 7**, suggested that routine weighing was perceived as being a potentially good conversational starting point for addressing weight gain in pregnancy, not a great reflection of GWG, and not a pleasant experience, with some women reporting being discouraged by the weight they were gaining. Moreover, descriptive results presented in **Chapter 5** revealed a proportion of women experienced embarrassment about their pregnancy weight gains (11%), felt embarrassed when clinicians weighed them (17%), and worried that they would get fat during pregnancy (30%). DiPietro et al. (2003) (176) found in their study that pregnant women who indicated negative attitudes towards pregnancy weight gains also exhibited higher levels of distress symptoms. When considering these findings in light of more recent literature such as an evident bi-directional relationship between BI dissatisfaction

and maternal psychology (depression and/or anxiety), as discussed in **Chapter 5**, it is possible that practices such as routine weighing indirectly cause weight-related distress for some women. Weighing may indirectly increase a woman's dissatisfaction with her BI, increasing her risk of experiencing weight-related distress, perinatal depression, and/or anxiety. Further consideration of these potential indirect effects is presented in **section 8.3.3**. Investigation of the psychological and behavioural effects of routine weighing using objective measures such as measures of BI as discussed in **Chapter 6**, may be useful as a proxy measure to detect risk of weight-related distress in pregnancy.

As described in **Chapter 1**, routine weighing is traditionally based in self-regulation theory. Self-regulation of weight gain outside of pregnancy provides feedback towards goal attainment such as weight loss or achieving a desired target weight (38, 40). Little is known of the mechanisms by which this is thought to work in pregnancy, particularly when weight gain is expected. Daley et al. (2019) (167) investigated weighing as a behavioural intervention and found no evidence to suggest weighing, as a self-regulation behavioural intervention, was an effective weight management strategy for use in pregnancy. It is therefore possible that routine weighing is an inappropriate behavioural weight management strategy for use in pregnancy (177). Self-regulatory failure, defined as failure to adhere to specific health behaviours, has been implicated in the development of maladaptive behavioural outcomes, such as obesity and diabetes, in the general population (177). There is an apparent mismatch between the behavioural intentions of routine weighing as a self-regulation strategy in pregnancy. For example, weight gain is characteristic of pregnancy, women have seemingly little control over their weight gain, and what control they do have can be mediated by pregnancy symptoms, body image dissatisfaction, maternal psychology, and low diet related self-efficacy, as discussed throughout this thesis. It is therefore plausible that where weight gain is inherent, such as in pregnancy, that repeated measurement of weight could contribute to self-regulation failure, manifesting in some women as weight-related distress, leading to the development of inappropriate weight gain (IGWG or EGWG). The results of the systematic review presented in **Chapter 2** (47) and the results of the most recent intervention study by Arthur et al. (2020) suggest, that weighing underweight women or daily weighing of pregnant women (any BMI) may contribute to less weight gains being exhibited during pregnancy when compared to usual antenatal care (168). Further investigation of these behavioural pathways is required to ensure the risks of routine weighing have been thoroughly considered.

8.3.2. The impact and influence of selected psychosocial factors on weight gain in pregnancy.

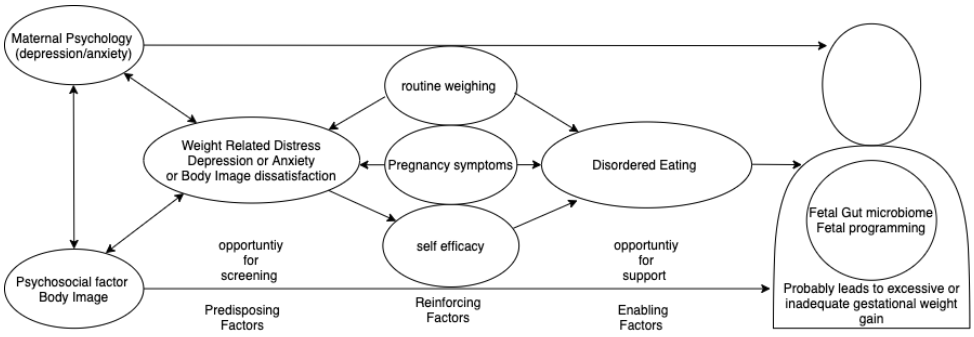
The relationships between psychosocial factors, pregnancy factors, and GWG are poorly understood. However, the studies presented within **Chapters 4-7** suggest that to meaningfully reduce the incidence of EGWG, both physiological and psychological health promotion strategies are required to promote overall maternal and infant health. **Chapters 4, 5 and 6** specifically have provided a body of research identifying a combination of selected psychosocial factors that are specific to pregnancy and are predictive of EGWG. Perhaps the most important discovery from this line of inquiry was that younger maternal age and BI dissatisfaction were significantly predictive of EGWG (138). **Chapters 4-6** have additionally made progress in addressing some of the methodological limitations associated with research in this area. Refining the WRB-Q into a brief questionnaire **(Chapter 6)** where all psychosocial constructs and questionnaire items have high predictive value for EGWG may go some way to address the heterogeneity of psychosocial factors and increasing the availability of pregnancy-specific instruments for broad research and clinical practice application. Furthermore, the study presented in **Chapter 7** suggests a direct relationship between early and late pregnancy symptoms and GWG. This finding is consistent with the wider literature on the topic and requires further empirical investigation.

8.3.3. Development of a conceptual pathway for understanding the complex relationships between body image dissatisfaction, maternal psychology and excessive gestational weight gain

Gestational weight gain is directly and indirectly affected by a woman's individual pregnancy experience and her wider psychosocial context **(Chapters 2-8)**. To date research has largely focused on unidimensional relationships between selected psychosocial factors and EGWG, with less focus on the potential indirect or mediating (barrier and enabler) relationships between selected factors (121). The study findings presented within this thesis **(Chapters 2-7)** and the additional discussion of evidence within this chapter, suggest an inter-relationship exists between body image dissatisfaction, maternal psychology (anxiety and/or depression), routine weight-monitoring, pregnancy symptoms, diet-related self-efficacy, and disordered eating symptoms, as contributors of EGWG. A conceptual model depicting these relationships is presented in **Figure 8.1.** Conceptual models describing theoretical relationships between psychosocial factors, including BI and GWG, have been proposed by Bergmeier et al. (2020) (121) and Hill et al. (2013) (50). To the best of the author's knowledge this is the first model to pragmatically consider both

pregnancy symptoms and health care interactions, such as routine weighing, as indirect mediators of BI dissatisfaction and EGWG. Developing a more carefully theorised understanding of the direct and indirect relationships between these factors may assist in guiding the development of tailored health promotion strategies and informing future clinical practice guidelines.

Figure 8.1 A conceptual pathway explaining the inter-relationships between maternal body image dissatisfaction, maternal psychology, routine weight-monitoring, diet-related self-efficacy, disordered eating and excessive gestational weight gain.



Maternal psychology and excessive gestational weight gain

Women are reported to be more susceptible to depressed mood and anxiety in general compared to men (178). During pregnancy women are more at more risk of experiencing depression and anxiety due to psycho-neurohormonal changes that take place across the perinatal period (59). Current statistics suggest that 1 in 5 women experience symptoms of anxiety with 1 in 10 women reporting symptoms of depression during pregnancy (31, 179). A systematic review and narrative synthesis by Hartley et al. (2015) (49), identified 4 studies examining the direct relationships between maternal psychology (anxiety and /or depression) and EGWG. Of these, 2 studies revealed statistically significant relationships between depression and EGWG. Bodnar et al. (2009) (180) in a small population of women from the USA (n=242), revealed a statistically significant relationship between depression and EGWG amongst overweight pregnant women (OR 3.2, 95% CI 1.2, 8.1, $p < 0.05$). Webb et al. (2009) (181) in a study of 1605 women from the USA, found high depression scores in early and mid-pregnancy to be associated with EGWG. No studies in this review revealed significant associations between anxiety and EGWG (49). In contrast, Molyneaux et al. (2016) (182) in a UK pregnancy cohort study (n=13,314), did not find significant relationships to exist between antenatal depression scores and EGWG. However, a more recent study by Braig et al. (2020) (183), amongst a German pregnancy cohort (n=748), did not detect a significant relationship between depression and GWG, but did observe high anxiety scores to be associated with higher GWG.

Riquin et al. (2019) (131) explain that research testing the relationships between maternal psychology and pregnancy outcomes may be limited due to women's fears of stigmatisation regarding mental health, suggesting that women intentionally moderate depression scale scores to avoid such judgements. Austin et al. (2017) (179), also suggest the prevalence of maternal anxiety and depression may be under estimated for these reasons. Additionally, the heterogeneity of depression and anxiety scales employed across studies have been identified as methodological limitations of research in this area (183). Further research is necessary to explore the relationships between maternal psychology and EGWG, particularly amongst cohorts of Australian pregnant women. Using nationally recognised and established screening tools, such as the Edinburgh postnatal depression scale, may assist to reduce methodological limitations.

Body image and excessive gestational weight gain

As reported in **Chapter 5,** direct temporal relationships have been consistently observed between BI dissatisfaction and EGWG (138). Systematic reviews by Kapadia et al. (2015) (52) and Hartley et al. (2015) (49) collectively identified 4 studies observing statistically significant relationships between BI dissatisfaction and EGWG. Roomruangwong et al. (2017) (126) similarly observed higher GWGs in women indicating dissatisfaction with their BI. Further research using valid and reliable measures of BI such as the WRB-Q, BI scale, as proposed within **Chapters 4,5,6 and section 8.2** of this chapter, may assist in overcoming current study limitations such as availability of pregnancy specific BI measures and time constraints, associated with the completion of traditional BI instruments (59, 121, 131).

Body image and maternal psychology and disordered eating

As discussed in **Chapter 5 and section 8.2** of this chapter, it is evident that a bi-directional relationship exists between BI and maternal psychology (depression and/or anxiety). Consistent temporal relationships have been demonstrated in systematic review literature between maternal depressed mood and BI dissatisfaction (130). Roomruangwong et al. (2017) (126) found an association between BI dissatisfaction and increased depression and anxiety scores amongst a small population of Thai women (n=126). Riquin et al. (2019) (131), in a French pregnancy cohort (n= 457), found depression to be 3 times greater in pregnant women with BI dissatisfaction compared to women satisfied with their body image. A more recent Australian study (n=408) conducted by Dryer et al. (2020) (59), found statistically significant associations between BI dissatisfaction and perinatal depression and anxiety. Additionally, Dryer et al. (2020) (59)

observed a direct relationship between BI dissatisfaction, and disordered eating symptoms. Disordered eating symptoms, including bulimic behaviours and high caloric intake, have been independently associated with BI dissatisfaction and maternal psychology (59, 121, 131). Therefore, as presented in **Figure 8.1,** the findings and discussion presented in this thesis suggest the existence of a prospective relationship between BI dissatisfaction, maternal psychology, and disordered eating symptoms, manifesting as inappropriate GWG (IGWG and EGWG). Further research is required to confirm these relationships.

Indirect relationships between, routine weighing, pregnancy symptoms, and diet-related self-efficacy

The study presented by Dryer et al. (2020) (59) investigating the direct relationships between body image, maternal psychology and disordered eating, additionally sought to investigate the indirect mediating effects of "Fat Talk", defined as the self-derogatory interpersonal talk between peers and family members such as "I'm fat … no you're not …". Findings from this analysis found "fat talk" to partially mediate (significant direct effect) BI dissatisfaction, depression, pregnancy related anxiety and disordered eating symptoms (59).

Weight stigma remains prevalent amongst health professionals (59, 151) and qualitative studies of pregnant women have further described their experiences of GWG while interacting with health care professionals as stressful, confusing and judgmental (48). Additionally, qualitative findings reported in **Chapter 7**, suggest that weight gain is a sensitive topic requiring respectful care with results presented in **Chapter 5** observing that a proportion of women feel embarrassed by their weight gain when being weighed (138). It is possible that perceived negative health care interactions, coupled with negative attitudes towards, or experiences of, routine clinician weighing cause weight-related distress and act as indirect mediators of BI dissatisfaction.

Davies et al. (2012) (184) discussed that although the relationship between maternal distress and EGWG are not fully understood, higher stress levels have been associated with higher BMIs compared to pregnant women reporting lower stress levels. Given the prevalence of women exceeding weight gain targets, it is hypothesised that weight-related distress arising from negatively perceived clinical practice interactions, indirectly mediates BI dissatisfaction, maternal psychological symptoms, and disordered eating symptoms affecting GWG. Demographic factors such as younger age, as identified in **Chapter 5**, may further mediate these interactions putting some women at increased risk for EGWG.

Moreover, the findings from **Chapter 7** suggest potential direct and indirect relationships between pregnancy symptoms, disordered eating symptoms, and GWG. As discussed in **Chapter 7** and **section 8.2** of this chapter, pregnancy symptoms have been consistently viewed as barriers to maintaining or initiating positive diet-related behaviours. Women with early pregnancy symptoms such as nausea, vomiting, and food aversions, as indicated in the qualitative findings presented within **Chapter 7**, might exhibit disordered eating symptomology. The model therefore suggests that women indicating BI dissatisfaction, who experience early or late pregnancy symptoms, are at risk of disordered eating, resulting in IGWG or EGWG.

Self-efficacy, the measurement of a person's ability or confidence to make a behaviour change has consistently been associated with weight management success outside of pregnancy (54). High perceived self-efficacy scores suggest an increased likelihood of, and motivation for, engaging in behaviour change (56). Findings from the univariate analysis conducted in **Chapter 6,** suggested that women who indicated low levels of diet-related self-efficacy, were at risk of experiencing EGWG. When considered within the model (Figure 8.1), low diet-related self-efficacy could indirectly mediate BI dissatisfaction, maternal psychology, disordered eating and GWG. Low weight-related self-efficacy has been associated with higher BMI and higher BI dissatisfaction in non-pregnant populations of women (185). Further research such as well-designed prospective longitudinal cohort studies enriched by participants qualitative experience and perspectives data, is required to test these hypotheses presented within the conceptual model.

Opportunity for Screening / Opportunity for support

The conceptual model presented in Figure 8.1 was guided by Predisposing, Reinforcing, and Enabling Constructs in Educational and Environmental Diagnosis and Evaluation (PRECEDE) / Policy, Regulatory and Organisational Constructs in Educational Environmental Development (PROCEED), theory of health promotion (101). As presented in **Chapter 1,** the PRECEDE /PROCEED model provides a framework for the development of comprehensive health promotion interventions (170). The model is essentially a stepwise process that takes a broad look at a population of interest and considers an individual's own social-ecology as influencing behaviour, that may then be changed or mitigated (170). Psychosocial factors are considered important predisposing, reinforcing and enabling factors and possible areas of interest for targeted interventions, with the identification of these factors considered a vital but often difficult part of the process (170). Predisposing factors are considered antecedents to, or motivators for, engagement in particular behaviours (57). Reinforcing factors generally are those that either help

or hinder motivation and intention for behaviour change, with enabling factors the direct precursors that help or hinder goal attainment (53, 57).

As discussed in **Section 8.2** of this chapter it is suggested that the scope of current psychosocial screening practices be broadened to include the detection of women at risk of BI dissatisfaction. Body image dissatisfaction is emerging as an important "predisposing" psychosocial factor predictive of maternal psychology (anxiety and depression), disordered eating symptoms, and EGWG (121, 138). Perceived negative attitudes towards pregnancy weight gain and routine weighing, as well as symptoms of pregnancy and diet-related self-efficacy may be important "reinforcing" factors potentially capable of mediating satisfaction with BI, maternal psychology, and eating behaviour. Eating behaviour is considered the "enabling" factor within the model, being the direct precursor to GWG outcomes. Therefore, it is suggested that an ideal opportunity for support lies with early psychosocial screening for BI dissatisfaction and diet-related self-efficacy, by using pregnancy specific instruments such as the short-form presented within **Chapter 6**. The early identification of women at risk of BI dissatisfaction and assessment of diet-related self-efficacy at the maternal booking appointment (occurring generally between 18 – 20 weeks gestation) (31), may provide the opportunity for timely referral to allied health professionals for the development of tailored health promotion strategies that address these factors. Guidelines such as these may meaningfully support women to make positive weight-related behaviour changes (physiologically and psychologically) and may also assist women to achieve healthy GWG.

8.4. Overall Strengths and Limitations

This thesis by publication has presented 6 individual but linked papers incorporating varied research designs and methodologies. The strengths of this body of work include new and incremental knowledge gains being added to the evidence base as a result of this thesis. In particular, routine maternal weight-monitoring was identified as an ineffective pregnancy weight management strategy, particularly amongst populations of Australian pregnant women. BI dissatisfaction was found to be predictive of EGWG. Negative attitudes towards weight gain and low diet related self-efficacy were also evidenced to have high predictive value for EGWG. The groundwork for the development of a pregnancy-specific instrument for measuring selected psychosocial factors predictive of EGWG was undertaken, with a short-form questionnaire being developed to address current methodological limitations with additional clinical practice

application. Lastly, a conceptual pathway detailing complex direct and indirect relationships between selected psychosocial factors and EGWG, arising from this thesis, was developed.

Methodological limitations have been acknowledged throughout each chapter. Overall, the major limitation of the systematic review presented within **Chapter 2** was the lack of studies available for meta-analysis. The 2 included RCTs were both conducted within Australia; therefore, the efficacy of routine weighing as a weight management strategy is largely unknown and unable to be generalised to other populations. The design and analysis of studies presented within **Chapters 4-6** were limited by the use of WATCH study data, collected between June 2006 and December 2007. These studies were informed by relatively small and culturally homogenous population samples (n=159). Qualitative findings presented in **Chapter 7** were also limited by the small sample size (n=5). All studies require caution with interpretation and are not generalisable outside of their study populations.

8.5. Recommendations for future research

Current evidence suggests that routine antenatal weighing, as stand-alone or self-regulation intervention, may not be effective for weight management in pregnancy, particularly within high income countries such as Australia and the UK. Less is known about the efficacy of the practice as a weight management strategy amongst other global populations of pregnant women. Moreover, GWG is relevant to pregnancy outcomes; EGWG is associated with large for gestational age infants with IGWG associated with small-for-gestational-age infants (7). It remains unclear if routine weighing could be an effective screening tool for the detection of adverse pregnancy outcomes such as large and small birth weight infants. Further testing of the efficacy of routine weighing, as a weight management strategy and pregnancy screening tool, within high income countries should be considered. In particular routine weighing as a weight management strategy should be considered outside routine antenatal care, to include alternative care models such as midwifery continuity of care, whereby a known midwife forms a therapeutic relationship with and provides care to a woman within her social context across the childbearing continuum (186, 187).

Given the widespread re-introduction of routine antenatal weight-monitoring following the recommendations made in the most recent Australian pregnancy care guidelines (31), further research is required to ascertain the acceptability of weighing amongst women and clinicians using both qualitative and quantitative techniques. Qualitative techniques may assist in

ascertaining clinician attitudes towards addressing pregnancy weight gain and routine maternal weight-monitoring and with addressing gaps in service provision.

Developing a better understanding of the psychological effects of routine clinician weighing is urgently required. The design and conduct of observational studies using valid and reliable measures of distress, such as anxiety and depression scales and/or measurements of satisfaction with body image (as a proxy measure of weight-related distress), may assist to improve maternity care in a holistic way.

The analysis of the WRB-Q and development of a short-form has identified selected psychosocial factors predictive of EGWG. Further testing of the short-form is now required amongst a large and independent sample of Australian pregnant women. The use of confirmatory factor analysis techniques is recommended, to determine the validity and reliability of the short-form and allow for generalised use of the instrument amongst cohorts of Australian pregnant women.

The analysis of selected psychosocial factors using the WATCH study data has provided further insight into the complex nature of the relationships with GWG. Body Image dissatisfaction seems to be an important direct predictor of EGWG. Therefore, further research should be conducted to ascertain the feasibility of implementing body image screening as a risk assessment measure for EGWG. Feasibility studies can assist to identify potential barriers to upscaling an intervention at the population level. Qualitative studies ascertaining women's experience and practitioner experience and perceptions of BI screening are also recommended. Further research is additionally recommended to design and test tailored health promotion interventions that address body image dissatisfaction and support women to optimise their dietary intake during pregnancy.

The qualitative analysis presented within **Chapter 7** identified a possible relationship between the onset of pregnancy symptoms and development of EGWG. Further studies should focus on the development of objective measurements of pregnancy symptoms for the future testing of these relationships as predictors of EGWG. Given these findings, it is also recommended that pregnancy screening additionally seek to ascertain self-efficacy for diet-related behaviour to ensure appropriate diet-related support strategies.

A conceptual model detailing direct and indirect relationships between body image dissatisfaction, maternal psychology, discorded eating symptoms, and EGWG has been proposed. Further research is required to test hypotheses arising from this model, by using techniques such

as mediation analysis, to further develop our understanding of the complex relationships between psychosocial factors and GWG in pregnancy.

8.6. Concluding Remarks

Supporting women to achieve healthy weight gain in pregnancy is a complex and multifactorial phenomenon. Weight gain is characteristic of normal fetal growth and pregnancy progression, except when it is considered inadequate or excessive. To date, the dominant physiological energy in / energy out approaches to weight management such as diet and exercise interventions have shown moderate effectiveness for optimising healthy weight gain within controlled trials. However, translation of these interventions into real world maternity care practice has been met with professional, organisational, and psychosocial barriers, with no clear guidance on how best to support women to achieve healthy gestational weight gain.

Pregnant women continue to gain weight outside of the limits of the American Institute of Medicine's gestational weight gain guidelines (widely cited and adopted as pregnancy weight gain reference values internationally). Proportionally, women are more likely to gain weight above the gestational weight gain guidelines than below; however, both inadequate and excessive weight gain pose risks to the pregnancy and beyond. In the short-term women are at increased risk of pregnancy related disease including pre-eclampsia and gestational diabetes, small and large for gestational age infants, and caesarean section. Perhaps of most concern, though still being teased out, are the long term, intergeneration health implications of inadequate gestational weight gain.

Increasingly, and in the absence of clear evidence, routine antenatal weight-monitoring is being suggested as an intervention to assist women to meet gestational weight gain targets. Evidence currently does not support weight-monitoring as a weight management strategy, with effects on maternal psychology largely being unknown. Routine weighing for the collection of weight gain data, relevant to pregnancy and birth outcomes such as infant birth weight, gestational diabetes, hypertension, and mode of birth require exploration. However, it is becoming more apparent that to optimise pregnancy weight gain, broad socio-ecological approaches to health promotion are required. Weight gain in pregnancy is directly and indirectly affected by a woman's individual pregnancy experience and her wider psychosocial context. Body image dissatisfaction is one psychosocial factor that has consistently been shown to be predictive of EGWG. Pregnancy is considered an opportune time for health promotion engagement, with women seemingly

motivated to engage in health behaviours for the benefit of their infants. Broadening current psychosocial screening to include detection of body image dissatisfaction, negative attitudes toward pregnancy weight gain, and diet-related self-efficacy, provides opportunity for the development of health promotion strategies that better support women both psychologically and physiologically to optimise their pregnancy weight gain. The longer term aim is to improve clinically relevant pregnancy and birth outcomes, with better health tracking over the life course.

Reference List

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APPENDICES

A1. Published manuscript "Weighing as a stand-alone intervention does not reduce excessive gestational weight gain compared to routine antenatal care: A systematic review and meta- analysis of randomized controlled trials"

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RESEARCH ARTICLE Open Access

Weighing as a stand-alone intervention does not reduce excessive gestational weight gain compared to routine antenatal care: a systematic review and meta-analysis of randomised controlled trials

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Abstract

Background: Excessive gestational weight gain is associated with short and long-term adverse maternal and infant health outcomes, independent of pre-pregnancy body mass index. Weighing pregnant women as a stand-alone intervention during antenatal visits is suggested to reduce pregnancy weight gain. In the absence of effective interventions to reduce excessive gestational gain within the real world setting, this study aims to test if routine weighing as a stand-alone intervention can reduce total pregnancy weight gain and, in particular, excessive gestational weight gain.

Methods: A systematic review and meta–analysis of randomised controlled trials (RCTs) was conducted between November 2014 and January 2016, and reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Seven databases were searched. A priori eligibility criteria were applied to published literature by at least two independent reviewers. Studies considered methodologically rigorous, as per the Academy of Nutrition and Dietetics Quality Criteria Checklist for Primary Research, were included. Meta-analysis was conducted using fixed-effects models.

Results: A total of 5223 (non-duplicated) records were screened, resulting in two RCTs that were pooled for meta-analysis ($n = 1068$ randomised participants; $n = 538$ intervention, $n = 534$ control). No difference in total weight gain per week was observed between intervention and control groups (weighted mean difference (WMD) -0.00 kg/week, 95% confidence interval (CI) -0.03 to 0.02). There was also no reduction in excessive gestational weight gain between intervention and control, according to pre-pregnancy body mass index (BMI). However, total weight gain was lower in underweight women ($n = 23$, BMI <18.5 kg/m^2) in the intervention compared to control group (−0.12 kg/week, 95% CI −0.23 to −0.01). No significant differences were observed for other pregnancy, birth and infant outcomes.

Conclusion: Weighing as a stand-alone intervention is not worse nor better at reducing excessive gestational weight gain than routine antenatal care.

Keywords: Antenatal care, Gestation, Pregnancy, Weighing, Weight gain

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Background

Obesity has dramatic effects on reproductive health with complications during pregnancy and at birth all the more prevalent in those carrying excess weight [1]. Globally obesity is more prevalent than undernutrition [2]. The World Health Organisation (WHO) estimates that over 1.9 billion adults (≥18 years) are overweight and 600 million obese [3]. In Australia, 63% of adult women (≥18 years) are reported to have a body mass index (BMI) in the overweight (25.0–29.9 kg/m^2) or obese (≥30.0 kg/m^2) categories [4]. For women who gave birth in Australia, the most recent Mothers and Babies report (2013) shows that one-fifth (19%) of pregnant woman were classified as obese at the beginning of pregnancy with one quarter (24%) overweight [5].

The risks of entering pregnancy obese are well documented [1, 6]. Excessive gestational weight gain (EGWG) as defined by the American Academy of Sciences Institute of Medicine (IOM) is also an independent predictor of adverse pregnancy and birth outcomes [6, 7]. The IOM weight gain guidelines devised in 1990 and revised in 2009 are the most widely cited guidelines for gestational weight gain [8, 9]. In the absence of Australian-based gestational weight gain guidelines, the IOM guidelines have been largely adopted as the standard reference [10, 11]. These guidelines recommend that women who are underweight at the beginning of pregnancy gain more weight than women who are overweight or obese [9].

Weight gain in excess of the IOM guidelines has been associated with both short and long term health risks, including pre-eclampsia, gestational diabetes, caesarean section, large for gestational age infants, postpartum weight retention and childhood obesity [12–14]. Evidence suggests that it is more common for women to gain weight above the IOM guidelines than within or below. In a large retrospective cohort study in the United States (n = 20,456), Stotland et al. [14] observed that more women gained above the IOM guidelines (43%) compared to those that gained within (37%) or below (20%). An Australian prospective cohort study of pregnancy weight gain (n = 664) similarly found 38% of women gained in excess of the IOM weight gain ranges [15]. Fifty-six percent of women who were overweight and obese (BMI ≥25 kg/m^2) had EGWG compared to 30% of women with a BMI <25 kg/m^2 [15]. Furthermore, in the majority of studies included in a recent systematic review, 47–72% of obese women had EGWG according to the IOM ranges [16].

Addressing EGWG has become a public health priority. Intervention studies have primarily focused on diet and physical activity either alone or in combination [17]. The most recent Cochrane review identified 65 randomised controlled trials (RCTs) of diet and/or exercise interventions. In an analysis of 24 included trials (n = 7096) diet, exercise or both in combination reduced EGWG on average by 20% (average risk ratio (RR) 0.80, 95% confidence intervals (CI) 0.73 to 0.87). However no differences were observed for the adverse outcomes of pre-eclampsia, infant macrosomia (birth weight >90th centile) or caesarean birth [17].

In the real world setting there are substantial barriers to upscaling diet and exercise interventions at the population level. These include limited access to specialist staff, time constraints, financial implications and motivation to engage in such interventions as part of clinical practice [18].

One gestational weight gain intervention that is feasible at a population level (i.e. low cost and easy to administer) is weighing during routine antenatal care. The schedule of antenatal care appointments consisting of 7–12 regular visits for low risk women with maternal health care providers, presents an opportunity for health promotion interventions to be trialled. The visits additionally provide a window of opportunity for potential behaviour change and lifestyle modification [19, 20]. A recent pilot study evaluating the feasibility of regular weighing in the context of routine antenatal care reported that weighing took on average 1–2 min of a midwife's time, was simple to do, and did not significantly add to midwives existing workloads [21]. A qualitative analysis of pregnant women's experience of routine weighing reported that weighing during antenatal appointments was an acceptable intervention that when introduced did not cause distress or anxiety [22].

The stand-alone practice of weighing in the field of weight management has been successful in aiding non-pregnant adults achieve weight loss, weight maintenance and prevent weight gain as a self-monitoring/self-regulation strategy [23–25]. However, this has not been demonstrated in pregnancy. Weighing was originally introduced during the 1940's as a vital sign of pregnancy, considered useful for the detection of low birth weight infants and pre-eclampsia [26]. Weighing declined in practice during the 1990's and ceased to be recommended as a sign for adverse pregnancy outcomes by the British National Institute of Health and Care Excellence (NICE) in 2003, due to a deficit in evidence that it was an effective screening tool [26–29].

The practice of weighing is limited to the first antenatal visit in Australia and the United Kingdom for the purposes of calculating an early pregnancy BMI [11, 30]. The risks and prevalence of women entering pregnancy obese and exceeding the IOM gestational weight gain guidelines have caused health care providers necessary concern and led to develop the development of antenatal care pathways, recommending a return to weighing during all antenatal care visits [6, 31].

Therefore, this systematic review aimed to summarise the body of high quality evidence and determine any effect of routine antenatal weighing as a stand-alone intervention to reduce pregnancy weight gain and, in particular, prevent EGWG.

Methods

This review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) [32].

Search strategy

An a priori review protocol and eligibility criteria were devised, with consideration given to the research question, study design, population, intervention and outcomes (see Additional file 1). An electronic search of seven databases was conducted, including Medline, Embase, Maternal and Infant Care (via Ovid; http://www.ovid.com/), Cumulative Index to Nursing and Allied Health Literature (CINAHL) (via EBSCO http://www.ebsco.com/cinahl), Scopus (via http://www.scopus.com), Web of science (http://apps.webofknowledge.com) and the Cochrane library (via http://www.cochranelibrary.com).

The initial search was conducted in November 2014 with the assistance of a research librarian (DB) using the following keywords and Boolean operators: "pregnant" OR "pregnancy" AND "weight gain" OR "weighing" AND "randomised controlled trial" OR "clinical trial" OR "random*" (see Additional file 2). All searches were limited to English language and to human studies. No date limits were applied. The Cochrane Library was searched separately to identify any previously conducted systematic reviews in the area. The search was updated in January 2016 to ensure recent evidence was captured (see Additional file 3). The database search results were exported into reference management software.

Study selection

In the first round, publication titles and abstracts were screened independently by at least two reviewers (SMF, RMT, AJH) according to inclusion and exclusion criteria outlined in Table 1. Articles not meeting the eligibility criteria were screened out in the order of (i) study design, (ii) population, (iii) intervention, and (iv) outcome. Articles that met the eligibility criteria were retrieved as full texts and further reviewed by SMF and RMT. Any disagreements in the selection of studies were discussed with consensus achieved. The reference lists of retrieved studies and relevant Cochrane systematic reviews were hand searched for any relevant article not detected by the primary electronic search strategy.

Quality assessment

Articles considered eligible for inclusion were assessed for methodological quality using the Academy of Nutrition and Dietetics Quality Criteria Checklist for Primary Research [33]. Cochrane suggests, it is preferable to use simple approaches for assessing validity that can be fully reported (i.e. how each trial was rated on each criterion) [34]. Similar to the Cochrane Collaboration's tool for assessing risk of bias in each included study, the Academy of Nutrition and Dietetics Quality Criteria Checklist for Primary Research tool requires judgement about risk of bias to be made within each domain and support for the judgement with sufficient detail for potential sources of bias [34]. Two independent reviewers (SMF, RMT) undertook the assessments with a third reviewer (AJH) mentoring the reviewers through the process.

Table 1 Inclusion/Exclusion Criteria

Inclusion criteria	Exclusion criteria
Randomised control trials with the intervention of any weight measurement, self-recorded or recorded by any health professional	Studies published in languages other than English Studies that are not randomised control trials
Studies that included pregnant women with a singleton pregnancy, of any age, weight, body mass index, without date limits	Studies in animals Multiple pregnancies
Studies that used more than one episode of weight measurement during pregnancy	Poor methodological quality studies
Neutral or good methodological quality studies	

The quality checklist for primary research includes ten 'scientific validity' questions; four of which must be satisfactory to gain a positive rating (Q2 - bias, Q3 – comparable groups, Q6 - intervention, Q7 - outcomes) [33]. Answers were supplied as either "YES" meeting the criteria, "No" not meeting the criteria, or "Unclear" if the criteria was not clearly described. Articles were rated as positive (+) if the validity questions 2, 3, 6, 7, and at least one additional question were answered as "YES"; negative (−) if "No" was answered for 6 or more of the validity questions; or neutral ( ) if answers to questions 2, 3, 6, or 7 did not indicate that the study was exceptionally strong [33]. Quality assessments of included studies are presented in the results.

Data extraction

Relevant data were extracted by two reviewers (SMF, AJH) and entered into a Microsoft Excel spreadsheet. Data included: authors, year of publication, sample size, population characteristics, intervention and duration of the study, measures of compliance and outcomes. Weight gain outcomes included: total gestational weight gain (kg), gestational weight gain by pre-pregnancy BMI (kg/wk), and EGWG according to IOM guidelines.

Pregnancy, infant and birth outcomes included: infant birth weight, macrosomia (>90th centile), intrauterine growth restriction (<10th centile), instrumental birth, caesarean birth, combined pregnancy induced hypertension (PIH) and pre-eclampsia (PE), gestational diabetes mellitus (GDM), infant hypoglycaemia, and Apgar <7 at 5 min.

Statistical analysis

Meta-analysis was conducted using the mean and standard deviation for continuous outcomes and counts for categorical outcomes. A fixed-effects model using inverse variance weights was conducted. Fixed-effect models weight studies according to the amount of information they contribute, whereas random-effects models incorporate an estimate of between-study variation (heterogeneity) in the weighting. The fixed-effect assumption is that the true treatment effect is the same in each study, despite any differences in study protocols [35]. We believe a fixed effect model is appropriate as larger studies should be given more weight than smaller ones, and as there are few studies used in our meta-analysis, using a random effects model would provide poor estimates of the distribution of the intervention effects.

Forest plots with unstandardised effect size are reported for continuous variables using weighted mean difference (WMD) and 95% confidence intervals. Categorical outcomes are reported as odds ratios (OR). BMI outcomes were combined across studies to form a single outcome. Test of significance were set at the $p < 0.05$ level with all statistical analyses programmed using Stata Statistical Software [36].

Results

Search results

A flowchart detailing the screening and selection of studies is shown in Fig. 1. The broad search identified 6465 articles ($n = 5223$ after removal of duplicates). Initial screening of the title and abstract excluded 4067 articles. Two full text papers were then assessed and both were eligible for quality checking and meta-analysis. Hand searching did not identify any further articles for assessment.

Study characteristics

The characteristics of studies included in this review are outlined in Table 2. Briefly, both studies were conducted in Australia. The study populations were women of any parity with singleton pregnancies enrolled during early pregnancy. Two types of weighing interventions were trialled. Jefferies et al. [37] used a self-weighing regime where women were instructed to record and document their own weight at 16, 20, 24, 28, 30, 32 and 36 week's gestation. The control group were weighed at recruitment (≤14 week's gestation) and at 36 week's gestation. Both groups received standard antenatal care [37]. The second study by Brownfoot et al. [38] trialled the intervention of clinician weighing of pregnant women during scheduled antenatal care visits. The control group were weighed at the time of recruitment into the study (<21 weeks gestation) and again at 36 weeks gestation only [38]. Both groups received standard antenatal care following the participating hospitals guidelines. Both studies used an intention-to-treat analysis but had low loss to follow-up (<9%).

Study quality

A summary of the quality assessment is presented below in Table 3.

Both studies answered "Yes" to all relevance questions. Of the four validity questions, the study by Jefferies et al. [37] received a "NO" for question 6, with reviewers questioning participant compliance with the intervention and validity of instruments within the intervention group. The corresponding author of the paper was contacted seeking additional information and clarification, however, no further information could be provided. This paper received a neutral quality rating with a score of 9 out of a possible 10 [18].

The second study conducted by Brownfoot et al. [38] reported sufficient information within their publication receiving a "YES" for all scientific validity questions. The paper gained a total score of 10 and received a positive quality rating.

Analysis results

Meta-analysis of continuous outcomes is displayed in Fig. 2. There was no difference in total gestational weight gain between the intervention ($n = 494$) and control groups ($n = 483$). In the sub-group analysis of weight gain by BMI category a statistically significant difference was found for underweight women. The amount of weight gained in underweight women was 0.12 kg/week ($n = 23$, $p = 0.040$) less in the intervention group compared to control.

There were no differences in the total proportion of women exceeding the IOM weight gain ranges between intervention ($n = 290$) and control ($n = 230$): OR 1.10 (95%CI, 0.81 to 1.50). Data on EGWG by BMI category are presented in Fig. 3 and show no differences in the intervention and control groups.

For all secondary pregnancy and birth outcomes (including birth weight on Fig. 2) no significant differences were found between intervention and control as per Fig. 4.

We performed a post-hoc power calculation to determine the minimum detectable difference in total gestational weight gain for the pooled total of 977 participants, distributed approximately evenly between intervention

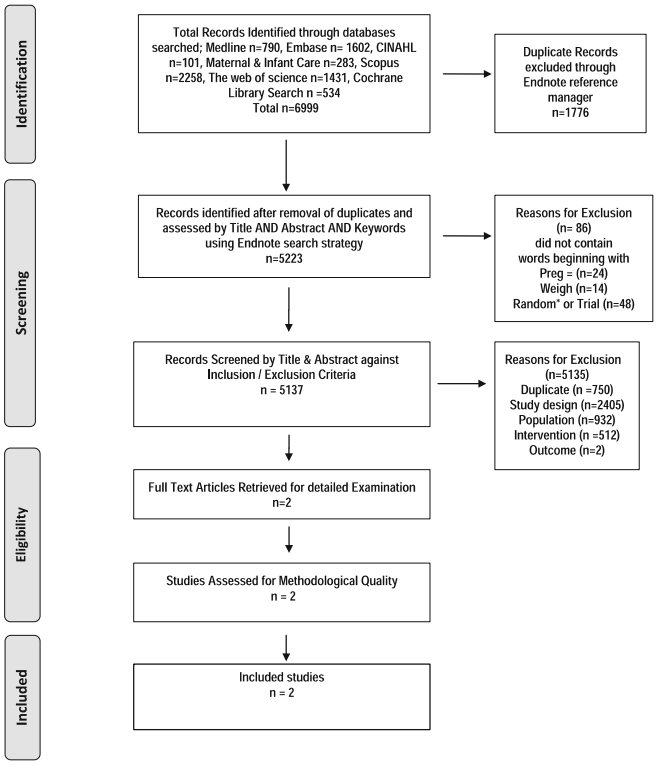

Fig. 1 Study Selection Flowchart. Flow chart adapted from Adapted From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6 (6): e1000097. doi:10.1371/journal.pmed100

and control groups. The minimum detectable difference was approximately 735 g in total gestational weight gain (~20 g per week), with 80% power, $\alpha = 0.05$, and SD ± 4.1 kg [37].

Discussion

This systematic review of RCTs aimed to determine the evidence base for weighing as a stand-alone intervention to reduce pregnancy weight gain and prevent EGWG. Two RCTs were retrieved and meta-analysed. Together they suggest that weighing, as a stand-alone intervention during routine antenatal care, is no better at reducing total pregnancy weight gain or preventing weight gain in excess of the IOM weight gain ranges than routine antenatal care.

A statistically significant lower rate of gain (kg/wk) was observed in women in the underweight BMI category between intervention and control. This finding should be interpreted with caution as it was derived from a BMI group that only included 23 women and due to multiple comparisons across BMI sub-groups could be due to random chance alone. However, it is also plausible that underweight women may be more sensitive to weighing and this practice may have an impact on their rate of weight gain.. Nohr et al. [39], in a large Danish birth cohort study ($n = 60,892$), determined that women who were categorised as underweight at the beginning of pregnancy (BMI <18.5 kg/m2) who had lower rates of GWG (<10kgs) were found to be more at risk of giving birth to small for gestational age infants (OR 1.9, 95%CI 1.7 to 2.1) [39]. Based on the existing evidence the IOM in 2009 recommended that underweight women should gain towards the upper limits of the weight gain ranges specifically to prevent small for gestational age infants [40].

Table 2 Characteristics of included studies

Author(s), Year Study, Title, Design, & Country	Aim, quality rating	Population characteristics	Intervention, duration of study	Compliance measure(s)	Outcome(s)	Conclusions	Limitations
Jefferies, K., Shub, A., Walker, SP., Hiscock, R & Permezel, M. 2009, Reducing excessive weight gain in pregnancy: a randomised controlled trial. RCT, Melbourne, Australia.	To assess the effect of regular weight measurements and advice about the recommended (IOM 1990) weight ranges on gestational weight gain (GWG). Neutral (–)	Pregnant women recruited before ≤14 week's gestation. Age >18 years.,<45 years., singleton pregnancy. English speaking, no pre-existing Type1 or 2 diabetes Intervention (I_1) $n = 148$ (–23), Control (C) $n = 138$ (–27)	(I_1) Weight measurements + advice compared to standard antenatal care (C). BMI calculated at first antenatal visit and advice on optimal weight gain given as per IOM 1990 guidelines. I_1 self-weighing recorded on participants own antenatal card at first visit, 16, 20, 24, 28, 30, 32, 34 and 36 weeks. (C) Weighed at first visit and at 36 weeks only.	(I_1) Weight self-recorded on personalised measurement card (tabular or graphical), using scales at hospital or participant's home until 34 weeks (I_1) + (C) weighed at recruitment & 36 weeks on hospital scales.	Mean difference in weight gain (Kgs/week) and between BMI subgroups. Total weight gain and proportion gaining in excess of the IOM 1990 weight gain guidelines. Maternal & neonatal pregnancy and birth complications	No difference in total weight gain Kgs/week) between (I_1) and (C). A statistically significant reduction in GWG (Kgs/Week.) between (I_1) and (C) in overweight BMI subgroup only (mean difference of 0.12 kg/week (95% CI, 0.03 to 0.22), $p = 0.01$.	Weight measurements were largely self-reported based on home and hospital scales. There was no measure of participation compliance with the (I_1). A small sample size was used with inadequate power to detect differences between groups for weight gain above IOM 1990 guidelines, pregnancy and neonatal complications.
Brownfoot, FC. Davey, MA. & Kornman, L. 2016 Routine weighing to reduce excessive antenatal weight gain: A randomised controlled trial. RCT Melbourne, Australia.	To assess the effect of clinician weighing at each antenatal visit with advice on a ppropriate GWG using the IOM 2009 weight gain in pregnancy guidelines. Positive (+)	Pregnant women recruited <21 weeks gestation. Age >18 years <45ys, singleton pregnancy. English speaking, no co morbidities or substance abuse identified. Intervention (I_1) $n = 386$ (–17), Control (C) $n = 396$ (–24)	(I_1) Weight recorded by a clinician at each antenatal appointment and documented in hospital antenatal record. The treating clinician encouraged to discuss weight gain (no scripted responses used). (C) Routine antenatal care including advice of appropriate weight gain within the IOM 2009 ranges. Both groups weighed at recruitment with BMI calculated. The (C) weighed again at ≥36 weeks gestation.	(I_1) Weight documented in hospital antenatal records at appointments by attending clinicians. (C) Weighed at recruitment and ≥ 36 weeks only and documented on hospital antenatal record. Data collected from the antenatal hospital record, mean frequency of weight measurements reported for both groups.	Mean difference in weight gain per week (Kgs/week) and between BMI subgroups. Proportion gaining within, less than and more than the IOM 2009 weigh gain ranges. Maternal & neonatal pregnancy and birth complications	No statistically significant differences reported in mean weight gain per week (I_1) 0.54 kg (±0.28) & (C) 0.53 kg (±0.24) $p = 0.63$ ($p = 0.05$). No difference in proportion of women gaining weight within, less than or more than IOM 2009 guidelines. No differences between groups for all neonatal and maternal complications.	Study not powered to detect a between group differences for all maternal and neonatal pregnancy and birth complications reported.

Table 3 Summary of the quality assessment for the included studies

First author, year of publication (reference)	Jefferies et al. 2009 [37]	Brownfoot et al. 2016 [38]
Validity questions		
1. Was the research question clearly stated?	Y	Y
2. Was the selection of study subjects/patients free from bias?	Y	Y
3. Were study groups comparable?	Y	Y
4. Was method of handling withdrawals described?	Y	Y
5. Was blinding used to prevent introduction of bias?	Y	Y
6. Were intervention/exposure factor or procedure and any comparison(s) described in detail?	N	Y
7. Were outcomes clearly defined and the measurements valid and reliable?	Y	Y
8. Was the statistical analysis appropriate for the study design and type of outcome indicators?	Y	Y
9. Were conclusions supported by results with biases and limitations taken into consideration?	Y	Y
10. Is bias due to study's funding or sponsorship unlikely?	Y	Y
Overall quality	N	P

American Dietetic Association Quality Criteria Checklist for Primary Research, *Y* yes, *N* no,
P, positive rating; *N* neural rating

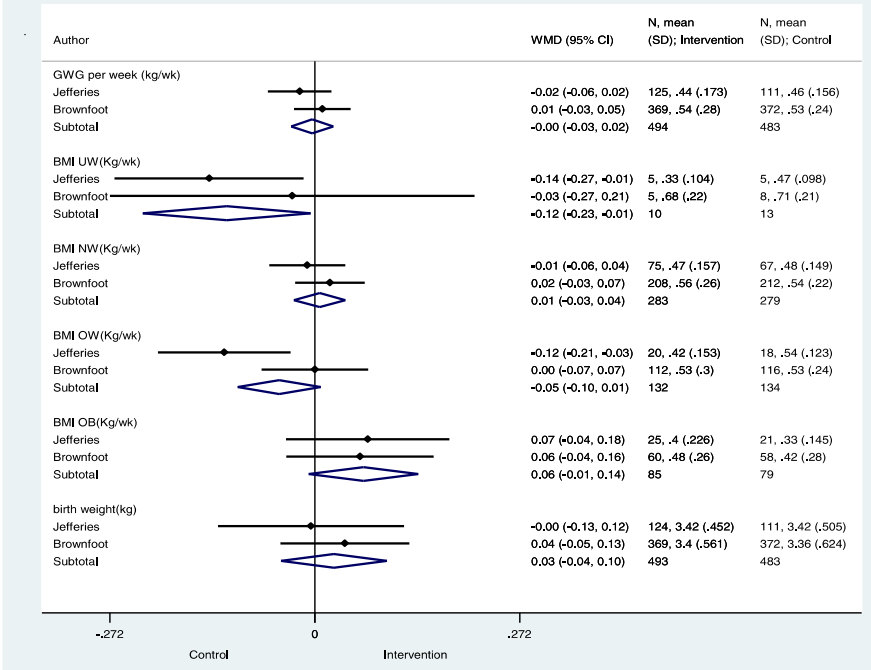

Fig. 2 Results for Continious Variables and Tests of Significance. Significance test(s) of Weighted Mean Difference (WMD = 0), Gestational Weight Gain (GWG) per week (kg/wk) $z = 0.23$, $p = 0.815$; Body Mass Index (BMI) Underweight (UW) (Kg/wk) $z = 2.06$, $p = 0.040$; BMI Normal Weight (NW) (Kg/wk) $z = 0.36$, $p = 0.716$; BMI Overweight (OW) (Kg/wk) $z = 1.68$, $p = 0.094$; BMI Obese (OB) (Kg/wk) $z = 1.74$, $p = 0.081$; Birth Weight (kg) $z = 0.70$, $p = 0.481$

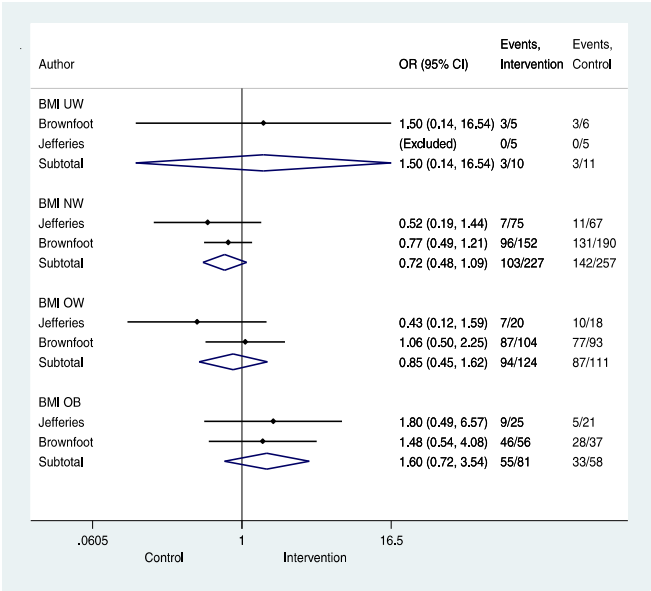

Fig. 3 Proportion of weight gain exceeding the IOM ranges and tests of significance. Significance test(s) of Odds Ratio (OR) =1; Body Mass Index (BMI) Underweight (UW) $z = 0.33$, $p = 0.741$; BMI Normal Weight (NW) $z = 1.55$, $p = 0.122$; BMI Over Weight (OW) $z = 0.50$, $p = 0.617$; BMI Obese (OB) $z = 1.15$, $p = 0.250$

It is extremely interesting that only two recent trials contributed data for this review, given the increased prevalence of obesity and EGWG and changes in practice over time. Additionally, weight gain is characteristic of pregnancy progression and a well-recognised determinant of fetal growth. There is convincing evidence that GWG is associated with infant birth weight: lower GWG is associated with low birth weight and greater GWG is associated with large for gestational age infants [12].

In light of this evidence it is difficult to reasonably explain why antenatal guidelines restrict the practice of routine antenatal weighing and not consider it as an important predictor of pregnancy outcomes, similar to serial measures of blood pressure.

Restricting routine weighing is in direct contrast to the IOM (2009) weight gain guidelines that specifically advise for pregnant women to be weighed at the initial and all subsequent antenatal visits to detect abnormal patterns of pregnancy weight gain [9]. The guidelines recommend that health care providers work in partnership with women to set individual weight gain targets according to their BMI and for weight gains to be graphically documented to enable women to be aware of their weight gains and educate them on the importance of appropriate pregnancy weight gain [9].

Dimperio et al. [41] in response to recommendations that routine weighing should be abandoned, argued that weighing was more than just a stand-alone pregnancy intervention and rather presented health care practitioners with the opportunity to counsel women before weight gains became extreme, advocating that weighing is a valuable screening tool rather than a diagnostic tool for adverse pregnancy outcomes [41].

Weighing as a stand-alone intervention may not be effective for reducing pregnancy weight gain and EGWG under controlled conditions however given the prevalence and risks associated with weight gains outside of the IOM guidelines it is negligent of maternity care providers not to address weight gain in pregnancy. Maternity care providers need to be working in partnership with women to achieve the IOM weight gain in pregnancy targets, monitoring their progress and providing feedback on that progress. Therefore, we recommend further research be undertaken into the impacts and acceptability of this intervention within various

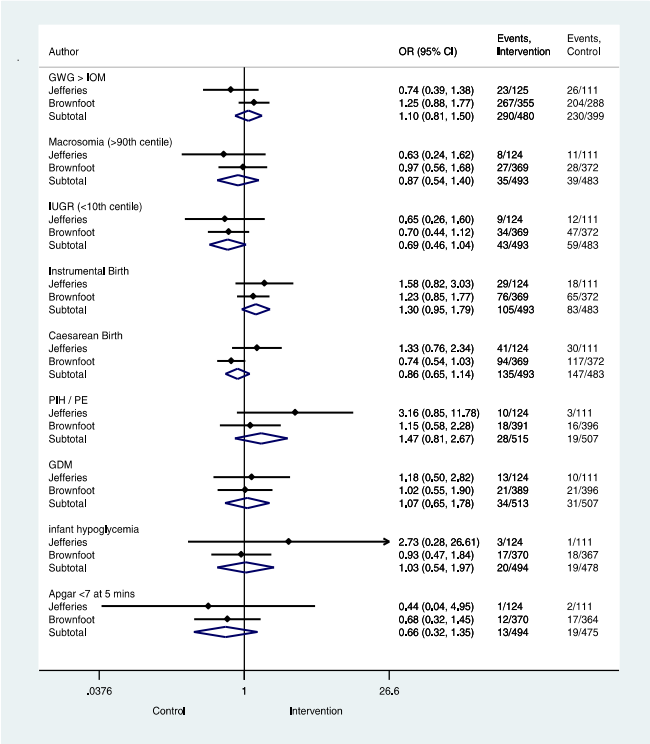

Fig. 4 Pregnancy and Birth Outcomes and Tests of Significance. Significance test(s) of Odds Ratio (OR) =1; Gestational Weight Gain (GWG) > Institute of Medicine (IOM) $z = 0.63$, $p = 0.532$; Macrosomia (>90th centile) $z = 0.58$, $p = 0.560$; Intra Uterine Growth Restriction (IUGR) (<10th centile) $z = 1.76$, $p = 0.079$; Instrumental Birth $z = 1.62$, $p = 0.105$; Caesarean Birth $z = 1.06$, $p = 0.288$; Pregnancy Induced Hypertension (PIH)/Pre-Eclampsia (PE) $z = 1.26$, $p = 0.206$; Gestational Diabetes Mellitus (GDM) $z = 0.27$, $p = 0.787$; Infant hypoglycemia $z = 0.10$, $p = 0.917$; Apgar <7 at 5 mins $z = 1.15$, $p = 0.252$

health care settings and models of pregnancy care, using both experimental and qualitative research methods.

Strengths

We have conducted a methodically rigorous and contemporary search to determine if weighing as a stand-alone intervention can reduce EGWG. All available experimental evidence has been assessed and reported in accordance with the PRISMA guidelines [32] and an appropriate methodological quality checklist [33].

Limitations

Although the included RCTs were deemed good quality, with neutral and positive quality ratings, the following limitations need to be considered. Giving benefit of the doubt, blinding within both studies was rated as adequate, even though neither the participant nor clinicians/researchers (who were also the outcome assessors) were blinded to the intervention. This is because the quality check question is phrased with the qualifier "as appropriate". Jefferies et al. [37] reported that participants were blinded to the purpose of the study, however, discussed that researchers conducting the study were not blinded to treatment groups. No participant blinding was used in the study by Brownfoot et al. [38] because of the nature of the intervention, and this was acknowledged in their limitations. Reviewers gave consideration to each study's methods and concluded that true blinding would be extremely difficult.

Secondary outcomes within both studies including, proportion of women gaining weight above the IOM recommendations, pregnancy birth and neonatal outcomes were not pre specified within each study's statistical analysis plan. These outcomes were not adequately powered to detect a difference between intervention and control limiting the generalisability of these findings.

The decision to exclude studies published in a language other than English was made a priori, for pragmatic reasons. Authors acknowledge that there is potential for this exclusion to have contributed to the low number of included studies.

Conclusion

This systematic review and meta-analysis concludes that weighing, as a stand-alone intervention is neither worse nor better at reducing excessive gestational weight gain than routine antenatal care alone. In light of the presented evidence we recommend that where antenatal guidelines advise women to gain weight within the IOM weight gain ranges that they be enacted in their entirety recommending that women be weighed at the first and all subsequent antenatal visits. We additionally recommend that further research studies be conducted to assess the impact and acceptability of weighing in pregnancy.

Additional files

Additional file 1. Study Protocol. Description of data: Systematic review study protocol. (DOCX 17 kb)

Additional file 2. Primary Search Strategy November 2014. Description of data: This file contains all details of the primary systematic review search strategy conducted in November 2014. Including databases, search terms and number of citations retrieved. (DOCX 18 kb)

Additional file 3. Primary Search Strategy (Updated January 2016). Description of data: This file contains all details of the updated primary systematic review search strategy conducted in January 2016. Including databases, search terms and number of citations retrieved. (DOCX 18 kb)

Additional file 4. Spreadsheet of values used for data analysis. (XLSX 13 kb)

Abbreviations

BMI: Body mass index; CI: Confidence interval; EGWG: Excessive gestational weight gain; GDM: Gestational diabetes mellitus; IOM: Institute of Medicine; NICE: National Institute of Health and Care Excellence; OR: Odds ratio; PE: Pre-eclampsia; PIH: Pregnancy induced hypertension; PRISMA: Preferred reporting items for systematic reviews and meta – analysis; RCTs: Randomised controlled trials; WMD: Weighted mean difference

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Availability of data and materials

The data set that supported the outcomes of this systematic review have been included with this submission as an excel spreadsheet uploaded as a Additional file 4.

Authors' contribution

SMF is the primary reviewer and author of this review paper. SMF carried out the initial and final primary and secondary search strategies, undertook screening of citations, quality appraisal; data extraction and the person responsible for managing the study and writing of this review paper. AJH conceived the study and contributed by designing the review protocol and inclusion/exclusion criteria. AJH conducted some initial screening of citations, carried out data extraction and made substantial contributions to the writing of the review paper. RMT is the second reviewer who carried out screening of citations, quality appraisal and editing of manuscript. AB is the statistician who carried out the meta-analysis. JA contributed to the study design and interpretation of data. Both MF and LE have made substantial contributions in the design, drafting and revising this manuscript. All authors have read and have given approval for this manuscript to be published.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not Applicable.

Ethics approval and consent to participate

Ethics approval was not required for the conduct of this study. Statements of ethical considerations from each article included in the review were appraised as per the American Dietetic Association Criteria checklist for primary research.

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A2. PRISMA Checklist

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	YES
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	YES
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	YES
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	YES
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	YES
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	YES
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	YES
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	YES
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	YES
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	YES
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	YES
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	YES
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	YES
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	YES

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	YES
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	YES
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	YES
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	YES
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	YES
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	YES
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	YES
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	YES
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	YES
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	YES
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	YES

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.

A3. Systematic review study protocol

Supplementary file 1 Study Protocol

Does routine weighing during pregnancy reduce excessive gestational weight gain?
A systematic review and meta-analysis of randomised controlled trials: Protocol

Research Question:

Does routine weighing during pregnancy reduce excessive gestational weight gain?

P (population) pregnant women, any age
I (intervention) weight measurement during routine antenatal care (exclusive of other dietary and lifestyle interventions)
C (comparator) control group
O (outcomes) reduction in weight gain

Study design:

A systematic review and meta-analysis of randomised controlled trials

Interventions:

Any intervention providing regular weighing to pregnant women, exclusive of other dietary and lifestyle modification as a means of avoiding excess weight gain/reducing weight gain

Outcome variables

Primary

- Weight gain / weight change (total weight gains, weight gains within, below and above IOM ranges)

Secondary

- Pregnancy outcomes (gestational diabetes, hypertension, pre-eclampsia)
- Birth Outcomes (caesarean birth, instrumental birth)
- Infant outcomes (infant birth weight, Apgar score, intrauterine growth restriction, macrosomia)

Inclusion criteria

- Pregnant women *(any age)*
- Singleton pregnancy
- More than one measure of weight during pregnancy
- Randomised controlled trials
- Neutral and good methodological quality studies

Exclusion criteria

- Studies not published in English
- Animal studies
- All other study designs, except randomised controlled trials
- Poor methodological quality studies

Subgroups / sensitivity analysis

- BMI sub-groups (underweight, normal weight, overweight and obese)
- Diabetes or other medical conditions
- Country's income level (OECD classification)
- Number of antenatal visits
- Care provider (midwife, GP, obstetrician etc.)

Databases to search:

- MEDLINE
- CINAHL
- Embase
- Maternal & Infant Care
- Scopus
- The Web of Science

Search terms / keywords

- pregnant
- pregnancy
- weight gain
- weighing
- randomised controlled trial
- clinical trials

Data extraction

- First Author, Year, Country and Reference Number
- Study design
- Number of participants
- Participant characteristics
- Intervention *(who gives the intervention i.e. self reported, how long the intervention is given for; how the intervention is delivered; marker of compliance)*
- Maternal age, country, any demographic factors
- Study aim
- Statistical analysis
- Conclusion
- Limitations
- Methodological quality

A4. Systematic review primary search strategy November 2014

Supplementary File 2.
Primary Search Strategy November 2014

DATABASE:	Medline (mp)	Embase Classic + Embase (mp)	Maternal & Infant Care (mp)	CINAHL
DATE: (dd/mm/yy)	12 / 11/ 14	12 / 11/ 14	12 / 11/ 14	12 / 11/ 14
KEYWORD SEARCH TERMS				
1. pregnancy	766759	774663	82481	135683
2. pregnant	128372	184624	24874	18791
3. 1 or 2	779159	817746	86544	137827
4. weight gain	52713	91919	2860	10815
5. weighing	19257	30595	1435	2550
6. 4 or 5	71375	121685	4180	13277
7. random?ed control* trial	409322	429024	3300	31798
8. clinical trial	598539	1016264	1311	19593
9. random* .ti,ab.	693573	936231	15986	43
10. 7 or 8 or 9	1129757	1677876	16294	47724
11. 3 and 6 and 10	968	1648	228	79
12. limit 11 to English & Human	675	1269	-	62
Total retrieved:	675	1269	228	62

[mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
[ti=title, ab=abstract]
[Medline covers the vast majority of journal articles found in PubMed, by including citations from more than 5,600 scholarly journals published around the world. The only content covered by PubMed and not Medline are manuscripts deposited in PMC (commonly would be in both) and NCBI Bookshelf (i.e. books and other documents). The advantage of searching Medline over PubMed is the ability to conduct the search using consistent Medical Subject Headings (MeSH)].

DATA BASE:	Scopus	Web of Science
DATE: (dd/mm/yy)	12/ 11/14	12/11/14
BASIC SEARCH: (per data base)	Title / Abstract / Keyword	Topic
KEY WORD SEARCH TERMS		
1. pregnancy or pregnant	907748	341385
2. weight gain or weighing	167967	127542
3. Random?ed control* trial or clinical trial or random*	2274962 (random* Title / Abs only)	1415786
4. 1 and 2 and 3	2108	1153
5. Limits: (English Language)	2002	1108
6. Excluded: *Subject area (Veterinarian)	1903	-
Total Retrieved:	1903	1108

Primary Search Strategy November 2014
Separate Cochrane Library search

DATABASE	Cochrane Library
DATE: dd/mm/yy	12/11/14
SEARCH	Title/ Abstract/ Keyword
1 pregnancy OR pregnant	28530
2 weight gain OR weighing	7559
3 Random?ed controlled trial OR clinical trial OR random*	626850
1 AND 2 AND 3	1004
Limited to Reviews	534
Total retrieved	534

A5. Systematic review updated search strategy January 2016

Supplementary File 3.
Primary Search Strategy (Updated January 2016)

DATABASE:	Medline (mp)	Embase Classic + Embase (mp)	Maternal & Infant Care (mp)	CINAHL
DATE: (dd/mm/yy)	25/ 01/ 16	25/ 01/ 16	25/ 01/ 16	25/ 01/ 16
KEYWORD SEARCH TERMS				
1. pregnancy	799584	826055	86091	152466
2. pregnant	130794	202279	26554	21830
3. 1 or 2	811763	873467	90589	155224
4. weight gain	53411	101332	3102	12518
5. weighing	19582	37291	1490	2831
6. 4 or 5	72394	133212	4472	15247
7. randomi?ed control* trial	414033	496392	3591	83324
8. clinical trial	597309	1087271	1402	157588
9. random* .ti,ab.	710244	1059961	17080	44
10. 7 or 8 or 9	1148653	1870256	17409	216382
11. 3 and 6 and 10	1027	1924	259	221
12. limit 11 to English & Human	714	1507	259	159
13. limited date 2014 to 2016 or current	714	1507	259	159
Total retrieved:	115	333	55	39
[mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] [ti =title, ab=abstract] [Medline covers the vast majority of journal articles found in PubMed, by including citations from more than 5,600 scholarly journals published around the world. The only content covered by PubMed and not Medline are manuscripts deposited in PMC (commonly would be in both) and NCBI Bookshelf (i.e. books and other documents). The advantage of searching Medline over PubMed is the ability to conduct the search using consistent Medical Subject Headings (MeSH)].				

DATA BASE:	Scopus	Web of Science
DATE: (dd/mm/yy)	25/ 01/ 16	25/ 01/ 16
BASIC SEARCH: (per data base)	Title / Abstract / Keyword	Topic
KEY WORD SEARCH TERMS		
1. pregnancy or pregnant	957880	368937
2. weight gain or weighing	183402	139892
3. Randomi?ed control* trial or clinical trial or random*	2 503177 (random* Title / Abs only)	1577431
4. 1 and 2 and 3	2396	1372
5. Limits: (English Language)	2277	1321
6. Excluded: *Subject area (Veterinarian)	2169	1260
7. Limited date 2014 to 2016 or current	355	323
Total Retrieved:	355	323

A6. Publication manuscript “The return of weighing in pregnancy: A discussion of evidence and practice.”

as a screening tool for the detection of adverse maternal and infant outcomes.[1] It is well known that inadequate or excessive gestational weight gain defined as weight gains above or below the American Institute of Medicine weight gain in pregnancy guidelines are associated with both short - and long-term adverse maternal and infant health outcomes.[1–6] These include gestational diabetes, caesarean birth, fetal growth restriction, fetal macrosomia, pre –term birth, nutrient deficiencies, and may contribute to the development of non-communicable diseases into adulthood.[4,7,8]

In Australia, the National Health and Medical Research Council (NHMRC) have recently revised their pregnancy care clinical practice guidelines, recommending that weighing (clinician and/or self-weighing) be reintroduced as part of antenatal care.[9] What is not clear is whether this consensus-based recommendation (i.e. formulated in the absence of quality evidence), is being presented as a weight management strategy, or as a screening tool for adverse pregnancy and infant outcomes.[9] The practice of weighing pregnant women has been the subject of a long standing debate within midwifery and obstetrics spanning the last 30 years.[10] During this time, evidence has been presented for and against weighing in pregnancy, as a weight management strategy,[10–16] and as a screening tool for adverse pregnancy outcomes.[10,11,17,18] The most recent recommendations will no doubt reignite debate and require ongoing evaluation of their application within clinical practice. It is thus timely to provide a discussion of evidence on the practice of weighing in pregnancy.

2. Background

The practice of weighing pregnant women was initially introduced as far back as the 1940s as a composite measure of overall maternal nutrition.[10] The practice also became a widely used antenatal screening tool for the detection of pre-eclampsia and low birth weight infants·in the subsequent decades.[10,11] The clinical utility of routine maternal weighing as a screening tool was first brought into question during the 1980s when it was revealed that maternal weight monitoring had little predictive value for the detection of preeclampsia, and ceased to be recommended for this purpose.[18]

During the 1990s, the practice of maternal weight monitoring was subject to further critique following the publication of a seminal, retrospective observational study by Dawes and Grudzinskas conducted in the United Kingdom (UK).[17,19,20] The authors presented their findings across two separate publications.[17,20] The first described wide variations in patterns of weight gain in 988 pregnant women with healthy pregnancy outcomes, suggesting that weighing as a screening tool for low birth weight infants was not supported.[17] Maternal booking weight obtained at first antenatal contact was found to be a more sensitive predictor of low birth weight infants, which was a maternal and infant health priority at the time.[17]

The usefulness of weighing as a screening tool was further questioned in a second publication from this same study, which revealed that maternal weight monitoring had little predictive value for adverse pregnancy and birth outcomes.[20] A follow up discussion paper by Dawes et al. suggested routine weighing caused unnecessary maternal anxiety, however no evidence was presented to support this claim.[19]

This series of publications from the early 1990s essentially initiated the contemporary debate surrounding the practice of weighing pregnant women,[10] suggesting that the practice be abandoned.[10,19] A professor of obstetrics and gynaecology (D. Hawkins) published a commentary in response to these suggestions, cautioning that the evidence presented by Dawes and Grudzinkas was not adequate to support the abandonment of weight monitoring, particularly given the increase in obese women entering pregnancy.[21] Dimperio et al. also cautioned against the abandonment of maternal weight monitoring until quality studies could be conducted conclusively showing it was of no value.[22] These authors additionally explained that low and high weight gains were a possible predictor of adverse pregnancy outcomes, noting that women who had low weight gain were at risk of pre term birth and intrauterine growth restriction, and those who gained excessively were at risk of birth complications such as caesarean birth.[22] Overtime however, and without quality evidence in the form of randomised controlled trials or large prospective observational studies, the practice of weighing declined within the UK and Australia.[10]

In the UK, weighing ceased to be recommended as a pregnancy screening tool by the National Institute of Clinical Excellence (NICE) antenatal care guidelines in 2003.[10,23] In Australia, a decline in weighing was reported by Mollart in 1999, who evaluated the impact of weighing cessation in a selected New South Wales antenatal clinic.[24] This paper described that ceasing the long standing practice of routine weighing was well received by women and clinicians, with most supporting the abandonment of the practice.[24]

3. Routine weighing and gestational weight gain

Weight gain is a well-recognised determinant of fetal growth and pregnancy progression. The physiological components that contribute to total gestational weight gain are compartmentalised into products of conception: fetus, placenta and amniotic fluid; and maternal tissue accretion: uterine tissue, breast tissue, blood and plasma volume expansion, and fat.[25] Research conducted by Hytten and Leitch throughout the 1950s and 60s described the mean weight gain for primiparous women with good pregnancy outcomes to be approximately 12.5 kg, which included roughly 3 kg of fat accumulation, suggested to support the increased energy demands for lactation.[25,37]

During the early 1990s the American Institute of Medicine, undertook a literature review of maternal weight gain patterns.[37] The review included 12 heterogeneous observational studies published between 1934 and 1986, that again revealed wide variations in mean total gestational weight gain with healthy pregnancy outcomes (7kg–18 kg, 15th and 85th percentile respectively).[37] Given the lack of consensus of what constitutes appropriate gestational weight gain the Institute of Medicine devised the first edition of the nutrition in pregnancy guidelines supporting the continued practice of maternal weight monitoring as part of routine pregnancy care.[20,37]

The Institute of Medicine guidelines first released in 1990, were primarily focused on addressing maternal undernutrition and the prevention of infant mortality associated with low birth weight.[37] The original weight gain guidelines are displayed in Table 1. These guidelines were applied in combination with weight for height or Body Mass Index (BMI) measures. BMI was considered a better measure of overall maternal nutrition than weight alone.[37] BMI categories were classified according to weight for height cut-off

Table 1
American Institute of Medicine (1990) weight gain in pregnancy guidelines.

BMI category	Recommended total gain (kg)
Underweight (BMI < 19.8)	12.5–18.0
Normal (BMI of 19.8 to 26.0)	11.5–16.0
Overweight (BMI > 26.0 to 29.0)	7.0–11.5
Obese (BMI > 29.0)	>6.8

Adapted from the American Institute of Medicine Committee on Nutritional Status During Pregnancy and Lactation. Nutrition During Pregnancy: Part 1 Weight Gain. National Academy of Sciences Institute of Medicine; 1990.

points from metropolitan lifestyle insurance data widely used within the United States of America (USA) at the time.[37]

A systematic review published in the American Journal of Clinical Nutrition,[11] expressed concerns at the deficit in research for the continued use of maternal weight monitoring in obstetric clinical practice 10 years after the release of the Institute of Medicine 1990 guidelines.[11] The publication pointed out that no studies (experimental or observational) were available that assessed the predictive value of pregnancy weight gain as a screening tool for maternal or fetal wellbeing.[11] In contrast to the UK and Australia, the publication concluded that there was no conclusive evidence to support the discontinuation of maternal weight monitoring in clinical practice.[11]

In the wider public health arena during the 1990s there was a growing concern regarding weight, with the emergence of a global obesity epidemic.[7] During the early 2000s the Institute of Medicine felt pressure to review their long-standing guidelines, releasing revised weight gain in pregnancy guidelines in 2009.[7,27] The new guidelines acknowledged a shift in public health focus from the prevention of maternal undernutrition and low birth weight infants, to the prevention of adverse outcomes associated with maternal obesity and excessive gestational weight gain.[7] The new weight gain ranges most notably differed from the original version,[37] with the adoption of the World Health Organization BMI categories, recommending that women who are underweight (BMI < 18.5 kg/m^2) at the beginning of pregnancy gain more weight than women who are overweight (25–29.9 kg/m^2) or obese ($\geq$ 30 kg/m^2) as per Table 2.[7] The guidelines highlighted that weight gain outside the recommended ranges was associated with adverse outcomes compared to women who gained within the weight gain ranges.[7,27] These guidelines have consistently supported the practice of routine maternal weight monitoring.[7]

4. Weighing as a weight management strategy

Weighing in the field of weight management has been found to be successful in aiding non-pregnant adults achieve weight loss, weight maintenance and prevent weight gain.[28–31] Self-weighing is based on self-regulation, within social cognitive theory, where behaviour is influenced by an interplay and reciprocity between the person, environment and behavior.[32] Self-regulation is essentially the process of self-monitoring of a particular behaviour, its determinants and effects.[32] Self-regulation requires reflection on the behaviour, goal planning and reactive evaluation to reach goal attainment. Self-efficacy is central to self-regulation and influences how a person perceives success and failures along the pathway to goal attainment.[32] Self-monitoring of weight or regular clinician weight monitoring is proposed to create an awareness of an individual's weight in relation to their diet and physical activity patterns.[30,31] Self-awareness serves the function of providing information for goal setting and continual evaluation towards the goal.[32] This knowledge can then be used for personal lifestyle adjustments in diet and physical activity patterns.[30–32]

A systematic review by VanWormer et al.[29] identified 12 studies investigating the impact of regular self-weighing (daily or weekly) on weight management amongst non-pregnant adults. Regular self-weighing was associated with greater weight maintenance and less total body weight when compared with infrequent or no self-weighing. In a similar updated review, Madigan et al.[30] identified 17 studies, of various methodological quality, reporting that regular self-weighing (daily, weekly or monthly) contributed to weight gain prevention.[30] This review additionally described that for weighing to be effective it needs to be habitual and frequent; daily weighing may be more effective than weekly or monthly in providing immediate feedback on behavior.[30] However authors, also describe the weekly "weigh in" as a potentially motivating factor by way of being accountable to a person other than themselves.[30] It follows that either self-weighing or clinician weighing may be a useful behavioural weight management strategy during pregnancy.

Table 2
American Institute of Medicine (2009) weight gain in pregnancy guidelines.

BMI category	Recommended total gain (kg)
Underweight (BMI < 18.5)	12.5–18.0
Normal (BMI 18.5–24.9)	11.5–16.0
Overweight (BMI 25.0–29.9)	7.0–11.5
Obese (BMI $\geq$ 30.0)	5–9

Adapted from Rasmussen KM, Yaktine AL. Nutrition During Pregnancy: Re-Examining the Guidelines.
Washington D.C.: National Academy of Sciences Institute of Medicine; 2009.

5. Evidence for routine weighing in pregnancy

A recent systematic review published in 2017 conducted by Fealy et al.,[15] is the first to evaluate the practice of routine maternal weighing as a stand-alone intervention to reduce pregnancy weight gain and prevent excessive gestational weight gain, compared to routine antenatal care.[15] In contrast to diet and exercise interventions, routine maternal weighing is considered a feasible intervention easily incorporated into clinical practice.[33] Surprisingly, despite weighing being a long-standing practice the merits of which has been consistently challenged, the review only found two randomised controlled trials, both conducted within Australia, by Brownfoot et al. published in 2016[12] and Jefferies et al. published in 2009.[16] The paper authored by Jefferies et al. evaluated the effectiveness of maternal self-weighing,[16] with the study conducted by Brownfoot et al. evaluating the effectiveness of clinician weighing compared to usual antenatal care.[12,16] The pooling of these studies (n = 1068) in a meta-analysis observed no differences in total gestational weight gain (kg/per week) between intervention and control groups (Weighted Mean Difference, −0.00 kg 95% Confidence Interval (CI), −0.03 to 0.02)[15]. Additionally, no differences were reported in the total proportion of women exceeding the Institute of Medicine weight gain ranges between intervention and control groups (Odds Ratio 1.10, 95% CI, 0.81–1.50).[15]

Following the publication of the review by Fealy et al.,[15] Daley et al.[13] published their findings from a small pilot feasibility trial (n = 76) evaluating regular antenatal weighing by community midwives.[13] The results were not statistically powered for effectiveness, but add support to the findings of the systematic review, showing no difference in gestational weight gain between intervention and control.[34]

The revised Australian pregnancy care guidelines (2018) pooled the results from the Daley publication[13] with the results of the study conducted by Brownfoot et al.[12] From a population of n = 711, the analysis again revealed no differences in excessive gestational weight gain (Relative Risk 1.05, 95% CI 0.95 to 1.16) or for mean weekly weight gain (0.01 kg per week, 95%CI −0.03 to 0.05).[9] This evidence reveals that routine maternal weighing as a standalone intervention is no more effective than routine antenatal care without weighing in supporting adequate gestational weight gain.[9]

6. Pregnancy weight gain guidelines

The revised Australian National Health and Medical Research Council guidelines now advise health care providers to assess height and weight at the first antenatal appointment for the calculation of a BMI, discuss weight and weight gain in pregnancy, and offer women the opportunity to be weighed and encourage

self- monitoring of weight gain at every antenatal visit.[9] Health care providers are also advised to discuss weight gain, diet and physical activity.[9] In the absence of Australian specific pregnancy weight gain guidelines, the American Institute of Medicine 2009, weight gain in pregnancy ranges have been adopted.[9] The revised Australian guidelines however caution maternity care providers, recommending that the ranges are a suggestion only, rather than being goal specific, weight gain targets.[9]

The Institute of Medicine nutrition in pregnancy guidelines[7] recommend that women be routinely weighed during antenatal care, not as a stand-alone intervention but as a package of care where health professionals work with women to engage in conversation, provide education and counsel women on the importance of nutrition and appropriate gestational weight gain.[7] Weighing essentially becomes part of a health promotion package of care, used within this context as a screening tool to detect abnormal patterns of pregnancy weight gain.[7] This is reasonable given that gestational weight gain is associated with infant birth weight; low gestational weight gain is associated with low birth weight and, greater gestational weight gain is associated with large for gestational age infants.[15,16,37,35]

The revised Australian pregnancy care guidelines are now somewhat more reflective of recommendations from the USA and Canada that support the Institute of Medicine weight gain in pregnancy guidelines as a comprehensive health promoting package of care.[7,36] However, it is unclear if the amendments to weight monitoring recommendations are moving towards maternal weight monitoring used as a screening tool for adverse pregnancy outcomes or as a weight management strategy.

7. Discussion

The debate for routine weighing in pregnancy has been ongoing for over 30 years. Current evidence suggests that routine maternal weight monitoring as a stand-alone intervention is ineffective for some women as a weight management strategy for achieving optimal gestational weight gain.[12,13,15,16]

Weighing practices within the USA have been consistent overtime, largely due to the widespread adoption of the Institute of Medicine weight gain in pregnancy guidelines.[7,37] This is in contrast to the changing antenatal weighing practices observed within the UK and Australia.[7,9,23,38,39] Regardless of country and independent of routine maternal weight monitoring practices, women have continued to gain excessive weight during pregnancy.[6,7,27,35,40,41] Excessive gestational weight gain, defined as gains over the Institute of Medicine weight gain in pregnancy guidelines have been associated with increases in maternal and fetal morbidity including higher rates of pre-eclampsia, caesarean birth,[2] postpartum weight retention,[4] low 5 min APGAR scores, neonatal hypoglycaemia, seizures,[6] and large for gestational age infants.[2,4] Therefore, having information on weight gain in pregnancy is clinically relevant to pregnancy outcome.

Pregnancy is described as an opportune time to intervene with health promoting behaviours.[14,26,42–45] Health promotion interventions to reduce excessive gestational weight gain have largely focused on diet and exercise interventions.[1,46] A recent systematic review published in 2018 conducted by Walker et al. revealed, in a meta-analysis of 60 trials, that diet and physical activity interventions alone, or in combination, can be effective at reducing gestational weight gain, when compared to usual antenatal care.[1] This finding is similar to other published systematic reviews, that also found moderate decreases in gestational weight gain when diet and lifestyle interventions are incorporated as part of antenatal care.[46,47] The review by Walker et al. additionally is one of the first systematic reviews to include the available evidence on mobile health (mhealth) interventions, such as smartphone applications.[1] Findings from the meta-analysis of mhealth interventions suggest that they are not effective in reducing gestational weight gain, with more studies needed to be conducted in this area.[1] These outcomes, while significant and positive in research trial conditions, have substantial barriers in upscaling at the population level. Such barriers include limited access to specialist staff, time constraints placed on clinicians, institutional financial implications, skills and knowledge and, individual motivation of health providers and consumers to engage in such interventions as part of antenatal care.[45,48]

It has been suggested that the ineffectiveness of interventions at the population level (given the rising trend in excessive gestational weight gain), may be related to a lack of understanding of the broader psychosocial and psychological factors and gap in knowledge of how these impact on weight gain in pregnancy.[46,49–53]

Less is known about a woman's capacity for actual weight related behaviour change during pregnancy.[44,54] Olander et al.[44] discuss that it is largely assumed women are motivated by pregnancy alone to change health related behaviour, and that pregnancy is an opportune time for interventions to be trialled.[44] However, weight gain in pregnancy is complex. Diet and exercise modification can be interrupted by physical pregnancy symptoms such as nausea and vomiting, as well as social determinates of health such as socio economic status and social support, making it difficult for women to afford or sustain these types of interventions.[44,54]

A systematic review and qualitative synthesis of the barriers and facilitators to appropriate gestational weight gain found compelling evidence that, the biomedical approach of limiting weight gain using the energy input and output approach, with diet and exercise interventions, is insufficient during pregnancy.[54] Women, whilst motivated to achieve healthy weight gain in pregnancy, could not do so due to reported significant barriers. These included personal beliefs, knowledge, emotion, logistics, practice, social and structural factors.[54] Facilitators for achieving healthy weight gain were, high income and good social support.[54] These findings are similar to a recent umbrella review of the qualitative barriers and enablers to smoking cessation for pregnant smokers.[55] This review found that although smoking campaigns have assisted to reduce the overall rates of smoking in pregnancy, women who continued to smoke were generally of low socio economic status, and were aware of the risks of smoking but continued, because they felt it had positive outcomes for their overall lifestyle and mental health.[55] Additionally, low socio economic status is a major contributing factor for maternal and fetal undernutrition, underweight, and obesity.[8] In low to middle-income countries in Africa and Asia, maternal and neonatal undernutrition account for approximately 3.1 million child deaths annually, pointing to the need for more research in this area.[8]

The findings of this discussion indicate that weight gain in pregnancy is a complex phenomenon that has implications that go beyond the debate on routine weighing in pregnancy. Routine maternal weight monitoring may play a role in assisting women to achieve adequate weight gain, as a package of care, but this needs to be considered within a broader, social ecological model of woman's health.

8. Conclusion

Weight gain in pregnancy is a multifactorial and complex phenomenon. The debate on routine weighing in pregnancy is ongoing. The revision of the Australian pregnancy care guidelines provides scope for differences in clinical practice moving beyond a 'one size fits all' approach, to one that is women focused, opening up conversation and the 'opportunity' for weighing to be

integrated into a woman's pregnancy care. It is unclear if the newly revised pregnancy care guidelines have recommended this practice as a screening tool for adverse pregnancy outcomes such as low, or high, infant birth weight, or if it is being employed as a weight management strategy. Ongoing evaluation of these guidelines is needed to assess their clinical translation, acceptability and uptake. Weight gain in pregnancy is determined by more than just diet and exercise. Future research is needed to explore the effect of interventions that embrace a social ecological view of health.

Conflict of interest

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A Revalidation of the Weight Related Behaviours Questionnaire within an Australian Pregnancy Cohort

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ABSTRACT

Problem: Studies investigating the direct and indirect relationships between psychosocial factors (i.e. attitudes, beliefs and values), health related behaviour (diet and physical activity) and gestational weight gain are increasing. To date heterogeneity of psychosocial measurement tools has limited research progress in this area, preventing measurement of effects by meta-analysis techniques.

Aim: To conduct a revalidation analysis of a Weight Related Behaviours Questionnaire, originally developed by Kendall, Olson and Frangelico within the United States of America and assess its performance for use within the Australian context.

Methods: A revalidation study using Exploratory Factor Analysis was undertaken to assess the factor structure and internal consistency of the six psychosocial scales of the Weight Related Behaviours Questionnaire, within the Woman and Their Children's Health (WATCH), pregnancy cohort. The questionnaire was self-completed between 18 – 20 weeks gestation. Psychosocial factors included; Weight locus of control; Self-efficacy; Attitudes towards weight gain; Body image, Feelings about the motherhood role; and Career orientation.

Findings: Weight locus of control, Self-efficacy and Body image, retained the same factor structure as the original analysis. The remaining psychosocial factors observed a different factor structure in terms of loadings or number of factors. Deleted items modelling suggests the questionnaire could be strengthened and shortened.

Conclusion: Weight Locus of control, Self-efficacy and Body image were observed as consistent, valid and reliable psychosocial measures for use within the Australian context. Further research is needed to confirm the model and investigate the potential for combining these scales into a shorter psychosocial measurement tool.

Introduction

Weight gain in pregnancy is a complex phenomenon (Fealy et al., 2020). Weight gain in pregnancy is expected and in general is a positive physiological characteristic of foetal growth and pregnancy progression (Institute of Medicine Committee on Nutritional Status During Pregnancy and Lactation, 1990). However, since the release of the revised American Academy of Sciences, Institute of Medicine (IOM), nutrition in pregnancy guidelines in 2009, obesity and gestational weight gain have become a primary focus of antenatal care, signifying a shift in focus from the management of maternal underweight to overweight and obesity risk management (Rasmussen and Yaktine, 2009; Skouteris et al., 2019).

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The Institute of Medicine weight gain in pregnancy guidelines recommend weight gains according to World Health Organisation (WHO) body mass index categories (BMI) (Rasmussen and Yaktine, 2009). Women with a BMI classified as underweight are recommended to gain more than women classified in the overweight and obese categories as follows; Underweight (BMI <18.5) 12.5 kgs - 18 kgs, Normal weight (BMI 18.5 –24.9) 11.5 kgs – 16.0 kgs, Overweight (BMI 25.0 – 29.9) 7 kgs – 11.5 kgs and Obese (BMI ≥ 30.0) 5 kgs – 9 kgs. Excessive gestational weight gain (EGWG) is therefore defined as total pregnancy weight gain exceeding the IOM weight gain ranges (Rasmussen and Yaktine, 2009). Since the development of the guidelines women have continued to gain in excess of the IOM recommendations (Goldstein et al., 2017), increasing their risks of experiencing adverse childbearing outcomes such as large or small for gestational age infants (Goldstein et al., 2017; Johnson et al., 2013), caesarean birth (Goldstein et al., 2017; Zilko et al., 2010), gestational diabetes (Hedderson et al., 2010), pre-eclampsia (Hutcheon et al., 2018) and postpartum weight retention (Zilko et al., 2010). Of concern are the long term and intergenerational disease risks of EGWG proposed by the Developmental Origins of Health and Disease (DOHaD) hypothesis (Safi-Stibler and Gabory, 2020). Early life exposure to intrauterine environments characterised by EGWG (over nutrition) have been proposed to increase an infant's susceptibility for childhood overweight, obesity, non-alcoholic fatty liver disease and type 2 diabetes, increasing the global burden of disease (Heerwagen et al., 2010; Safi-Stibler and Gabory, 2020).

There are no interventions effective at reducing EGWG that are generalisable to large and diverse populations of pregnant women, to inform clinical practice guidelines (Walker et al., 2018). Intervention studies to date have primarily targeted health behaviour change techniques such as diet and/or physical activity and implementing self-regulation strategies such as routine self-weighing or clinician weighing (Fealy et al., 2017; Muktabhant et al., 2015; Vincze et al., 2019; Walker et al., 2018). While healthy eating and physical activity are important for overall maternal and foetal health, diet and physical activity strategies employed during pregnancy have reported moderate effectiveness in decreasing EGWG. These strategies only working for some women, with weight monitoring during pregnancy no more effective at reducing EGWG than standard antenatal care (Muktabhant et al., 2015; Vincze et al., 2019; Walker et al., 2018). Additionally, these interventions have reported difficulties with upscaling at the population level and have demonstrated minimal effectiveness for reducing the adverse maternal and infant outcomes associated with EGWG (Fealy et al., 2020; Skouteris et al., 2019).

Less is known of the complex interactions and relationships of a woman's physical (i.e. nausea and vomiting), psychological (i.e. anxiety and depression) and psychosocial health (i.e. attitudes, beliefs, age, education level), on health-related behaviour (i.e. diet and physical activity) and weight gain during pregnancy (Fealy et al., 2020). There is an increasing body of evidence exploring the myriad of exiting psychosocial factors and their associated direct and indirect relationships with health behaviour and their influence on EGWG (De Jersey et al., 2017; Hartley et al., 2015; Kapadia et al., 2015). Psychosocial factors such as: age, level of education, depression, anxiety, attitudes, beliefs, self-efficacy, body image and social support, are known antecedents to and moderators (barriers and enablers) of health behaviour, potentially influencing (positively or negatively) GWG (Glanz et al., 2015; Hanson et al., 2017; Hartley et al., 2015; Kapadia et al., 2015).

A systematic review and narrative synthesis by Kapadia et al. (2015), investigating psychological and psychosocial factors as antecedents to EGWG, identified levels of cognitive dietary restraint, perceived barriers to healthy eating, negative attitudes towards weight gain, being concerned about weight, high targeted weight gain and inaccurate body perception, as potential predictors of EGWG (Kapadia et al., 2015). A similar systematic review and narrative synthesis by Hartley et al. (2015), identified depression, body image dissatisfaction and social support as potential predictors of EGWG. While both reviews have examined these important relationships, limitations within and between studies have hindered research progress in this area preventing aggregation of data and estimates of effect using meta-analysis techniques (Hartley et al., 2015; Kapadia et al., 2015). One significant limitation is the current heterogeneity of measurement tools used to examine the relationships between psychosocial factors and EGWG. Further research is warranted to guide the development of pregnancy specific psychosocial measurement tools for use within large and diverse populations of pregnant women and progress research in this area (Hartley et al., 2015; Kapadia et al., 2015).

Kendall et al. (2001), developed the WeightRelated Behaviours Questionnaire (WRB-Q), to assist with the identification of psychosocial factors that influence weight related behaviour and test their relationships with pregnancy related health behaviour and gestational weight gain (Kendall et al., 2001). The development of the WRB-Q was underpinned by the theoretical framework for health promotion by Green and Kreuter (1991), called the Predisposing, Reinforcing, and Enabling Constructs in Educational and Environmental Diagnosis and Evaluation (PRECEDE) / Policy, Regulatory and Organisational Constructs in Educational Environmental Development (PROCEED) model (Green and Kreuter, 1991). Kendall et al. (2001) additionally applied health behaviour theory during the development process, primarily social cognitive theory conceptualised by Bandura (1991), to guide the identification of psychosocial factors that may moderate health behaviour during pregnancy (Bandura, 1991; Kendall et al., 2001).

Drawing on measurement tools from the available weight management literature (Hofstetter et al., 1990; Palmer et al., 1985; Saltzer, 1982) and qualitative study findings (Devine et al., 2000, 1994), Kendall et al. (2001) developed the WRB-Q, consisting of 49 individual questionnaire items with 6 psychosocial factors and scales of measurement. Since its development the WRB-Q has been used to explore the potential relationships and interactions between health behaviours (such as diet and physical activity), GWG and postpartum weight retention, primarily within American and Canadian pregnancy cohorts (Hinton and Olson, 2001; Lipsky et al., 2016; Olson and Strawderman, 2003; Olson et al., 2017). To our knowledge the WRB-Q has not been validated for use within an Australian pregnancy cohort. Therefore, to progress research and address current gaps in the evidence base, including heterogeneity of measurement tools, the aim of this study was to conduct a revalidation of the WRB-Q within the Australian Women And Their Children's Health (WATCH) pregnancy cohort and ascertain its performance and suitability as a psychosocial measurement tool for use within the Australian context.

Methods

The weight-related behaviours questionnaire

The Weight-Related Behaviours Questionnaire was originally tested and validated within a large ($n = 622$) prospective cohort study of American pregnant women (Bassett Mothers Health Cohort), recruited between November 1994 and November 1996. The detailed study paper outlining this analysis has been previously published (Kendall et al., 2001).

The entire WRB-Q is comprised of 49 items measuring 6 psychosocial factors. These include: 1) Weight locus of control scale (4 items); 2) Self-efficacy scale, related to diet, weight control, and exercise (8 items); 3) Attitudes towards weight gain scale (13 items); 4) Body image scale (4 items); 5) Feelings about the motherhood role scale (7 items); and 6) Career orientation scale (13 items) (Kendall et al., 2001). Each of the 49 items were measured using Likert scales with responses ranging from 'strongly agree' to 'strongly disagree', from 'very sure' to 'very unsure', from 'too heavy' to 'too light', and from 'very satisfied' to 'not at all satisfied'(Kendall et al., 2001).

The Weight locus of control items measure perceived personal control over weight gain (internal locus of control), or if weight is perceived as outside of personal control (external locus of control) (Kendall et al.,

2001).The Self-efficacy items measure perceived confidence for behaviour change in relation to diet, weight control and exercise. The Attitudes towards weight gain items measure positive attitudes towards pregnancy weight gain, or weight gain avoidance during pregnancy (Kendall et al., 2001). The Body image items measure personal satisfaction with own weight and personal perception of body weight. The Feelings about the motherhood role items measure positive and negative perceptions of motherhood and the Career orientation items indicate a preference towards career or family (Kendall et al., 2001).

Population

The Women And Their Children's Health (WATCH) study was a small (n = 180 women and n = 182 children) but detailed longitudinal pregnancy cohort study conducted in New South Wales, Australia. Participants were recruited between June 2006 and December 2007 (Hure et al., 2012). The majority of women in this study (60%) were recruited to participate during early pregnancy (<18 weeks) by research midwives at one large tertiary hospital antenatal clinic with a small number of women recruited via word of mouth and local media coverage (Hure et al., 2012). Women were eligible to participate if they were < 18 weeks gestation and planned to birth at the respective tertiary hospital, as outlined in the detailed WATCH study protocol previously published (Hure et al., 2012).

The first study visit occurred when women were approximately 18 – 20 weeks pregnant with follow-up visits conducted at 24, 30 and 36 weeks of pregnancy. Postnatal follow-up was conducted at 3, 6, 9 and 12 months and at 2,3 and 4 year time points (Hure et al., 2012). The WeightRelatedBehaviours Questionnaire was self-completed by participants at the first study visit occurring between 18 – 20 weeks' gestation (Hure et al., 2012). Pregnancy and birth data were collected from the health institution's electronic database. Pre pregnancy weight was self-reported by women on recruitment to the study with all follow up weights measured by researchers. Total GWG was calculated by subtracting the last recorded pregnancy weight reading at approximately 36 weeks, from the self-reported pre-pregnancy weight reference (Hure et al., 2012).

The research protocol for the WATCH study was approved by the Hunter New England Human Research Ethics Committee (approval number 06/05/24/5.06) and approval was registered with the University of Newcastle (Hure et al., 2012).

Data analysis

This was an instrument revalidation study using Exploratory factor analysis (EFA) of the WRB-Q within the WATCH pregnancy cohort. Exploratory Factor Analysis was performed on statistical analysis software (SAS v9.4) using 'proc factor', and varimax rotation. Questionnaire item responses were found to be non-normally distributed so Principle Axis Factoring (PAF) methods, suitable for non-normal distributed data were used. When different questionnaire factor structures were compared to the original validation within the Bassett Mothers Health cohort, the Cronbach's alpha (α) coefficients were calculated according to the original factor structure not the 'new' factor structure, to enable direct comparison between the two cohorts. Cronbach's Alpha (α) coefficients are presented as a value between 0 – 1, with values between 0.70 and 0.90 generally indicating acceptable internal consistency (Adeniran, 2019; Taber, 2018). The strength of individual questionnaire items was analysed using Spearman's rank correlation coefficient with two – sided p values (<0.05). All items were further subjected to additional deleted items modelling to assess if the deletion of individual items could improve the internal consistency (α) of each psychosocial scale.

Confirmatory Factor Analysis (CFA) could not be performed to assess the factor structure within the WATCH cohort, as this generally requires larger samples of 200–400 participants (Fabrigar and Wegener, 2012). As the questionnaire had already been validated within a large population of pregnant women during the original analysis by Kendall et al. (2001), EFA was considered a sound statistical methodology. EFA was applied to each of the 6 psychosocial scales to determine factor structure (in terms of factor number and loading) and Cronbach's alphas (overall and within factor) for comparison with the original analysis performed by Kendall et al. (2001). Factor analysis techniques (i.e. EFA and / or CFA) require complete sets of data, so to ensure as many possible observations were retained, mean substitution was utilised to fill in missing data. However, this was only conducted when the number of missing items within each of the 6 psychosocial scales were fewer than 30%. Ignoring missing items can lead to reduced sample size and loss of power, and so in the absence of specific instructions regarding how to handle missing items within the WRB-Q scales, we utilised person mean imputation for missing items within each scale (Bell et al., 2016). Bell et al. (2016), explain there are no clear guidelines for handling missing items however, person mean imputation can be performed relatively well when at least 50% of the scale had been answered. For our analysis missing questionnaire items were replaced with the mean of the answered items in the subscale only when there were less than 30% per person, so no values were mean imputed if >30% of scale data was missing, a similar process to that reported by Hübner et al. (2016). The majority of missing responses were from the career orientation scale (n = 19), with 14 values mean imputed and 5 values excluded from the analysis. WATCH cohort characteristics were analysed using descriptive statistics (mean, SD and percentages) using statistical software (SAS v9.4).

Results

Of the WATCH study participants (n = 180), n = 159 returned the WRB-Q resulting in an 88% response rate. Of these 73% (n = 132) returned complete responses across all 6 psychosocial scales. The total population sample analysed for each of the psychosocial scales were as follows: N = 159 for the Weight locus of control and Attitudes towards weight gain scales; N = 158 for the Self-efficacy scale; N = 157 for the Feelings towards the motherhood role scale, and n = 154 for both the Body image and Career orientation scales.

A comparison of characteristics between the original Bassett Mothers Health cohort (USA) and the WATCH cohort (Australia), are presented in Table 1. Participants in the Bassett Mothers Health cohort were recruited between 1994 and 1996. Participants in the WATCH cohort were recruited between 2006 and 2007. The cohorts were similar in terms of age, marital status, parity and mean GWG, however were different in terms of level of education.

The entire WRB-Q and results of the EFA are displayed in Table 2. Weight locus of control, Self-efficacy and Body image were observed to retain the same item Factor structure as the original Bassett Mothers Health cohort analysis, conducted by Kendall et al. (2001). The remaining psychosocial scales exhibited different Factor structures, either in terms of loadings or number of item Factors.

The analysis within the WATCH pregnancy cohort found the same two-item Factor solution across the four Weight locus of control items. Cronbach's alphas were higher in the current analysis for Factor 1, but lower for Factor 2, and lower overall compared to the Bassett Mothers Health cohort (α = 0.49 versus 0.73).

For the Self-efficacy items, the original Bassett Mothers Health cohort analysis found a three-item Factor solution, with the first three items loading on Factor 1, the next three items on Factor 2, and the final two items on Factor 3. The current analysis of WATCH cohort data also found a three-item Factor solution with Factors 2 and 3 but different item factor loadings to the original analysis for Factor 1. Cronbach's alpha coefficients were calculated for the three factors (using the same items as were included in the original Cronbach's calculations) and were higher for Factor 2 (α = 0.82) and 3 (α = 0.82), but lower for Factor 1 (α = 0.65). The overall Cronbach's alpha was lower for this scale

Table 1
Cohort characteristics.

	Original Bassett Mothers Health cohort (N = 622)	WATCH study cohort (N = 159)
Age *Mean (SD)*	28.8 (nr)	28.9 (5.6) *missing n = 12*
Country of birth Australia *n (%)*	(nr)	138 (87%)
Other *n (%)*	(nr)	21 (13%)
Education ≥ High School *n (%)*	92.5%	105 (71%) *missing n = 12*
Education ≤ High School *n (%)*	7.5%	42 (29%) *missing n = 12*
Married *n (%)*	72.8%	84 (61%)
Unmarried *n (%)*	27.2%	54 (39%) *missing n = 22*
Nulliparous *n (%)*	41.3%	66 (45%)
Multiparous *n (%)*	58.3%	80 (55%) *missing n = 13*
Total Gestational Weight Gain (kgs) *Mean (SD)*	13.5 (5.3)	13.3 (7.2) *missing n = 12*

Demographic data for the Bassett Mothers Health Cohort derived from Kendall et al. (2001). Evaluation of psychosocial measures for understanding weight-related behaviours in pregnant women. Annals of behavioural medicine: a publication of the Society of Behavioural Medicine, 23(1), 50–58 & Olson and Strawderman (2003). Modifiable behavioural factors in a biopsychosocial model predict inadequate and excessive gestational weight gain. Journal of the American Dietetic Association, 103(1), 48–54.
nr = not reported.

Table 2
Weight- related behaviours questionnaire: exploratory factor analysis results and cohort comparisons of factor structure.

	WATCH Cohort Analysis (Australia)			Bassett Mothers Cohort Analysis (USA)		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
Weight Locus of Control *Circle the number that best represents how you feel (Likert scale strongly agree – strongly disagree)*						
1.Whether my weight change is up to me.	**0.69**	−0.03		**0.88**	0.01	
2. If I eat right, get enough exercise and rest, I can control my weight the way I want.	**0.67**	0.11		**0.87**	0.02	
3. Being the right weight is mainly good luck	−0.08	**0.52**		−0.00	**0.88**	
4. No matter what I try to do, if I gain or lose weight, or stay the same, it is just going to happen.	0.17	**0.51**		0.03	**0.86**	
Cronbach's alpha (by factor)	*0.73*	*0.53*		*0.71*	*0.69*	
Overall Cronbach's Alpha	**0.49**			**0.73**		
Self-Efficacy *How sure are you that you can? (Likert scale very sure – very unsure)*						
5. Fit into your regular clothes	0.28	−0.01	0.04	**0.96**	−0.05	−0.07
6. Take off any extra weight you gain	**0.79**	0.25	0.02	**0.91**	0.02	−0.01
7. Get back in shape	**0.73**	0.28	0.22	**0.85**	0.05	0.12
8. Eat balanced meals	0.14	**0.69**	0.14	−0.12	**0.90**	−0.06
9. Eat foods that are good for you & avoid foods that are not.	0.09	**0.79**	0.05	0.03	**0.85**	0.03
10. Eat foods that are good for you even when family or social life takes a lot of your time.	0.16	**0.72**	0.21	0.18	**0.76**	0.05
11. Get regular exercise	0.15	0.20	**0.75**	0.00	−0.02	**0.98**
12. Get regular exercise even when family or social life takes a lot of time.	0.10	0.10	**0.77**	0.00	0.01	**0.97**
Cronbach's alpha (by factor)	*0.82*	*0.65*	*0.82*	*0.90*	*0.81*	*0.94*
Overall Cronbach's Alpha	**0.76**			**0.85**		
Attitudes towards weight gain *Circle the number that best represents how you feel (Likert scale strongly agree-strongly disagree)*						
13.The weight I gain during my pregnancy makes me feel ugly.	**0.80**	0.25	0.04	**0.83**	−0.09	0.11
14. I worry that I may get fat during this pregnancy.	**0.74**	0.32	−0.09	**0.76**	−0.01	−0.10
15. I am embarrassed at how big I have gotten during this pregnancy.	**0.77**	0.43	0.19	**0.80**	−0.07	0.16
16. I'm embarrassed whenever the nurse weighs me.	**0.70**	0.36	0.24	**0.75**	0.05	0.07
17. I am trying to keep my weight down so I don't look so pregnant.	**0.52**	0.17	0.33	**0.50**	0.18	−0.12
18. I would like to gain between 12.5 and17.5 kgs during this pregnancy.	0.09	0.30	−0.05	−0.23	**0.78**	0.31
19. I would gain 20 kg if it meant a healthier baby.	0.08	**−0.51**	0.21	−0.13	**0.62**	−0.24
20. I will feel badly if I gain more than 20 kgs during this pregnancy.	**0.61**	−0.15	−0.05	0.37	**0.57**	0.07
21. I like being able to gain weight for a change.	0.41	−0.03	0.04	0.22	**0.54**	0.07
22. As long as I'm eating a well-balanced diet, I don't care how much I gain during this pregnancy.	**0.55**	−0.16	−0.13	0.20	**0.54**	−0.19
23. I'm sure I will be able to fully control the amount of weight I will gain during this pregnancy.	−0.06	−0.19	**0.49**	0.15	0.0	**0.73**
24. You can't totally control the amount of weight you gain when you are pregnant.	0.05	−0.06	**0.52**	−0.01	0.06	**0.66**
25. I feel that women have to be very careful about getting fat during pregnancy.	0.46	0.05	−0.01	0.42	0.17	−0.39
Cronbach's alpha (by factor)	*0.89*	*0.39*	*0.54*	*0.80*	*0.65*	*0.36*
Overall Cronbach's Alpha	**0.75**			**0.78**		

(*continued on next page*)

Table 2 (*continued*)

	WATCH Cohort Analysis (Australia)			Bassett Mothers Cohort Analysis (USA)		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
Body Image						
Circle the number that best represents how you feel (Likert scale very satisfied – very dissatisfied, too heavy, about right, too light)						
26. How satisfied are you with your current shape?	**0.82**	0.41		**0.95**	0.04	
27. How satisfied are you with your current weight?	**0.82**	0.42		**0.90**	0.10	
28. Do you consider your current weight to be…	0.40	**0.79**		0.02	**0.95**	
29. Do you consider your current body shape to be…	0.40	**0.78**		0.13	**0.87**	
Cronbach's alpha (by factor)	*0.93*	*0.89*		*0.94*	*0.92*	
Overall Cronbach's Alpha	**0.91**			**0.89**		
Feelings about the motherhood role						
Circle the number that best represents how you feel (Likert scale strongly agree – strongly disagree)						
30. Having a baby brings a lot of stress into a woman's life.	0.35			**0.84**	–0.28	
31. I am not sure how I will manage after I have the baby.	**0.56**			**0.67**	0.15	
32. I am afraid I will lose my identity after I have the baby.	**0.63**			**0.60**	0.26	
33. After a woman has a baby, she is mainly just somebody's mother.	**0.65**			**0.59**	0.20	
34. I am sure I will be a good mother	0.47			**0.41**	0.22	
35. I felt proud when I found out I was going to have a baby	0.44			0.01	**0.82**	
36. I felt scared when I found out I was going to have a baby.	0.41			0.03	**0.80**	
Cronbach's alpha (by factor)	*0.67*	*0.43*		*0.70*	*0.55*	
Overall Cronbach's Alpha	**0.71**			**0.74**		
Career orientation						
Circle the number that best represents how you feel (Likert Scale – strongly agree – strongly disagree)						
37. I want a job that will help me grow.	0.05	0.07	**0.62**	**0.82**	0.14	
38. Being able to express myself through a job means a great deal to me.	0.34	0.02	**0.65**	**0.78**	0.01	
39. I am determined to achieve my educational and work goals.	0.27	0.07	**0.65**	**0.71**	0.07	
40. Success in my work is very important to how I feel about myself.	**0.50**	0.00	0.37	**0.71**	0.10	
41. I see myself as working for pay my whole adult life.	**0.57**	0.03	0.15	**0.62**	0.03	
42. The responsibilities for home and family should be equally shared when both partners work.	–0.02	0.01	0.16	**0.49**	–0.34	
43. I need more in life than what being a wife and mother can give me.	0.47	0.11	0.16	**0.47**	0.26	
44. Women who hope to be successful in a job must do so at the expense of home and family.	–0.03	0.26	0.14	**0.46**	0.04	
45. Women should seek work that will fit in family needs in terms of work hours, leave time, etc.	0.10	**0.73**	0.03	–0.27	**0.76**	
46. Women must make changes in their careers for family needs.	0.17	**0.70**	–0.10	–0.06	**0.70**	
47. Women should not work full-time when their children are young.	0.20	**0.67**	0.07	0.22	**0.62**	
48. Feeling loved and needed is more important to me than having a career.	**0.56**	0.30	–0.12	0.17	**0.58**	
49. I would be very happy staying at home and not working at a job.	**0.73**	0.09	0.02	0.40	**0.46**	
Cronbach's alpha (by factor)	*0.66*	*0.73*		*0.75*	*0.67*	
Overall Cronbach's Alpha	**0.74**			**0.81**		

amongst the WATCH cohort compared to the original analysis ($\alpha = 0.76$ versus 0.85).

For the Body image items, the original Bassett Mothers Health analysis found a 2-item Factor solution across the 4 items, with 2 items loading on each Factor. The current WATCH analysis found the same 2- Factor solution, with the same items loading on each Factors. The overall scale alpha coefficient performed as well in the WATCH cohort as in the original Bassett Mothers Health analysis ($\alpha = 0.91$ versus 0.89, respectively).

The questionnaire item correlations for the Weight locus of control, Self-efficacy and Body image categories are presented in Table 3. To summarise these results, item correlations for the Weight locus of control scale were observed to be the strongest for items within the same Factor. For the Self-efficacy scale, item correlations were again strongest for items loading within the same Factor with the exception of item Q5 -*"How sure are you that you can fit into your regular clothes,* which did not load strongly on any Factor within the WATCH cohort analysis. All body image items were found to be highly correlated.

Deleted items modelling carried out on the Weight locus of control, Self-efficacy and Body image scales are presented in Table 4. The results of this analysis indicated that the overall Cronbach's alpha coefficient for the Weight locus of control scale improved slightly after deleting item Q3 -*"Being the right weight is mainly good luck*" ($\alpha = 0.56$ verses $\alpha = 0.49$), suggesting that this scale may be improved with the removal of this item. When applied to the Self-efficacy scale, modelling indicated that the removal of item Q5 -*"Fit into your regular clothes*", could improve the Cronbach's alpha coefficient of this scale ($\alpha = 0.79$ verses $\alpha = 0.76$). For the Body image items all Cronbach's alphas decreased with the deletion of each item indicating that no items need omitting.

Discussion

This analysis has retested the validity and reliability of the WRB-Q within an Australian pregnancy cohort. The main findings indicate that the WRB-Q as being partly suitable for measuring psychosocial factors in the Australian context. Of the 6 psychosocial scales we observed that the Weight locus of control, Self-efficacy and Body image scales retain the same Factor structure as the original Bassett Mothers Cohort analysis conducted by Kendall et al. (2001). The shared Factor structure of these 3 psychosocial scales indicates consistent construct validity across time. These results additionally suggest that there is potential for the combination of these 3 scales into a shorted psychosocial measurement tool. The Attitudes towards weight gain, Feelings about the motherhood role, and Career orientation scales returned a different Factor structure to the original Bassett Mothers cohort analysis. These results suggest that they may not be suitable as psychosocial measures for use within the Australia context. The scales however demonstrated acceptable in-

Table 3
Scale item correlations.

Weight locus of control (n = 159)	Q1	Q2	Q3	Q4				
Q1	1.00000	**0.57187**	−0.09215	0.11935				
		<0.0001	0.2480	0.1340				
Q2		1.00000	0.08097	0.19440				
			0.3103	0.0141				
Q3			1.00000	**0.35759**				
				<0.0001				
Q4				1.00000				
Spearman's Rho and p-value								
Self – Efficacy (n = 158)	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**
Q5	1.00000	0.28369	0.10956	−0.00105	0.03340	0.03006	0.09331	0.06888
		0.0003	0.1706	0.9896	0.6770	0.7077	0.2436	0.3898
Q6		1.00000	**0.72219**	0.25270	0.23774	0.28224	0.18259	0.08749
			<0.0001	0.0014	0.0026	0.0003	0.0217	0.2744
Q7			1.00000	0.35269	0.22362	0.29568	0.37253	0.28994
				<0.0001	0.0047	0.0002	<0.0001	0.0002
Q8				1.00000	**0.61781**	**0.54329**	0.30765	0.18492
					<0.0001	**<0.0001**	<0.0001	0.0200
Q9					1.00000	**0.63789**	0.22461	0.11404
						<0.0001	0.0046	0.1537
Q10						1.00000	0.27298	0.28683
							0.0005	0.0003
Q11							1.00000	**0.66012**
								<0.0001
Q12								1.00000
Spearman's Rho and p-value								
Body Image (n = 154)	**Q26**	**Q27**	**Q28**	**Q29**				
Q26	1.00000	**0.83114**	**0.64231**	**0.73707**				
		<0.0001	**<0.0001**	**<0.0001**				
Q27		1.00000	**0.73954**	**0.65370**				
			<0.0001	**<0.0001**				
Q28			1.00000	**0.80674**				
				<0.0001				
Q29				1.00000				
Spearman's Rho and p-value								

Table 4
Deleted items modelling.

Weight locus of control Deleted Items Cronbach's α	Raw Variables		Standardized Variables	
	Correlation with Total	Alpha	Correlation with Total	Alpha
Q1	0.294495	0.420017	0.282067	0.415460
Q2	0.427261	0.294319	0.406368	0.293217
Q3	**0.127560**	**0.546547**	**0.120824**	**0.556712**
Q4	0.321052	0.393549	0.339803	0.360182
Self- efficacy Deleted Items Cronbach's α	**Correlation with Total**	**Alpha**	**Correlation with Total**	**Alpha**
Q5	**0.154773**	**0.784592**	**0.146079**	**0.790219**
Q6	0.514318	0.695857	0.507454	0.729234
Q7	0.578706	0.686513	0.576343	0.716582
Q8	0.500599	0.704142	0.523386	0.726338
Q9	0.470355	0.705975	0.502686	0.730097
Q10	0.566190	0.689647	0.591691	0.713717
Q11	0.477347	0.705046	0.483284	0.733593
Q12	0.369311	0.725216	0.380391	0.751690
Body image Deleted Items Cronbach's α	**Correlation with Total**	**Alpha**	**Correlation with Total**	**Alpha**
Q26	0.831215	0.855278	0.807888	0.879599
Q27	0.838792	0.850219	0.815148	0.877021
Q28	0.759369	0.884108	0.779625	0.889544
Q29	0.762119	0.882908	0.781955	0.888729

ternal consistency suggesting that they may be useful as stand-alone, single psychosocial scales.

Moreover, all 6 psychosocial scales were observed to have acceptable internal consistency when retested within the WATCH cohort with the exception of the Weight locus of Control scale, demonstrating a lower overall internal consistency in comparison to the original analysis. Explanations for the lower reliability of this scale (α <0.50) could be due to the lower number of items within the scale or due to poor correlation between scale items Adeniran, 2019; Taber, 2018; Tavakol and Dennick, 2011). The results of the current analysis suggest that poor correlation between scale items as the most likely explanation. Item correlations for the Weight Locus of Control scale were higher for the items loading on the same Factor and lower for items loading across the different Factors (i.e. items Q1 and Q3, Q1 and Q4). Tavakol and Dennick (2011), explain that when the internal consistency is due to poor item correlation, that this may indicate the presence of redundant items, advising revision of items to see if any can be discarded. In the current WATCH analysis novel deleted items modelling was performed for each of the 6 psychosocial scales. For the weight locus of control scale deleted items modelling indicated that the internal consistency can be strengthen to an acceptable level (>0.50) by the removal of item Q3 -*"Being the right weight is mainly good luck"*. When applied to

the Self-efficacy scale deleted items modelling indicted that the internal consistency of this scale can be improved by the deletion of item Q5 - "*How sure are you that you can fit into your regular clothes?"* The internal consistency of the Body image items tested within the WATCH cohort, performed better overall and better in comparison to the original Bassett Mothers cohort analysis. All Body Image items in the WATCH analysis were observed to be highly correlated with deleted items modelling suggesting that no items should be removed from this scale.

Possible explanations for the inconsistency of the Factor structure for the Attitudes towards weight gain, Feelings about the motherhood role, and Career orientation scales could be due differences in, and changes to public health messages regarding weight gain in pregnancy experienced between the cohorts over time (Fealy et al., 2020). Most notable is the shift in public health focus (mostly within high income countries) over the last two decades, from the prevention of undernutrition and low birth weight, to obesity prevention, GWG and diabetes management (Fealy et al., 2020; Institute of Medicine Committee on Nutritional Status During Pregnancy and Lactation, 1990; Rasmussen and Yaktine, 2009). The differing factor structure for the Feelings towards the motherhood role and Career orientation scales may also be explained by changing social roles experienced overtime and may not reflect the cultural attitudes of participants within this Australian pregnancy cohort (Kingsbury et al., 2017).

The Feelings towards motherhood role items, were originally derived from previously published works by Devine and colleagues, suggesting that first time mothers anxious about taking on the motherhood role were more likely to retain weight after birth, with women found to have a strong career orientation more likely to return to work early and lose their pregnancy weight (Devine et al., 2000, 1994). It is possible that these items were more orientated towards first time mothers and may explain some of the missing responses and differing factor loadings, as 55% ($n = 80$) of the WATCH population were identified as multiparous. The Career orientation items were adopted from previously published works by Hemmelgarn (1990), for use amongst employed mothers. It is possible that WATCH participants not in active employment may have perceived some of the items as not applicable to their circumstances, choosing to omit their responses. One other explanation could be attributed to the difference in education levels with 71% of WATCH participants indicating that they were high school educated or above compared to 92% of participants in the Bassett Mothers Health cohort. Given that lower education levels are associated with unemployment this may also assist in explaining why these particular scale items recorded the majority of missing responses (De Witte et al., 2013). Future research investigating the direct and indirect relationship between psychosocial and demographic factors (i.e. education level) in combination with gestational weight gain would be useful to provide further insight into the complex mechanisms of EGWG.

This revalidation analysis has identified that the Weight Locus of Control, Self-efficacy and Body image scales from the WRB-Q as valid and reliable psychosocial measures for use within Australian context. Investigating the relationships between these psychosocial scales as predictors of EGWG within larger diverse cohorts of Australian pregnant women is warranted. Further research such as conducting instrument short form analysis, may be useful to confirm if these scales and individual questionnaire items can be developed into a short pregnancy specific, psychosocial measurement tool.

Strengths

To our knowledge this is the first time the entire WRB-Q has been tested within an Australian population of pregnant women. We additionally performed novel deleted item modelling to identify potential redundant items for removal and overall scale improvement. The results suggest that these scales (Weight Locus of control, Self-efficacy and Body image) may be candidates for combining into a short form questionnaire, potentially reducing participant burden and increasing the questionnaire's appeal for broader clinical research application.

Limitations

Due to the small sample size, the current analysis was an EFA rather than a CFA and as such interpretation of findings needs caution. For instance, changes in Cronbach's alpha values for each of the psychosocial scales may represent natural variation in the behaviour of the scale, or actual improvement in the performance of the scale. Therefore, further analysis using CFA on a larger sample of pregnant women is needed to confirm the factor structure of the WRB-Q as proposed by the current EFA. Further investigation into the external validity of the performance of the factors is also required to determine whether the improvement in alpha scores correlated to improved prediction of the psychosocial construct being measured. The large number of items mean imputed for the Career orientation scale may distort the observed results. While increasing the sample size for this analysis, the mean imputation of values are not reflective of the actual participant responses further undermining the validity of this scale.

Conclusion

The revalidation of the WRB-Q within an Australian pregnancy cohort suggests that the Weight Locus of control, Self-efficacy and Body image scales are consistent, valid and reliable psychosocial measures for use within the Australian context. Findings additionally suggest these scales may be candidates for combining into a short form questionnaire. Further research is required to confirm the factor structure and internal consistency of these measures on a more diverse and larger sample of Australian pregnant women. Additional testing of these scales as predictors of EGWG is required.

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Author agreement

On behalf of all authors I can state that this is original work, the article has not received prior publication nor is under consideration by another journal, all authors approve of the manuscript being submitted and we agree to abide by copyright terms of Elsevier.

Ethical statement

The research protocol for the WATCH study was approved by the Hunter New England Human Research Ethics Committee (approval number 06/05/24/5.06) and approval was registered with the University of Newcastle.

Author statement

As lead and corresponding author I can confirm that this manuscript was prepared with no institutional or corporate financial support for the conduct of the research and/or preparation of the manuscript. I can confirm all listed authors made significant contributions to the manuscript. These are itemised as follows; Ms Shanna Fealy: conceptualisation, original draft preparation, writing and reviewing; Professor John Attia: Statistical analysis, reviewing and editing; Dr Lucy Leigh:statistical methodology and analysis;Professor Michael Hazelton:reviewing, editing and

supervision; Professor Maralyn Foureur:reviewing, editing and supervision; Professor Clare E Collins:investigation, reviewing, editing and supervision; Professor Roger Smith: investigation, reviewing, editing and supervision and Associate Professor Alexis Hure: conceptualisation, investigation, original draft preparation, writing, reviewing, editing and supervision.

Declaration of Competing Interest

On behalf of all authors I declare that there are no conflicts of interest.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.midw.2021.102951.

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Demographic and social-cognitive factors associated with gestational weight gain in an Australian pregnancy cohort

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ABSTRACT

Aim: To identify and describe the demographic and social-cognitive factors associated with excessive gestational weight gain using the Weight-Related Behaviours Questionnaire, within an Australian pregnancy cohort.
Background: Supporting women to achieve optimal weight gain in pregnancy is complex. Social-cognitive factors are recognised antecedents to, and mediators of, weight related behaviour change. Less is known about their role during pregnancy.
Methods: 159 women enrolled in a pregnancy cohort study completed the Weight-Related Behaviours Questionnaire (WRBQ) at approximately 19 weeks gestation, and total gestational weight gain was later measured at 36 weeks. Summary scores were reported descriptively. Multivariable logistic regression was used to test demographic (maternal age, pre pregnancy body mass index, parity, smoking status, marital status, education) and social-cognitive factors (weight locus of control, self- efficacy, attitudes towards weight gain, body image, feelings about motherhood, career orientation) as predictors of excessive gestational weight gain.
Findings: Maternal age was the sole demographic factor predictive of excessive gestational weight gain. Older participants (34-41 yrs) were less likely to gain excessive weight when compare to younger participants (18–24 yrs): Odds Ratio 0.20, 95% Confidence Interval 0.05, 0.82. Body image (measured as personal satisfaction and perception of own weight) was the sole social-cognitive factor associated with excessive gestational weight gain. For every one unit improvement in body image score, there was a 33% decreased odds of excessive gestational weight gain (OR 0.67, 95% CI 0.53, 0.85).
Conclusion: This study suggests that younger maternal age and lower perceived body image are predictive of excessive gestational weight gain.

1. Introduction

Supporting women to achieve healthy weight gain in pregnancy is complex (De Jersey et al., 2017; Fealy et al., 2020). Weight gain is a normal part of the childbearing experience and in general a positive marker of fetal growth and pregnancy progression (Institute of Medicine Committee on Nutritional Status During Pregnancy and Lactation, 1990; Rasmussen & Yaktine, 2009). In contrast, the global prevalence of women experiencing excessive gestational weight gain (EGWG), defined as weight gains above the American Institute of Medicine (IOM) Weight Gain in Pregnancy Guidelines (2009) is a public health concern (Rasmussen & Yakatine, 2009). A systematic review of 23 cohort studies (n = 1, 309,136) by Goldstein et al. (2017) has demonstrated that it is more common for women to gain weight above the

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IOM guidelines (47%, n = 621,004), compared to those gaining below (23%, n = 300, 723) or within (30%, n = 387, 409), independent of pre pregnancy body mass index (BMI) (Goldstein et al., 2017).

Excessive gestational weight gain is associated with adverse perinatal and intergenerational health outcomes. These include, an increased odds of having a large for gestational age infant (birth weight > 90th centile) (Odds Ratio (OR) 1.85, 95% Confidence Interval (CI) 1.76, 1.95), and an increased odds for caesarean birth (OR 1.30, 95% CI 1.25, 1.35) (Goldstein et al., 2017). Individual studies have found EGWG to be associated with increased risk of pregnancy-specific disease such as hypertensive disorders and gestational diabetes (Cedergren, 2006; Johnson et al., 2013; Oken et al., 2007; Stotland et al., 2006). Long term and intergenerational health impacts of gestational weight gain (GWG) are explained by the Developmental Origins of Health and Disease (DOHaD) hypothesis, whereby fetal programming occurs via epigenetic pathways, increasing the offspring's risk of non-communicable diseases over the lifespan (Nyirenda & Byass, 2019). An in-utero environment characterised by maternal malnutrition, causing maternal overweight, is further suggested to lead to childhood chronic disease risk such as obesity, diabetes and non-alcoholic fatty liver disease (Gluckman & Hanson, 2008; McMillen & Robinson, 2005; Nyirenda & Byass, 2019; Poston, 2012).

The experience of weight gain during pregnancy is multifactorial, influenced by a multitude of social-ecological factors. These are described as demographic (age, education, income), physical (diet, exercise), psychological (anxiety, depression) and social-cognitive factors (attitudes, beliefs, social support, self-efficacy, body image) (Fealy et al., 2020; Hansen et al., 2018; Hartley et al., 2015; Hill et al., 2013; Kapadia et al., 2015; Olander et al., 2018). These social-ecological factors are considered important predisposing, enabling and reinforcing constructs within health behaviour theory, that can directly or indirectly influence personal health related behaviours such as diet and exercise (De Jersey et al., 2017; Glanz et al., 2015). To date however, the mechanisms by which social-ecological factors influence weight management outside of, and during pregnancy, is poorly understood (De Jersey et al., 2017; Hansen et al., 2018).

Social-ecological factors have largely been neglected in the design of health promoting interventions aimed at reducing EGWG. Individual studies have primarily focused on modifying the nutrition and physical activity behaviours of pregnant women (Muktabhant et al., 2015; Vincze et al., 2019; Walker et al., 2018). Collectively, these interventions have been found to be moderately successful for some women, with significant barriers identified in the upscaling and translating of these interventions into real world maternity care settings (Fealy et al., 2017; Heslehurst et al., 2014; Walker et al., 2018). Moreover, there is limited consideration and understanding of a pregnant woman's capacity for diet and exercise behaviour modification outside of research conditions (Muktabhant et al., 2015; Olander et al., 2018; Vincze et al., 2019; Walker, Bennett, et al., 2018). Common pregnancy symptoms such as nausea, vomiting, lethargy and anxiety, as well as social determinates of health, including socioeconomic status and social support, can make it difficult for some women to modify (i.e. afford and sustain) their diet and physical activity behaviours (Fealy et al., 2020; Olander et al., 2018; Vanstone et al., 2017).

Demographic and social-cognitive factors such as age, educational attainment, attitudes, beliefs, self-efficacy, body image and social support are recognised antecedents to, and mediators (barriers and enablers) of, health behaviour change (Bergmeier et al., 2020; Hartley et al., 2015; Kapadia et al., 2015). A systematic review and narrative synthesis of thirty-five studies (25 cohort, 8 cross-sectional and 2 case–control) by Kapadia et al. (2015), investigating psychosocial and psychological factors as antecedents of EGWG, considered levels of cognitive dietary restraint, perceived barriers to healthy eating, negative attitudes towards weight gain, negative body image, being concerned about weight gain, high targeted weight gain and inaccurate body perceptions, as potential risk factors for EGWG (Kapadia et al., 2015). Hartley et al. (2015) conducted a similar systematic review and narrative synthesis exploring psychosocial risk factors associated with EGWG. In a synthesis of twelve studies (2 randomised controlled trials, 8 longitudinal, 2 cross - sectional), this review identified depression, body image dissatisfaction, and social support, as potential psychosocial factors associated with EGWG. Of the 47 studies reported in these two systematic reviews, 9 were identified as being duplicated across both review articles. Both studies highlight the need for further research, specifically research that is replicable using valid and reliable measurement tools, to reduce between study heterogeneity and work towards a consensus of social-cognitive factors that influence weight gain during pregnancy (Hartley et al., 2015; Kapadia et al., 2015).

To better understand the influence of social-cognitive factors on weight gain in pregnancy, Kendall et al. (2001) developed the Weight Related Behaviours Questionnaire (WRB-Q), to assist with identifying and understanding the mechanisms by which, social-cognitive factors mediate GWG amongst populations of pregnant women (Kendall et al., 2001). Due to the multitude of social-cognitive factors evidenced to exhibit relationships with GWG, the WRB-Q provides a valid and reliable consensus of factors for investigation (Hartley et al., 2015; Kapadia et al., 2015; Kendall et al., 2001). Therefore, the purpose of this study was to identify and describe the demographic and social-cognitive factors predictive of EGWG, within the Australian Women and Their Children's Health (WATCH) cohort study.

2. Methods

2.1. Weight Related Behaviours Questionnaire

The Weight Related Behaviours Questionnaire measures 6 social-cognitive factors across 49 individual question items. The social-cognitive factor categories included within the WRB-Q are: 1) *Weight locus of control* (4 questions), measuring the degree to which a person feels that behaviour change is within personal control (internal locus of control), or outside of personal control (external locus of control) (Kendall et al., 2001; Saltzer, 1982); 2) *Self-efficacy* (8 questions), measuring confidence for behaviour change related to diet, weight control and exercise; 3) *Attitudes towards weight gain* (13 questions), measuring attitudes towards gaining weight or weight gain avoidance; 4) *Body image* (4 questions, 2 measured as personal satisfaction with own weight and 2 measured as personal perception of own weight); 5) *Feelings about the motherhood role* (7 questions), measuring positive and negative aspects of motherhood; 6) *Career orientation* (13 questions), measuring preference towards career or family orientation (Kendall et al., 2001). Each social-cognitive factor was measured using a Likert scale with responses ranging from strongly agree to strongly disagree (factors 1,3,5,6), from very sure to very unsure (factor 2), from too heavy to too light (factor 4), and from very satisfied to not at all satisfied (factor 4) (Kendall et al., 2001).

The questionnaire was originally tested for reliability and validity amongst a large cohort of pregnant women (n = 622) in the United States of America (USA), between March 1995 and December 1996, as reported in the Kendall et al. (2001) study paper. The questionnaire has been used in seminal works, mainly within USA, to examine factors that influence GWG and postpartum weight retention (Hinton & Olson, 2001; Lipsky et al., 2016; Olson & Strawderman, 2003; Olson et al., 2017). The internal consistency for each of the 6 social-cognitive factor scales, demonstrated acceptable internal consistency when retested within the WATCH pregnancy cohort, with the exception of the weight locus of control scale as follows; 1) *Weight locus of control* (α 0.49); 2) *Self-efficacy* (α 0.76); 3) *Attitudes towards weight gain* (α 0.75); 4) *Body image* (α 0.91); 5) *Feelings about the motherhood role* (α 0.71); 6) *Career orientation* (α 0.74).

2.2. Population

The Women And Their Children's Health (WATCH) study was a detailed prospective Australian longitudinal cohort study. Women were recruited (between June 2006 and December 2007) to participate in the study during early pregnancy (< 18 weeks), with follow up to 4 years post birth (n = 180 women and n = 182 children) (Hure et al., 2012). The detailed WATCH study protocol has been previously published (Hure et al., 2012). Demographic and birth data were extracted from electronic hospital birth records. The Weight Related Behaviours Questionnaire was administered to participants at the first study visit occurring between 18 and 20 weeks gestation. The research protocol for the WATCH study was ethically approved (approval number 06/05/24/5.06) (Hure et al., 2012).

2.3. Weight and height measures

Maternal weight and height measurements were obtained at each study visit using the same set of annually calibrated scales and wall mounted stadiometer, by an accredited practising dietitian with level 1 anthropometry training (Hure et al., 2012). Maternal height and weight were taken in clothing with no shoes. Height was measured on two consecutive appointments to the nearest 1 mm, with an average of the two measures used. Where both height measures varied more than 1.5% a third measure was taken, and the median used as the maternal height reference (Hure et al., 2012). Maternal pre-pregnancy weight (kilograms) was self-reported at the first study visit, with all subsequent weights measured by researchers at study visits. Pre-pregnancy BMI was calculated using pre-pregnancy weight and the recorded maternal height reference. Total GWG was calculated by subtracting the last recorded pregnancy weight reading at approximately 36 weeks from the self-reported pre-pregnancy weight reference (Hure et al., 2012).

Pre-pregnancy BMI was classified into World Health Organization (WHO) categories. Guidelines for GWG were based on the American IOM 2009 Nutrition in Pregnancy Guidelines (Rasmussen & Yaktine, 2009). The outcome of interest, EGWG was defined as weight gain greater than the maximum recommended weight gain, according to pre-pregnancy BMI category, recorded at the last pregnancy appointment at approximately 36 weeks gestation.

3. Statistical analysis

Demographic, pregnancy and birth characteristics of the WATCH cohort were analysed using descriptive statistics (mean, SD, numbers and percentages). Individual questionnaire items were additionally analysed using descriptive statistics (numbers and percentages). The participant questionnaire scores were summarised (trichotomised or dichotomised) for presentation purposes as per Supplementary File 1.

Multivariable logistic regression modelling was then performed to test the association between demographic and social-cognitive variables and EGWG. Prior to this analysis, 29 items were reverse coded so that higher scale scores were representative of a higher level of social-cognitive factor being measured (see Supplementary File 1).

Multivariable logistic regression model diagnostics indicated that leaving maternal age as a continuous predictor violated the assumption of linearity, and as a result maternal age was categorised into quintiles. A further six logistic regression models were then performed for each of the 6 social-cognitive factors. Each model was subject to covariate adjustment (Area Under the Curve - AUC) for each of the listed demographic factors, and each was compared to determine whether the addition of these factors improved the accuracy of the model. Assessment of model diagnostics for this analysis again indicated that the linearity assumption was violated for all social-cognitive factors except for body image, and these were categorised into quintiles. The criterion for statistical significance was set at $p < 0.05$ (two tailed). Demographic and multivariable logistic regression were programmed using SAS v9.4 (SAS Institute, Cary, North Carolina, USA). Descriptive questionnaire data were calculated using STATA/IC v13.0 (StataCorp, Texas, USA) and Microsoft® Excel v16.24.

Table 1
WATCH Cohort demographic, pregnancy and birth characteristics.

WATCH cohort (***N*** = 159)	
Age (Mean/SD)	28.9 (5.64)
Missing 12	
Country of birth Australia *n* (%)	138 (94%)
Other n (%)	9 (6.1%)
Education ≥ Year 12 (high school) *n* (%)	105 (71%)
Education ≤ Year 12 (high school) *n*(%	42 (29%)
Missing 12	
Married *n* (%)	84 (61%)
Unmarried n (%)	54 (39%)
Missing 22	
Parity- Primiparous *n* (%)	66 (45%)
Party- Multiparous *n* (%)	80 (55%)
Missing 13	
Smoker n (%)	15 (10%)
Developed gestational diabetes n (%)	6 (4.1%)
Missing 14	
Developed hypertension in pregnancy n (%) (pre-eclampsia/ gestational hypertension)	9 (6.1%)
Missing 13	
Mode of birth n (%)	
Vaginal birth	104 (66%)
Instrumental birth	22 (14%)
Caesarean birth	32 (20%)
Missing 1	
Infant Birth Weight (grams)	
Mean (SD) *n = 144*	3495.0 (557.02)
Breastfeeding n (%)	
(at approx. 3-months post-partum n = 140)	94 (67%)
(at approx. 6 months post-partum n = 120)	68 (57%)

4. Results

The entire WRB-Q, social-cognitive factors and missing data are presented in Supplementary File 1. Of the WATCH study participants 88% (n = 159) returned the WRB-Q, with 73% (n = 132) returning complete responses across all six social-cognitive factor categories. The *Weight locus of control* and *Attitudes towards weight gain* categories returned the highest range of complete responses, with the *Career orientation* category returning the most incomplete responses (3–5% missing responses across all 13 items).

Population demographics of the WATCH sample are summarised in Table 1.

The majority of participants were born in Australia, identified as being married, were high school and above educated, none smokers and experiencing a subsequent pregnancy (i.e. multiparous). Birth data indicated that the majority of participants experienced a vaginal birth, with only 20% experiencing a caesarean birth. The proportion of participants diagnosed with gestational diabetes, gestational hypertension/pre-eclampsia were representative of wider state based maternal and infant data trends, for the years in which pregnancy and birth data were collected for the WATCH study (Centre for Epidemiology and Research NSW Department of Health, 2010).

Maternal weight characteristics are shown in Table 2, with the mean pre-pregnancy weight and the stratification of participants by pre-pregnancy BMI category.

In total, 41% of participants had already exhibited EGWG by approximately 36 weeks gestation, independent of pre-pregnancy BMI. When stratified by BMI, participants in the underweight and overweight categories proportionally exhibited greater gains than those in the normal weight or obese BMI categories.

To summarise the descriptive results presented in Supplementary File 1, the cohort generally possessed high internal levels of *Weight locus*

Table 2
WATCH Maternal weight characteristics.

WATCH cohort (N = 159)	
Pre-pregnancy weight (kg) Mean (SD)	69.63 (16.97)
Pre-pregnancy BMI by Category (*n, %*)	
Underweight (< 18.5 kg/m^2)	8 (5.4%)
Normal (≥18.5–24.9 kg/m^2)	75 (51%)
Overweight (≥25–29.9 kg/m^2)	34 (23%)
Obese (Obese ≥ 30 kg/m^2)	30 (20%)
Missing 12	
Excess weight gain by pre-pregnancy BMI (*n, %*)	
Underweight (< 18.5 kg/m^2)	5 (62.5%)
Normal (≥18.5–24.9 kg/m^2)	24 (32.0%)
Overweight (≥25–29.9 kg/m^2)	20 (58.8%)
Obese (Obese ≥ 30 kg/m^2)	11 (36.7%)
Total sample gaining excess weight (*n, %*)	60 (41%)

of control and *Self-efficacy*. Most women had positive *Attitudes towards gaining weight during pregnancy* and were satisfied with their *Body image*. There were generally positive *Feelings towards the role of motherhood* and the women were oriented to family rather than *Career orientated*. Of these social-cognitive factors, there was a proportion of women whose item responses indicated that weight gain as outside personal control, low levels of *Self- efficacy*, preference towards weight gain avoidance, dissatisfaction with/or negative *Body image* and negative *Feelings towards the role of motherhood*. It is these women that we hypothesise require better linkage with health services and greater support to optimise weight gain in pregnancy.

The results of the multivariate logistic regression on cohort demographic factors are presented in Table 3. Maternal age was found to be the single demographic factor inversely associated with EGWG.

When compared to the youngest participants in quintile 1 (18–24 yrs), older participants in the fifth quintile (34–41 yrs) were less likely to experience EGWG (OR 0.20, 95% CI 0.05, 0.82, p 0.0146). When the 6 social-cognitive factors from the WRB-Q were tested as predictors of EGWG (Table 4), *Body image* was the only social-cognitive factor found to be statistically associated with EGWG. For every one unit increase in *Body image* score (i.e. more positive about their body), there was a 33% decreased odds of experiencing EGWG (OR 0.67, 95% CI 0.53, 0.85, p 0.0008).

The AUC (adjusted for maternal age, pre-pregnancy BMI category, parity, smoking status, marital status, and education) improved to the greatest extent after the addition of *Body image*, but did not improve significantly with the addition of the other social-cognitive factors (*Feelings towards the motherhood role*, *Career orientation, Attitudes towards weight gain*, and *Weight locus of control* or *Self-efficacy*).

Table 3
Multivariable logistic regression of excess GWG.

Variable (*n* = 138)	Odds ratio (95% confidence interval CI)	P-value	AUC
Maternal Age (years) (*ref = Quintile 1, age18–24 yrs*)[a]			
Quintile 2 (age 24.2–26.9)	1.15 (0.32, 4.10)	0.0146	0.732
Quintile 3 (age 27.3–30.2)	0.32 (0.09, 1.18)		
Quintile 4 (age 30.3–33.8)	1.23 (0.34, 4.44)		
Quintile 5 (age 34.0–41.2)	0.20 (0.05, 0.82)		
Pre-pregnancy BMI (ref = "Normal")			
Obese	1.49 (0.53, 4.18)	0.1025	
Overweight	3.31 (1.23, 8.86)		
Underweight	2.91 (0.52,16.29)		
Parity (ref = 0 primiparas)			
1	0.89 (0.35, 2.31)	0.9687	
2+	0.91 (0.34, 2.45)		
Smoking (ref = No)			
Yes	0.88 (0.22, 3.50)	0.8582	
Married (ref = No)			
Yes	0.60 (0.25, 1.43)	0.2467	
Education ≥ year 12 (*ref = No*)			
Yes	1.54 (0.61, 3.86)	0.3600	

[a] Model diagnostics indicated that leaving maternal age as a continuous predictor violated the assumption of linearity, and as a result maternal age was categorised into quintiles.

Table 4
Regression of excess GWG on social-cognitive factors.

Social-cognitive categories	Odds ratio (95% confidence interval CI)	P-value	AUC[a]
Body Image (n = 137)	0.67 (0.53, 0.85)	0.0008	0.794
Career Orientation (*n = 135*) (ref quintile 1, score range 22 - 29)			
Quintile 2 - Score Range (30 – 32)	0.35 (0.09, 1.32)	0.4854	0.762
Quintile 3 - Score Range (32 – 33)	0.39 (0.10, 1.53)		
Quintile 4 - Score Range (34–35)	0.84 (0.25, 2.74)		
Quintile 5 - Score Range (36–47)	0.64 (0.19, 2.21)		
Feelings about motherhood (*n = 137*) (ref = quintile 1, score range 18–23)			
Quintile 2- Score Range (24–25)	3.07 (0.77,12.27)	0.3678	0.763
Quintile 3- Score Range (26–27)	1.95 (0.53, 7.23)		
Quintile 4- Score Range (28–30)	3.80 (1.00,14.53)		
Quintile 5- Score Range (31–35)	2.81 (0.71,11.13)		
Weight locus of control (n = 138) (ref = quintile 1, score range 7 - 11)			
Quintile 2- Score Range (12 – 13)	0.73 (0.24, 2.21)	0.7824	0.728
Quintile 3- Score Range (4–14)	0.40 (0.10, 1.58)		
Quintile 4- Score Range (15–15)	0.83 (0.18, 3.70)		
Quintile 5- Score Range (16–20)	0.75 (0.25, 2.24)		
Self-efficacy (*n = 138*) (ref = quintile 1, score range 3 - 23)			
Quintile 2- Score Range (24–27)	1.43 (0.45, 4.54)	0.9057	0.727
Quintile 3- Score Range (28–29)	1.11 (0.32, 3.80)		
Quintile 4- Score Range (30 – 31)	0.78 (0.21, 2.94)		
Quintile 5- Score Range (32–38)	1.25 (0.36, 4.32)		
Attitudes towards weight gain (n = 138) (ref = quintile 1, score range 17 - 27)			
Quintile 2- Score Range (28–30)	0.58 (0.16, 2.08)	0.3865	0.747
Quintile 3- Score Range (31 – 33)	1.25 (0.34, 4.56)		
Quintile 4- Score Range (34–38)	1.02 (0.32, 3.27)		
Quintile 5- Score Range (39–52)	2.17 (0.66, 7.18)		

[a] Adjusted under the curve (AUC) Adjusted for maternal age, pre-pregnancy BMI category, parity, smoking status, marital status, and education Assessment of model diagnostics for this analysis indicated that the linearity assumption was violated for all social-cognitive factors with the exception of body image, and these were categorised into quintiles.

5. Discussion

The current study has explored the associated relationships between selected demographic and social-cognitive factors and EGWG, in a cohort of Australian pregnant women. The results suggest a temporal relationship exists between age and body image and EGWG within this cohort.

Age is a known predictor of GWG, however the relationship

between these variables has been inconsistent. The original IOM (1990) guidelines, in a review of 9 studies (published between 1977 and 1989), reported that women of a younger age were more susceptible to lower GWG. The revised IOM guidelines (2009) in an updated review (14 studies, published between 1977 and 2006), suggested that older women (≥34ys) were entering pregnancy with higher BMI's, but exhibiting lower GWG compared to younger childbearing women (< 25ys) (Rasmussen & Yaktine, 2009). A large Danish cohort study (n = 60,892 pregnancies) conducted by Nohr et al. (2008), similarly observed that older women (≥34ys) exhibited lower GWG (15.2% gaining > 20 kg) compared to younger women (< 25ys, 31% gaining > 20 kg. In this study older women (≥34ys, 6.9%) were less likely to be classified as obese according to pre pregnancy BMI compared to younger women (< 25 years 10.1%) (Nohr et al., 2008). A more recent cross-sectional study, investigating dietary patterns, socio demographic factors and GWG in a cohort of Polish women (n = 458), did not find age to be associated with GWG. Within this study, a higher pregnancy BMI (> 25.0 kg/m^2, OR 6.44, 95% CI 2.87, 14.42) and smoking cessation after conception (OR 9.01, 95% CI 1.20, 41.23) were associated with EGWG (≥ IOM weight gain in pregnancy guidelines) (Suliga et al., 2018).

The current WATCH analysis did not identify a relationship between any other demographic factors and EGWG. This analysis observed that women most at risk of EGWG were of a younger age with a negative body image, identified by mid-pregnancy.

Body image refers to the internal representation a person has towards their external appearance and is often separated into two measures: body satisfaction and body attitudes (thoughts and beliefs) (Andrews et al., 2017; Hill et al., 2013; Roomruangwong et al., 2017; Thompson et al., 1999). In non-pregnant populations body image dissatisfaction is reported as a constant norm across the lifespan (Ålgars et al., 2009; Runfola et al., 2013). Runfola et al. (2013) combined data from two cross-sectional studies of American women (n = 5868) aged between 25 and 89 years and observed that 91% of participants were dissatisfied with their body image. In this study age was found to mediate body dissatisfaction, with women aged 35–44 years reporting the highest levels of body dissatisfaction. Women aged 65–74 years recorded the lowest levels of body dissatisfaction, with women in the 25–34-year age group also reporting high body dissatisfaction scores (Runfola et al., 2013). These findings outside of pregnancy, are in contrast to the body image scores observed within the WATCH pregnancy cohort. The majority of women in the WATCH study indicated overall satisfaction with their body image when assessed during mid pregnancy.

Consistent with our findings, systematic reviews by Kapadia et al. (2015) and Hartley et al. (2015), exploring the relationships between psychological and social cognitive factors as predicators of EGWG, collectively identified 7 individual studies investigating body image dissatisfaction in pregnant women. Of these studies, 4 observed significant associations between body dissatisfaction and EGWG (Hartley et al., 2015; Kapadia et al., 2015). A recent study by Roomruangwong et al. (2017), investigated the relationships between body dissatisfaction, anxiety, depression, BMI and GWG, in a small population (n = 126) of Thai pregnant women. Findings indicated that body image dissatisfaction was increased in women with a mean age of 27.3 years and was lower in women with a mean age of 30.3 years. Participants reporting body image dissatisfaction were of a higher pre pregnancy BMI (mean 23.8 SD 4.1) and exhibited higher GWG (mean 13.8 kg SD4.9), compared to those who were satisfied with their body image (Roomruangwong et al., 2017). In addition body image dissatisfaction during the perinatal period was found to be associated with increased depression and anxiety scores (Hamilton Depression Rating Scale, Edinburgh Postnatal Depression Scale, Beck depression Inventory), antenatal depression diagnosis, depression, mood disorders and postnatal depression (Roomruangwong et al., 2017).

There is a growing body of evidence exploring the potential direct and indirect relationships between maternal psychology (depression and anxiety) body image and EGWG (Andrews et al., 2017; Hill, Skouteris, McCabe, Fuller-Tyszkiewicz, et al., 2013; Roomruangwong et al., 2017; Thompson et al., 1999). Hill, Skouteris, McCabe, Milgrom, et al. (2013), presented a conceptual model to theoritically explain the potential relationship and pathways between psychosocial, psychological, demographic factors and GWG. This model theorised that maternal psychological, psychosocial and demographic factors as preceeding mediators of body image and self-effiacy. Satisfaction with body image and self-efficacy are suggested to indirectly influence (positively or negatively) motivation for behaviour change (i.e. diet and physical activity), affecting GWG outcomes (Hill, Skouteris, McCabe, Milgrom, et al., 2013).

Indirectly, consistent temporal relationships have been demonstrated between body image dissatisfaction and maternal depressed mood, with depression preceding body image dissatisfaction (Fuller-Tyszkiewicz et al., 2013). A recent prospective cohort study (n = 253) by Riquin et al. (2019), found a significant relationship between body image dissatisfaction and perinatal depression. The risk of perinatal depression was found to be 3 times greater in women with body image dissatisfaction (OR 3.7, 95% CI 1.9–7.2) compared with women who were satisfied with their body image (Riquin et al., 2019). These studies suggest the existence of a bidirectional relationship between body image dissatisfaction and depression (i.e. body image dissatisfaction increases the risks of depression and depression increasing the risks of body dissatisfaction) (Riquin et al., 2019).

A more recent review and discussion of maternal body image dissatisfaction by Bergmeier et al. (2020), suggests direct theoretical relationships may exist between body image dissatisfaction, the development of antenatal depression and anxiety affecting eating behaviour and EGWG (Bergmeier et al., 2020).

While further research is needed to model these relationships, it is possible that the interrelationship between body image dissatisfaction and maternal depressive symptoms are both directly and indirectly associated with EGWG. Analysis techniques such as mediation analysis may be a pragmatic next step in the research process (Lapointe-Shaw et al., 2018) and intervention studies trialling support strategies could also help in determining causation.

The remaining social-cognitive factors, Weight locus of control, Self-efficacy, Attitudes towards weight gain, Feelings about the motherhood role and Career orientation, were not associated with EGWG in this cohort. A similar study conducted by De Jersey et al. (2017), investigating the relationship between psychosocial heath cognitions and EGWG (at 36 weeks), found a relationship between healthy weight women (BMI < 25.0) and weight locus of control, assessed in early pregnancy. In this study a higher perceived weight locus of control was associated with lower risk (adjusted odds ratio 0.6) for EGWG (De Jersey et al., 2017). Similar to our findings and using a larger population sample, the study did not find a statistical relationship between self-efficacy and EGWG (De Jersey et al., 2017). This is in contrast to findings outside of pregnancy that have consistently associated self-efficacy with weight loss and weight maintenance success (De Jersey et al., 2017; Kendall et al., 2001).

The current WATCH analysis provides further insight into the complex nature of GWG and contributes to the accumulating evidence suggesting a shift in focus from diet and exercise interventions for optimising GWG, to acknowledging the moderating role of social-cognitive and demographic factors, on weight gain in pregnancy. We have highlighted that “one size fits all” approaches such as addressing the physiological components of diet and exercise, whilst working for some women, are not enough to address the complexities of weight gain in pregnancy. This is consistent with findings outside of pregnancy (Holley et al., 2016). We suggest, future research work towards developing a consensus of social-cognitive factors that are predictive of EGWG, with greater consideration given to demographic factors such as age and social-cognitive factors, such as body image, when designing

interventions to improve adherence to GWG targets.

5.1. Strengths

To our knowledge this is the first description of the WRB-Q in an Australian cohort of pregnant women. This study has been conducted using a previously validated questionnaire for the identification of social-cognitive factors amongst pregnant women and a combination of self-reported (pre-pregnancy) and objectively measured weight.

5.2. Limitations

We are not able to determine from our analyses whether the observed association is causal, non-causal association or consequence. However, in our prospective cohort study the relationship is temporal in that the WRB-Q was administered at roughly 19 weeks gestation. It is possible that early pregnancy weight gain had already affected body image by the time the questionnaire was administered. Prospective studies that assess body image prior to pregnancy would help elucidate this role. The measurement for total GWG was taken at approximately 36 weeks also may not reflect the total weight gain prior to giving birth. While the sample size for this study was limited, we were able to detect significant associations for those predictors with a particularly large effect size. We have not undertaken a post-hoc power analysis as it is generally accepted as inappropriate and misleading (Gilbert & Prion, 2016; Zhang et al., 2019). The low internal consistency observed for the weight locus of control scale (α 0.49) does undermine the reliability of results observed for this scale and suggest that these findings be interpreted with caution. The majority of participants within this study were born in Australia, high school educated and above and married or partnered. Therefore, this cohort is not representative of vulnerable populations, for example migrant women, those with lower education, or women with limited social support.

6. Conclusion

This study provides further insight into the complex nature of GWG. This study suggests that a temporal relationship exists between body image dissatisfaction in mid pregnancy and EGWG. Future research is needed to ascertain the causal pathways between social cognitive factors particularly age and body image, when assessing a woman's capacity for weight-related behaviour change during pregnancy amongst large and diverse cohorts of pregnant women.

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CRediT authorship contribution statement

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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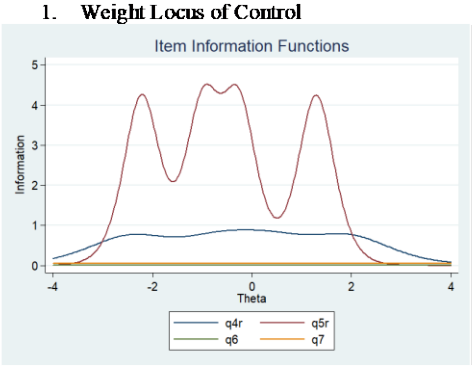
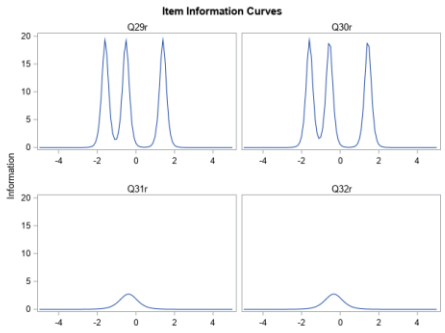
A9. Graphical item information function results

Supplementary file 1. Graphical item Information function results

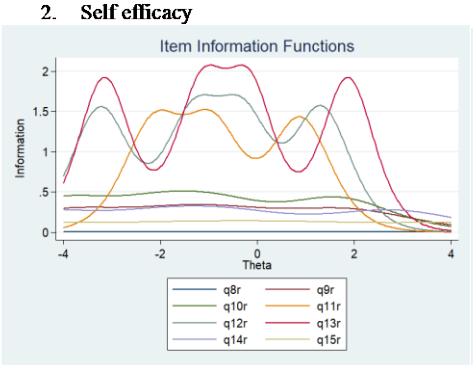
1. **Weight Locus of Control**



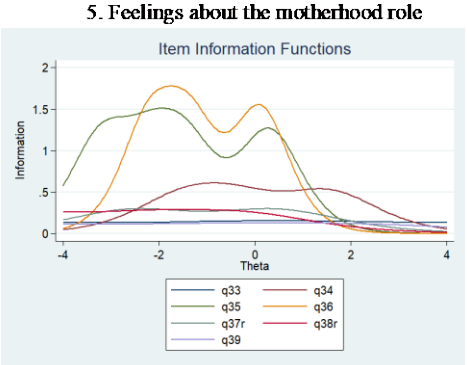
4. **Body Image**



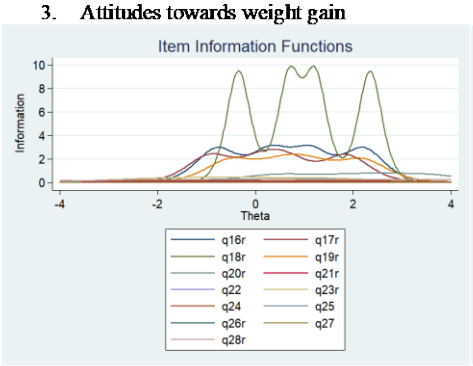
2. **Self efficacy**



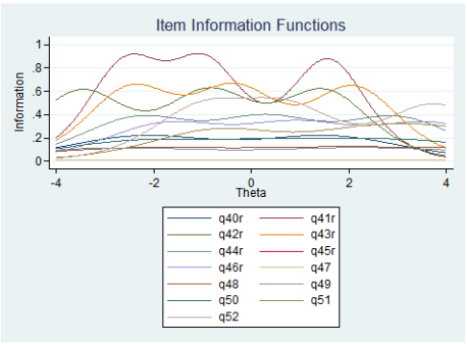
5. **Feelings about the motherhood role**



3. **Attitudes towards weight gain**



6. **Career oreintation**



**Note - Items numbererd from 4–52 for analysis purposes. These items are preresented as questionnaire items 1–49 within the main manuscript.*

A10. Summary table of weight-related behaviour questionnaire responses from the WATCH pregnancy cohort

Supplementary File 1.

Summary Weight Related Behaviour Questionnaire responses from the WATCH pregnancy cohort *(n=159)*

Weight Locus of Control Likert scale 1 to 5, underlined scores measure preference towards internal locus of control) *Italics measure external locus of control* Circle the number that best represents how you feel	**Strongly Agree or Agree (1-2)**	**Neither Agree nor Disagree (3)**	**Strongly Disagree or Disagree (4-5)**	**Missing Responses (n)**
Q1 *Whether my weight change is up to me	40%	27%	*33%*	0
Q2 *If I eat right, and get enough exercise and rest, I can control my weight the way I want.	**60%**	21%	*19%*	0
Q3 Being the right weight is mainly good luck	*7%*	23%	**70%**	0
Q4 No matter what I try to do, if I gain or lose weight, or stay the same, it is just going to happen.	*30%*	21%	49 %	1
Self-Efficacy Likert scale 1 to 5, underlined scores measure greater self-efficacy *Italics measure lower self-efficacy* How sure are you that you can?	**Very Sure or Sure (1-2)**	**Neither sure nor Unsure (3)**	**Very Unsure or Unsure (4-5)**	**Missing Responses (n)**
Q5 *Fit into your regular clothes	31%	21%	*49%*	3
Q6 *Take off any extra weight you gain	**66%**	16%	*18%*	1
Q7 *Get back into shape	**73%**	16%	*11%*	1
Q8 *Eat balanced meals	**78%**	18%	*5%*	1
Q9 *Eat foods that are good for you and avoid foods that are not	**60%**	26%	*14%*	1
Q10 *Eat foods that are good for you even when family or social life takes a lot of your time.	**56%**	27%	*17%*	1
Q11 *Get regular exercise	**65%**	19%	*16%*	1
Q12 *Get regular exercise even when family or social life takes a lot of your time.	40%	30%	*30%*	1
Attitudes towards weight gain Likert scale 1 to 5, underlined scores measure positive attitudes towards weight gain. *Italics measure weight gain avoidance* Circle the number that best represents how you feel	**Strongly Agree or Agree (1-2)**	**Neither Agree nor Disagree (3)**	**Strongly Disagree or Disagree (4-5)**	**Missing Responses (n)**
Q13 *The weight I gain during pregnancy makes me feel ugly	*15%*	23%	**62%**	1
Q14 *I worry that I may get fat during this pregnancy	*30%*	16%	**54%**	0
Q15 *I am embarrassed at how big I've gotten during this pregnancy	*11%*	12%	**77%**	0

Q16 *I'm embarrassed whenever the nurse weighs me	*17%*	15%	**68%**	2
Q17 *I am trying to keep my weight down, so I don't look pregnant	*1%*	6%	**93%**	0
Q18 I would like to gain between 12.5 and 17.5 kilograms during this pregnancy	38%	36%	*25%*	2
Q19 I would gain 20 kilograms if it meant a healthier baby	**58%**	25%	*17%*	1
Q20 *I will feel badly if I gain more than 20 kilograms during this pregnancy	*52%*	20%	28%	1
Q21 I like being able to gain weight for a change	12%	33%	*55%*	0
Q22 As long as I'm eating a well-balanced diet, I don't care how much I gain during this pregnancy.	**55%**	25%	*20%*	0
Q23 *I'm sure I will be able to fully control the amount of weight I will gain during this pregnancy	*10%*	29%	**61%**	1
Q24 You can't totally control the amount of weight you gain when you are pregnant	**72%**	19%	*9%*	0
Q25 *I feel that women have to be very careful about getting fat during pregnancy.	*19%*	36%	45%	0

Body Image Underlined scores measure preference towards satisfaction with body weight/ shape *Italics measure body weight/ shape dissatisfaction* Circle the number that best represents how you feel	**Very Satisfied or Satisfied**	**Very Dissatisfied or Dissatisfied**	-	**Missing Responses (n)**
Q26 *How satisfied are you with your current shape?	**68%**	*32%*	-	2
Q27 *How satisfied are you with your current weight?	**70%**	*30%*	-	1
	Too Heavy	**About Right**	**Too Light**	**Missing Responses (n)**
Q28 Do you consider your current weight to be…	*34%*	**63%**	*3%*	1
Q29 Do you consider your current body shape to be…	*36%*	**62%**	*2%*	1

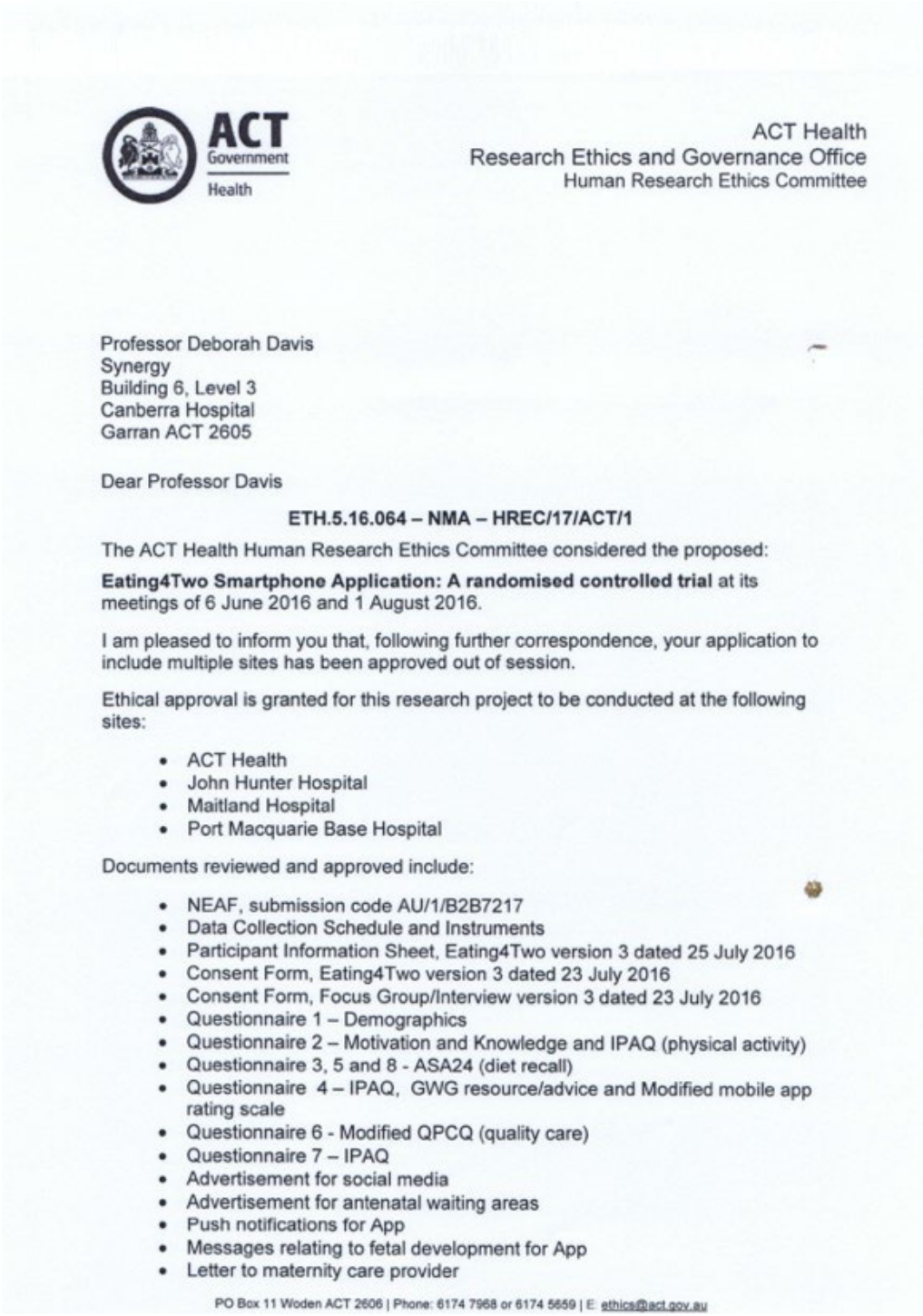
Measures of Feelings About Motherhood Likert scale 1 to 5, underlined scores measure positive feelings *Italics measure negative feelings* Circle the number that best represents how you feel	**Strongly Agree or Agree** (1-2)	**Neither Agree nor Disagree** (3)	**Strongly Disagree or Disagree** (4-5)	**Missing Responses (n)**
Q30 Having a baby brings a lot of stress into a woman's life.	*39%*	34%	27%	2
Q31 I'm not sure how I will manage after I have the baby	*18%*	20%	**62%**	2

Q32 I am afraid I will lose my identity after I have the baby	*4%*	8%	**88%**	2
Q33 After a woman has a baby, she is mainly just somebody's mother	*4%*	8%	**88%**	3
Q34 *I am sure that I will be a good mother.	**91%**	9%	*0%*	2
Q35 *I felt proud when I found out I was going to have a baby	**86%**	13%	*1%*	2
Q36 I felt scared when I found out I was going to become a mother.	*38%*	15%	**47%**	2
Career Orientation Likert scale 1 to 4, underlined scores measure preference towards career orientation. *Italics measure orientation towards family* Circle the number that best represents how you feel	**Strongly Agree or Agree** (1-2)	**Strongly Disagree or Disagree** (3-4)	-	**Missing Responses (n)**
*Q37 *I want a job that will help me grow*	**87%**	*13%*	-	6
*Q38 *Being able to express myself through a job means a great deal to me.*	**77%**	*23%*	-	5
*Q39 *I am determined to achieve my educational and work goals*	**72%**	*28%*	-	6
*Q40 *Success in my work is very important to how I feel about myself*	**58%**	*42%*	-	6
*Q41 *I see myself as working for pay my whole adult life*	**43%**	*57%*	-	6
*Q42 *The responsibilities for home and family should be equally share when both partners work*	**95%**	*5%*	-	5
*Q43 *I need more in life than what being a wife and mother can give me*	**29%**	*71%*	-	6
Q44 Women who hope to be successful in a job must do so at the expense of home and family	*18%*	82%	-	8
Q45 Women should seek work that will fit in family needs in terms of work hours, leave time, etc	*75%*	25%	-	8
Q46 Women must make changes in their careers for family needs	*79%*	**21%**	-	7
Q47 Women should not work full time when their children are young	*61%*	**39%**	-	7
Q48 Feeling loved and needed is more important to me than having a career	*91%*	**9%**	-	6
Q49 I would be very happy staying at home and not working at a job.	*67%*	**33%**	-	6

*Questionnaire items reverse coded for analysis and interpretation

Bold text Indicates higher level of social-cognitive factor being measured (items scores ≥50%)

A11. ACT Health, Eating4Two trial ethics approval



ACT Government
Health

ACT Health
Research Ethics and Governance Office
Human Research Ethics Committee

Professor Deborah Davis
Synergy
Building 6, Level 3
Canberra Hospital
Garran ACT 2605

Dear Professor Davis

ETH.5.16.064 – NMA – HREC/17/ACT/1

The ACT Health Human Research Ethics Committee considered the proposed:

Eating4Two Smartphone Application: A randomised controlled trial at its meetings of 6 June 2016 and 1 August 2016.

I am pleased to inform you that, following further correspondence, your application to include multiple sites has been approved out of session.

Ethical approval is granted for this research project to be conducted at the following sites:

- ACT Health
- John Hunter Hospital
- Maitland Hospital
- Port Macquarie Base Hospital

Documents reviewed and approved include:

- NEAF, submission code AU/1/B2B7217
- Data Collection Schedule and Instruments
- Participant Information Sheet, Eating4Two version 3 dated 25 July 2016
- Consent Form, Eating4Two version 3 dated 23 July 2016
- Consent Form, Focus Group/Interview version 3 dated 23 July 2016
- Questionnaire 1 – Demographics
- Questionnaire 2 – Motivation and Knowledge and IPAQ (physical activity)
- Questionnaire 3, 5 and 8 - ASA24 (diet recall)
- Questionnaire 4 – IPAQ, GWG resource/advice and Modified mobile app rating scale
- Questionnaire 6 - Modified QPCQ (quality care)
- Questionnaire 7 – IPAQ
- Advertisement for social media
- Advertisement for antenatal waiting areas
- Push notifications for App
- Messages relating to fetal development for App
- Letter to maternity care provider

PO Box 11 Woden ACT 2606 | Phone: 6174 7968 or 6174 5659 | E: ethics@act.gov.au

- Focus Group/Interview sample questions

I confirm that the ACT Health Human Research Ethics Committee is constituted according to the National Statement on Ethical Conduct in Human Research 2007 and is certified for single review of multi-centre clinical trials. ACT Health HREC operates in compliance with applicable regulatory requirements and the International Conference on Harmonization Guidelines on Good Clinical Practice.

I attach for your records an Outcome of Consideration of Protocol form for this study, which was originally approved for five years from 1 August 2016 to 1 August 2021. To maintain consistency across the sites this approval period applies to the now multi-site study.

The Coordinating Principal Investigator is responsible for notification to site Principal Investigators. The Coordinating Principal Investigator and Principal Investigators should forward a copy of this letter to their site's Research Governance Office.

Site-Specific Assessment (SSA)

SSA authorisation is required at all sites participating in the study, SSA must be authorised at a site before the research project can commence at that site.

The completed Site-Specific Assessment form and a copy of this ethics approval letter must be submitted to the Research Governance Office for authorisation by the Chief Executive or delegate. This applies to each site participating in the research.

Yours sincerely

Louise Morauta PSM PhD
Chair
ACT Health Human Research Ethics Committee

5 January 2017

PO Box 11 Woden ACT 2606 | Phone: 6174 7968 or 6174 5659 | E: ethics@act.gov.au

ACT HEALTH HUMAN RESEARCH ETHICS COMMITTEE

Outcome of Consideration of Protocol

Submission No: **ETH.5.16.064** **Date of Approval:** **1 August 2016**

Project Title: Eating4Two Smartphone Application: A randomised controlled trial

Submitted by: Professor Deborah Davis

Your project was considered by the ACT Health Human Research Ethics Committee and Approved for a period of 5 years from 1 August 2016 to 1 August 2021

First Annual Review due: 15 July 2017

Conditions of Approval:

- At regular periods, and not less than annually, Principal Investigators are to provide reports on matters including:
  - unforeseen events that could affect the continued ethical acceptability of the project
  - proposed changes in the protocol
  - updates of the investigator brochures
  - continued compliance with approved consent procedures and updates of consent documentation
  - Data Safety Monitoring Board Reports (where applicable)
  - security of records
  - updated insurance coverage
  - compliance with other approved procedures.
- All published reports are to carry an acknowledgement stating:
  - Approved by ACT Health Human Research Ethics Committee on 1 August 2016

Louise Morauta PSM PhD
Chair
ACT Health Human Research Ethics Committee
5 January 2017

PO Box 11 Woden ACT 2606 | Phone: 6174 7968 or 6174 5659 | E: ethics@act.gov.au

ACT Government
Health

ACT Health
Human Research Ethics and Governance Office
Low Risk Sub-Committee

Professor Deborah Davis
Synergy
Building 6, Level 3
Canberra Hospital
Garran ACT 2605

Dear Professor Davis

ETH.5.16.064 - HREC/17/ACT/1

Thank you for your letter of 27 February 2018, requesting amendments relating to:

Eating4Two Smartphone Application: A randomised controlled trial

The wording, images and links requested for Facebook advertising of the Eating4two study have been approved.

This information is now recorded on the Committee's files

Yours sincerely,

Ian Pieper
Ethics Manager
ACT Health Human Research Ethics Committee
Low Risk Sub-Committee
21 March 2018

PO Box 11 Woden ACT 2606 | Phone: 6174 7968 or 6174 5659 | E: ethics@act.gov.au

A12. Mid North Coast Local Health District site specific, Eating4Two trial research Authorisation forms

Health
Mid North Coast
Local Health District

27th March 2017

Ms Shanna Fealy
28 Sapphire Drive
Port Macquarie
NSW 2440

Dear Shanna

Re: Site Research Authorisation.

HREC Reference: HREC/17/ACT/1

SSA Reference: SSA/17/NCC/13

Project Title: Eating4Two Smartphone Application: A randomised controlled trial.

Protocol: N/A

Thank you for submitting an application for site authorisation of the above referenced project. I am pleased to inform you that authorisation has been granted for this project to take place at the Port Macquarie Base Hospital.

The following documents have been authorised for distribution at the above site:

- Participant Information Sheet, Version 3 dated 25th July 2016.
- Consent Form, Version 3 dated 23rd July 2016.
- Consent Form, Focus Group/Interview Version 3 dated 23rd July 2016.
- Questionnaire 1 – Demographics.
- Questionnaire 2 – Motivation and Knowledge and IPAQ (physical activity).
- Questionnaire 3, 5 and 8 – ASA24 (diet recall)
- Questionnaire 4 – IPAQ, GWG resource/advice and modified mobile app rating scale.
- Questionnaire 6 – Modified QPCQ (Quality care).
- Questionnaire 7 – IPAQ.
- Advertising for antenatal waiting areas.
- Letter to maternity care provider.

In addition I acknowledge receipt of the following documents:

- HREC approval letter dated 5th January 2017.
- NEAF AU/1/B2B7217
- Data collection schedule and instruments.
- Adverstising for social media.
- Push notifications for App
- Messages relating to foetal development for App.
- Focus Group interview sample questions.
- SSA AU/2/CE7B214

The following conditions apply to this research project. These are additional to those conditions imposed by the Human Research Ethics Committee that granted ethical and scientific approval:

1. Recruitment of participants can only be conducted by those Investigators listed in the Site Specific Application and who have signed the Declaration of Researchers.
2. Proposed amendments to the research protocol or conduct of the research which may affect the ethical or scientific acceptability of the application and are submitted to the approving HREC for review must be copied to the Research Governance Officer.
3. Proposed amendments which affect the ongoing documents/materials for circulation at the site listed above, or which alter the information submitted in your application for site authorisation, must be submitted to the Research Governance Officer.
4. ***For drug or device trials:*** You agree that you will not commence the trial named above until the Clinical Trial Notification (CTN) has been submitted to the Therapeutic Goods Administration (TGA) using the online form. This site authorisation letter fulfils the documentation required to indicate the Approving Authority approval. A copy of the TGA acknowledgment of receipt of a CTN must be submitted to the MNCLHD Research Office as soon as it is available.
5. For any researcher who is not employed by the MNCLHD and is conducting the research on-site at any facility within this LHD are required to comply to site specific privacy, confidentiality, vaccination and identification processes.
6. Where appropriate, I recommend that you consult with your Medical Defence Union to ensure that you are adequately covered for the purposes of conducting this study.
7. *[if student involvement]* Site approval is granted on the assumption that all students and early career researchers are adequately supervised by the principal and senior investigators on a project. This supervision would ensure that all privacy concerns are met (including the completion of confidentiality agreements by participating students) and that both students and participants are supported in the conduct of the study in line with the approved research protocol.

Yours Sincerely

Maureen Lawrence
Research Governance Officer
Mid North Coast Local Health District.

Cc. Sandra Eadie, Maternity Unit Manager PMBH.
Carol Prince, Antenatal Services PMBH.

A13. University of Newcastle Eating4Two trial human research ethics approval forms

HUMAN RESEARCH ETHICS COMMITTEE

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Notification of Expedited Approval

To Chief Investigator or Project Supervisor:	**Doctor Alexis Hure**
Cc Co-investigators / Research Students:	**Ms Shanna Fealy** **Professor Maralyn Foureur** **Professor Deborah Davis**
Re Protocol:	**Eating4Two Smartphone Application: A randomised controlled trial**
Date:	**13-Jun-2017**
Reference No:	**H-2017-0074**
Date of Initial Approval:	**13-Jun-2017**

Thank you for your **Response to Conditional Approval (minor amendments)** submission to the Human Research Ethics Committee (HREC) seeking approval in relation to the above protocol.

Your submission was considered under **Expedited** review by the Ethics Administrator.

I am pleased to advise that the decision on your submission is **Approved** effective **13-Jun-2017**.

In approving this protocol, the Human Research Ethics Committee (HREC) is of the opinion that the project complies with the provisions contained in the National Statement on Ethical Conduct in Human Research, 2007, and the requirements within this University relating to human research.

Approval will remain valid subject to the submission, and satisfactory assessment, of annual progress reports. *If the approval of an External HREC has been "noted" the approval period is as determined by that HREC.*

The full Committee will be asked to ratify this decision at its next scheduled meeting. A formal *Certificate of Approval* will be available upon request. Your approval number is **H-2017-0074**.

If the research requires the use of an Information Statement, ensure this number is inserted at the relevant point in the Complaints paragraph prior to distribution to potential participants You may then proceed with the research.

Conditions of Approval

This approval has been granted subject to you complying with the requirements for *Monitoring of Progress*, *Reporting of Adverse Events*, and *Variations to the Approved Protocol* as detailed below.

PLEASE NOTE:
In the case where the HREC has "noted" the approval of an External HREC, progress reports and reports of adverse events are to be submitted to the External HREC only. In the case of Variations to the approved protocol, or a Renewal of approval, you will apply to the External HREC for approval in the first instance and then Register that approval with the University's HREC.

- ***Monitoring of Progress***

Other than above, the University is obliged to monitor the progress of research projects involving human participants to ensure that they are conducted according to the protocol as approved by the HREC. A progress report is required on an annual basis. Continuation of your HREC approval for this project is conditional upon receipt, and satisfactory assessment, of annual progress reports. You will be advised when a report is due.

- ***Reporting of Adverse Events***

1. It is the responsibility of the person **first named on this Approval Advice** to report adverse events.
2. Adverse events, however minor, must be recorded by the investigator as observed by the investigator or as volunteered by a participant in the research. Full details are to be documented, whether or not the investigator, or his/her deputies, consider the event to be related to the research substance or procedure.
3. Serious or unforeseen adverse events that occur during the research or within six (6) months of completion of the research, must be reported by the person first named on the Approval Advice to the (HREC) by way of the Adverse Event Report form (via RIMS at https://rims.newcastle.edu.au/login.asp) within 72 hours of the occurrence of the event or the investigator receiving advice of the event.
4. Serious adverse events are defined as:
    - Causing death, life threatening or serious disability.
    - Causing or prolonging hospitalisation.
    - Overdoses, cancers, congenital abnormalities, tissue damage, whether or not they are judged to be caused by the investigational agent or procedure.
    - Causing psycho-social and/or financial harm. This covers everything from perceived invasion of privacy, breach of confidentiality, or the diminution of social reputation, to the creation of psychological fears and trauma.
    - Any other event which might affect the continued ethical acceptability of the project.

5. Reports of adverse events must include:
    - Participant's study identification number;
    - date of birth;
    - date of entry into the study;
    - treatment arm (if applicable);
    - date of event;
    - details of event;
    - the investigator's opinion as to whether the event is related to the research procedures; and
    - action taken in response to the event.

6. Adverse events which do not fall within the definition of serious or unexpected, including those reported from other sites involved in the research, are to be reported in detail at the time of the annual progress report to the HREC.

- ***Variations to approved protocol***

If you wish to change, or deviate from, the approved protocol, you will need to submit an *Application for Variation to Approved Human Research* (via RIMS at https://rims.newcastle.edu.au/login.asp). Variations may include, but are not limited to, changes or additions to investigators, study design, study population, number of participants, methods of recruitment, or participant information/consent documentation. **Variations must be approved by the (HREC) before they are implemented** except when Registering an approval of a variation from an external HREC which has been designated the lead HREC, in which case you may proceed as soon as you receive an acknowledgement of your Registration.

Linkage of ethics approval to a new Grant

HREC approvals cannot be assigned to a new grant or award (ie those that were not identified on the application for ethics approval) without confirmation of the approval from the Human Research Ethics Officer on behalf of the HREC.

Best wishes for a successful project.

Associate Professor Helen Warren-Forward
Chair, Human Research Ethics Committee

For communications and enquiries:
Human Research Ethics Administration

Research & Innovation Services
Research Integrity Unit
NIER, Block C
The University of Newcastle
Callaghan NSW 2308
T +61 2 492 17894
Human-Ethics@newcastle.edu.au

RIMS website - https://RIMS.newcastle.edu.au/login.asp

Linked University of Newcastle administered funding:

Funding body	Funding project title	First named investigator	Grant Ref

A14. Eating4Two trial, site specific participant information form

PARTICIPANT INFORMATION SHEET
RESEARCH PROJECT

Study Title: Eating4Two: A study to test a phone app that aims to assist pregnant women to achieve a healthy weight gain in pregnancy

Principal Investigator: Professor Deborah Davis

Research Sites: Centenary Hospital for Women and Children (ACT), Calvary Hospital (ACT), John Hunter Hospital, Maitland Hospital, Port Macquarie Base Hospital

Before you decide whether or not you wish to participate in this study, it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish.

1. What is the purpose of this study?

The purpose of this project is to test the effect of a smart phone application (App) on the weight gain of pregnant women.

2. Why have I been invited to participate in this study?

You are eligible to participate in this study if you:

- are over the age of 18 years and of any BMI category (it is not just aimed at overweight or obese women)
- are planning to have your baby at the Calvary Hospital (ACT), John Hunter Hospital, Maitland Hospital, or Port Macquarie Base Hospital
- are pregnant (no more than 14 weeks) with one baby only (not twins)
- are fluent in English language
- have access to the Internet for completion of online questionnaires
- have your own smart phone, email address and scales to weigh yourself
- are free from diabetes at the beginning of pregnancy

3. What if I don't want to take part in this study or if I want to withdraw later?

Participation in this study is voluntary. It is completely up to you whether or not you participate. If you decide not to participate, it will not affect the treatment you receive now or in the future. Whatever your decision, it will not affect your relationship with the staff caring for you.

New information about the App being studied may become available during the course of the study. You will be kept informed of any significant new findings that may affect your willingness to continue in the study. If you wish to withdraw from the study once it has started, you can do so at any time without having to give a reason. If your maternity care provider considers that use of the App is not within your best interests then they will advise you to stop using the App

You may withdraw from the study at any time and for any reason or no reason. Please tell the study team that you wish to withdraw from the study. Information that has been collected about you, prior to your withdrawal, will continue to be used in the data analysis. No new information will be collected or used after you have withdrawn from the study.

In addition, if you are allocated to the group that uses the App we will send your maternity care provider a letter to let them know. If they consider that use of the App is not in your best interests (at any time throughout your pregnancy) then they will advise you to stop using the App and you should act on this.

4. What does this study involve?

This study will be conducted over the course of your pregnancy and conclude 6 months post birth. The App being investigated in this study is an addition to standard treatment. You will receive all the usual care, support and advice that are normally provided by your maternity service. Sometimes health professionals don't know the best way to assist women to achieve a healthy weight gain in pregnancy so comparisons need to be made between different treatments and/or interventions. To do this, study participants are put into groups and given different treatments/interventions, and the results are compared to see whether one treatment/intervention is better than another.

You will be randomly assigned to one of two groups (use of the App or usual care);

- Those assigned to the App group will be provided with free access to the App and be asked to use the App for the duration of their pregnancy.
- The App has been developed by a nutritionist and midwife in collaboration with an obstetrician and psychologists, using the latest evidence based information. The App does not replace the care and advice provided to you by your maternity caregiver but can complement your usual care.
- The App will calculate your BMI, graph your weight change and compare this to the Institute of Medicine (IOM) recommended pregnancy weight gain guidelines. You will also have access to nutrition tips and advice that can be accessed at your leisure. In addition, you will receive regular notifications from the App providing you with motivational messages and tips to help you manage your weight gain in pregnancy.
- Women in this group will need to weigh themselves weekly and have their weight recorded by their maternity caregiver at 38 weeks, when they are admitted to hospital for birth and 6 months after the birth of their baby.
- If you are assigned to the usual care group, you will be provided with a booklet called "good nutrition in pregnancy" published by the ACT government and this will supplement the information provided to you by your midwives and/or doctors. Women in this group will have their weight recorded by their maternity caregiver

at 38 weeks, when they are admitted to hospital for birth and 6 months after the birth of their baby. Those assigned to the App group will be asked;

- to input required information into the App including height, pre-pregnancy weight and baby's due date. This will take no more than five minutes of your time and will only need to be done once.
- to weigh yourself weekly and enter this into the app. This will take less than five minutes of your time per week.

This information along with the frequency of your access to the App will be sent on a regular basis automatically from your App to the researchers.

All participants will be asked to;

- provide consent to have their clinical data accessed from the hospital database.
- complete 8, mostly online questionnaires providing information about diet, physical activity, motivation and knowledge about weight gain in pregnancy, information sources, and satisfaction with antenatal care at the beginning of the study, at 38 weeks of pregnancy, 8-12 weeks and 6 months after the baby is born. The table below shows the timing and approximate time taken to complete the questionnaires.

Time points	Questionnaires	Approximate time taken to complete
Less than 15 weeks pregnancy (2 questionnaires: up to 60 mins total)	Questionnaire 1: hard copy	10 minutes
	Questionnaire 2: online	Up to 20 minutes
	Questionnaire 3: online	Up to 30 minutes
38 weeks gestation (2 questionnaires: up to 60 mins total)	Questionnaire 4: online	Up to 30 minutes
	Questionnaire 5: online	Up to 30 minutes
8-12 weeks postpartum (1 questionnaire: 5 mins)	Questionnaire 6: online	5 minutes
6 months postpartum (2 questionnaires: up to 40 mins total)	Questionnaire 7: online	10 minutes
	Questionnaire 8: online	Up to 30 minutes
Total time commitment for questionnaires		**2 hours 45 minutes**

- **Optional**: participate in a focus group (or individual interview for those who prefer in person or by phone) approximately 8-12 weeks after the birth of their baby to explore general issues related to weight gain in pregnancy (approximately 60 minutes). Focus groups and interviews will be audio recorded and later transcribed by a professional transcriber. Up to 10 focus groups and 20 interviews are planned and participants for this part of the study will be chosen on a first come first served basis.

5. How is this study being paid for?

The study is being sponsored by Diabetes Australia. Participation in this study will not cost you anything. Participants will not be paid for their involvement.

6. Are there risks to me in taking part in this study?

Participation in this study may make you focus more on your weight and this may cause worry in some women. We don't anticipate any other risks if you continue to eat sensibly and see your maternity caregiver as regularly as recommended.

7. What if something goes wrong?

If you suffer any injuries or complications as a result of this study, you should contact the study team as soon as possible, who will assist you in arranging appropriate medical treatment. If you are eligible for Medicare, you can receive any medical treatment required to treat the injury or complication, free of charge, as a public patient in any Australian public hospital.

8. Who is organising and funding the research?

This study is being conducted by the study team headed by Professor Deborah Davis. The study is being funded by Diabetes Australia.

No investigator or member of research staff will receive a personal financial benefit from your involvement in this study. The health professionals involved declare no personal conflict of interest relevant to the undertaking of this study.

9. How will my confidentiality be protected?

The health professionals involved in your care will not necessarily know whether or not you are participating in this study. Any identifiable information that is collected about you in connection with this study will remain confidential and will be disclosed only with your permission, or except as required by law. Only the researchers named above will have access to your details and results that will be held securely at the University of Canberra in a password protected computer. Audio recordings of focus groups and interviews will be transcribed without any identifying information (for example if your name is mentioned it will be transcribed as [focus group participant #1]) with a numerical identifier and then the audio file will be destroyed.

10. What happens with the results?

Results will be shared with other health professionals through publications in professional journals and presentations at conferences.

In any publication, information will be provided in such a way that you cannot be identified. Results will be provided to you, if you wish.

11. What happens to my treatment when the study is finished?

Your involvement in the study will finish about 6 months after the birth of your baby. Throughout the study period and beyond, you should continue to access your usual health care providers as required.

12. What should I do if I want to discuss this study further before I decide?

A research assistant will contact you to discuss the study with you and answer any queries you may have. At the Port Macquarie site this will be Registered Midwife Shanna Fealy. You are also able to take some time to discuss it with your family, friends, treating health professionals or any other person you choose. If you would like to know more at any stage, please do not hesitate to contact Professor Deborah Davis:

Office: 6206 3869 Email: Deborah.davis@act.gov.au

13. Complaints and compensation

If you suffer any injuries or complications as a result of this research project, you should contact the study team as soon as possible and you will be assisted with arranging appropriate medical treatment. If you are eligible for Medicare, you can receive any medical treatment required to treat the injury or complication, free of charge, as a public patient in any Australian public hospital. You may be able to seek compensation through the courts.

14. Who should I contact if I have concerns about the conduct of this study?

This study has been approved by the ACT Health Human Research Ethics Committee. If you have any concerns or complaints about the conduct of this study, and do not feel comfortable discussing this with study staff, you may contact the Committee secretariat who is nominated to receive complaints about research projects. You should contact the secretariat on 6174 7968 or acthealth-hrec@act.gov.au

Alternatively you may contact the Mid North Coast Local Health District Research Governance Officer on 0428882170.

Thank you for taking the time to consider this study.
If you wish to take part, please sign the attached consent form.
This information sheet is for you to keep.

A15. Eating4Two, site specific consent form

Consent Form to Participate in a Research Project.

I, _____ *(name of participant)*

of _____ *(address)*

have been asked to consent to my participation in a research project entitled:

Eating4Two: A study to test a phone app that aims to assist pregnant women to achieve a healthy weight gain in pregnancy

In relation to this study I have read the Patient Information Sheet and have been informed of the following points:

1. Approval has been given by the ACT Health Human Research Ethics Committee.
2. The aim of the study is to test the effect of a smart phone application (App) on the weight gain of pregnant women.
3. The study App is available for research purposes only and cannot be obtained otherwise. The study App may not be available following completion of the trial.
4. The results obtained from the study may or may not be of direct benefit to my medical management.
5. The study will involve usual care or usual care and use of a smartphone App.
6. Possible adverse effects or risks related to this study may include worry about weight and weight gain in pregnancy.
7. If I am allocated to the use of the App group, I understand that my maternity caregiver will be advised.
8. My involvement in this study may be terminated if any of the following circumstances develop: my maternity care provider advises it.
9. If my maternity care provider advises, I will cease using the App.
10. Should I develop a problem which I suspect may have resulted from my involvement in this project, I am aware that I may contact Professor Deborah Davis on 6206 3869.
11. Should I have any problems or queries about the way in which the study was conducted, and I do not feel comfortable contacting the research staff, I am aware that I may contact;
    - I. ACT Health Human Research Ethics Committee Secretariat, Canberra Hospital, Yamba Drive, Garran ACT 2605 (ph: 6174 7968) or
    - II. Calvary Health Care ACT Human Research Ethics Committee, Calvary Public Hospital, Mary Potter Cct, Bruce 2617 (ph: 6264 7162)
    - III. Alternatively you may contact the Mid North Coast Local Health District Research Governance Officer on 0428882170.

Eating4Two PMBH Version 1 dated 27th February 2017 based on Master Version 3 dated 23rd July 2016.

12. I can refuse to take part in this project or withdraw from it at any time without affecting my medical care.
13. Participation in this project will not result in any extra medical or hospital costs to me.
14. I understand that while the results of the research will be made accessible my involvement and my identity will not be revealed.
15. In giving my consent, I acknowledge that the relevant Health Directorate Officials Staff directly involved in the study, may examine my medical records only as they relate to this project.

After considering all these points, I accept the invitation to participate in this study.

Name: (please print) _____**Date:** _____

Signature (Participant) _____

A16. Hunter New England health human research ethics committee study variation form and approval for the Women And Their Children's Health (WATCH) Study

HUNTER NEW ENGLAND
HUMAN RESEARCH ETHICS COMMITTEE

APPLICATION FOR VARIATION OF ETHICS APPROVAL
FOR RESEARCH INVOLVING HUMANS
Version: October 2010

1 CHIEF INVESTIGATOR *or* PROJECT SUPERVISOR *(first named on the approval notification)*

Name: Title / first name / family name	Professor Roger Smith
Qualifications & position held:	MBBS (Hons), FRACP, PhD, FRANZCOG Director, Mothers and Babies Research Centre Professor of Endocrinology, Faculty of Health, University of Newcastle
Organisational unit & mailing address:	Mothers and Babies Research Centre Level 3, Endocrinology, John Hunter Hospital Locked Bag 1, Hunter Region Mail Centre, NSW 2310
Telephone and Fax:	Phone: +61 (2) 4921 4380 Fax: +61 (2) 4921 4394
Email address:	Roger.Smith@newcastle.edu.au

2 TITLE OF PROJECT *(as it appears on the approval notification)*

The WATCH Study – Women And Their Children's Health

3 APPROVAL DETAILS
What is the Hunter New England Human Research Ethics Committee reference number for the project?

06/05/24/5.06

What was the date of approval from the Hunter New England Human Research Ethics Committee,

09/06/2006

4 IS THIS RESEARCH BEING CONDUCTED AS

SINGLE CENTRE RESEARCH (i.e. only within Hunter New England Health) ☑

MULTI CENTRE RESEARCH

If so, please name those sites for which approval from the Hunter New England Human Research Ethics Committee extends:

5 STUDENT RESEARCH

Is the research being completed as part or whole of a degree or qualification?			Yes	✓	No	

If *YES:*	Name of student:	Rachael Taylor
	Course of study:	Research Masters (Behavioural Science in relation to Medicine)
	Principal supervisor:	Dr Alexis Hure
	Name of Institution	The University of Newcastle

If *YES:*	Name of student:	Dr Lila Mohapatra
	Course of study:	PhD (Medicine)
	Principal supervisor:	Prof Roger Smith
	Name of Institution	The University of Newcastle

If *YES:*	Name of student:	Shanna Fealy
	Course of study:	PhD (Clinical Epidemiology and Public Health)
	Principal supervisor:	Dr Alexis Hure
	Name of Institution	The University of Newcastle

6 PROJECT STATUS

Has the project commenced?	Yes	✓	No	

If *YES*, when did the project commence? *(dd/mm/yy)*:	26/06/2006

If *NO provide reasons*:

7 RESEARCH PERSONNEL

Does the variation involve changes to the research personnel working on the project? Yes ✓ No

This might include such instances as the addition of new investigators or research assistants to the research team, removing the names of those who are no longer working on the project, adding a student researcher and his/her project supervisor or perhaps a situation where the project supervisor for a student project is changing.

If *YES*, go to the **next section (7.1)**
If *NO*, go to **Question 8**

7.1 **Addition of research personnel who are NOT students** *(leave blank if not applicable)*

For each new member of the research team who is not a student of the University of Newcastle, please provide the following details.

Name: Title / first name / family name	
Qualifications & employment position:	
Organisational unit & mailing address:	
Telephone and Fax:	
Email address:	
Role on research project:	
Experience relevant to the research project:	

Copy table and repeat for each additional person as required.

7.2 Addition of a student researcher *(leave blank if not applicable)*

For each student researcher being added to the project, please provide the following details.
Note: If the student's supervisor is not already recorded as an investigator, ensure they are added by completing section **6.1**.

Name of student:	Ms Shanna Fealy		
School/Faculty/Campus	School of Medicine and Public Health, Health and Medicine, Port Macquarie Campus		
Telephone and Fax:	0415601169		
Email address:	Shanna.fealy@newcastle.edu.au		
Course of study:	PhD Clinical Epidemiology and Public Health		
Principal supervisor:	Dr Alexis Hure		

Copy table and repeat for each additional student as required.

7.3 Deletion of research personnel *(leave blank if not applicable)*

For each person who is leaving the research team, please provide the following details.

Name: Title / first name / family name	
Organisational unit	
Email address:	
Previous role on research project:	
Reason for leaving project *(brief statement)*	

Copy table and repeat for each additional person as required.

8 DETAILS OF PROPOSED VARIATION

Using Plain English, provide details of the proposed variation(s) to the research protocol. Where appropriate, present in terms of **from** the existing protocol **to** the new protocol.

(Attach the original of any documents that are new or revised as a result of the variation, eg advertisements, participant information sheets, surveys, clinical protocols. For revised documents, please highlight changes and identify them with VERSION # and DATE.)

Midwife Shanna Fealy will undertake secondary data analysis for the requirements of her research higher degree, which is focused on weight gain in pregnancy.

9 JUSTIFICATION FOR VARIATION
Why is the variation necessary?

The WATCH Study has a large amount of prospective longitudinal data collected and we continue to analyse and publish findings from this cohort.

10 RESEARCH PARTICIPANTS

Does the variation involve recruiting new participant groups, or changing the way in which participants are to be recruited?	Yes		No	✓

If *YES*, provide full details using the following headings:

What is the participant group? **What is the number of participants involved and what is the justification for choosing this number?** **From where will the participants be recruited?** (Identify any schools, hospitals, organisations, etc, that are to be involved.) **How and by whom will participants be approached to receive the invitation to participate?** **How much time will participants have to consider the invitation to participate?**

11 ETHICAL CONSIDERATIONS
What ethical considerations, if any, are raised by the proposed variation? (Refer to the *National Statement on Ethical Conduct in Research Involving Humans*, section 1 and other sections relevant to the project.)

The privacy and confidentiality of our participants is the primary ethical consideration with respect to the addition of research personnel including students. Data are de-identified for analysis.

12 GOVERNANCE CONSIDERATIONS

Please advise if this variation will have any implications for governance such as changes to the site specific assessment form or the regulatory documentation	Yes		No	✓

If Yes, please advise the change and the documentation affects (and submit accordingly.)

13 REVISED DOCUMENTATION

Please list all the documentation that needs to be revised and is being submitted with this application for variation (ensure that the version numbers and dated are also revised)

14 DECLARATION

In signing this application, I declare that:

1. The research protocol conforms to the *National Statement on Ethical Conduct in Human Research (2007)*, which I have read.

2. The required number of any documents that are new or revised as a result of the variation, are attached, eg advertisements, participant information sheets, consent forms, surveys, clinical protocols.

3. The variation will not be implemented prior to receiving approval from the ethics committee(s).

4. I make this application on the basis that the information it contains is confidential and will be used by Hunter New England Health for the purposes of ethical review and monitoring of the research project described herein, and to satisfy reporting requirements to regulatory bodies. The information will not be used for any other purpose without my prior consent.

5 I agree to the title of my research being listed for reporting purposes as required by Hunter New England Health, NSW Health or the NHMRC

YES ☑ NO

If you object to the title of your research being included could you please provide a valid reason for its omission from the reporting process.

Signature of chief investigator/project supervisor:	Roger Smith
Date:	

PLEASE ENSURE AN ELECTRONIC COPY OF THIS FORM AND ATTACHED DOCUMENTS IS SUBMITTED TO

HNEHREC@HNEHEALTH.NSW.GOV.AU

22 June 2016

Professor R Smith
Mothers & Babies Research Centre
Endocrinology
John Hunter Hospital

Dear Professor Smith

Re: The WATCH Study – Women and Their Children's Health (06/05/24/5.06)

Thank you for submitting a request for an amendment to the above project. This amendment was reviewed by the Hunter New England Human Research Ethics Committee. This Human Research Ethics Committee is constituted and operates in accordance with the National Health and Medical Research Council's *National Statement on Ethical Conduct in Human Research (2007)* (National Statement) and the *CPMP/ICH Note for Guidance on Good Clinical Practice*. Further, this Committee has been accredited by the NSW Department of Health as a lead HREC under the model for single ethical and scientific review.

I am pleased to advise that the Hunter New England Human Research Ethics Committee has determined the variation meets the requirements of the National Statement on Ethical Conduct in Human Research and has granted ethical approval for the following amendment requests:

- For the addition of Ms Shanna Fealy as student researcher

For the study: **The WATCH Study – Women and Their Children's Health**

Approval has been granted for this study to take place at the following site:

- **John Hunter Hospital**

Approval from the Hunter New England Human Research Ethics Committee for the above study is given for a maximum of 5 years from the date of the approval letter of your initial application after which a renewal application will be required if the study has not been completed. The above study is approved until **July 2016.**

The *National Statement on Ethical Conduct in Human Research (2007)* which the Committee is obliged to adhere to, include the requirement that the committee monitors the research protocols it has approved. In order for the Committee to fulfil this function, it requires:

Hunter New England Research Support & Development Office
Locked Bag No 1
New Lambton NSW 2305
Telephone: (02) 49214950 Facsimile: (02) 49214818
Email: HNELHD-HREC@hnehealth.nsw.gov.au
http://www.hnehealth.nsw.gov.au/ethics/Pages/Research-Ethics-and-Governance-Unit.aspx

- A report of the progress of the above study to be submitted at 12 monthly intervals. Your review date is **July 2016.** A proforma for the annual report will be sent two weeks prior to the due date.

- A final report must be submitted at the completion of the above study, that is, after data analysis has been completed and a final report compiled. A proforma for the final report will be sent two weeks prior to the due date.

- All variations or amendments to this study, including amendments to the Information Sheet and Consent Form, must be forwarded to and approved by the Hunter New England Human Research Ethics Committee prior to their implementation.

- The Principal Investigator will immediately report anything which might warrant review of ethical approval of the project in the specified format, including:

    - any serious or unexpected adverse events

        - Adverse events, however minor, must be recorded as observed by the Investigator or as volunteered by a participant in this study. Full details will be documented, whether or not the Investigator or his deputies considers the event to be related to the trial substance or procedure.

        - Serious adverse events that occur during the study or within six months of completion of the trial at your site should be reported to the Ethics Officer of the Hunter New England Human Research Ethics Committee as soon as possible and at the latest within 72 hours.

        - Copies of serious adverse event reports from other sites should be sent to the Hunter New England Human Research Ethics Committee for review as soon as possible after being received.

        - Serious adverse events are defined as:

            - Causing death, life threatening or serious disability.
            - Cause or prolong hospitalisation.
            - Overdoses, cancers, congenital abnormalities whether judged to be caused by the investigational agent or new procedure or not.

    - Unforeseen events that might affect continued ethical acceptability of the project.

- If for some reason the above study does not commence (for example it does not receive funding); is suspended or discontinued, please inform Dr Nicole Gerrand, the Manager, Research Support & Development Office as soon as possible.

The Hunter New England Human Research Ethics Committee also has delegated authority to approve the commencement of this research on behalf of the Hunter New England Local Health District. This research may therefore commence.

Should you have any queries about your project please contact Dr Nicole Gerrand as per the contact details at the bottom of the page. The Hunter New England Human Research Ethics Committee Terms of Reference, Standard Operating Procedures, membership and standard forms are available from the Hunter New England Local Health District website.

Please quote **06/05/24/5.06** in all correspondence.

Hunter New England Research Support & Development Office
Locked Bag No 1
New Lambton NSW 2305
Telephone: (02) 49214950 Facsimile: (02) 49214818
Email: HNELHD-HREC@hnehealth.nsw.gov.au
http://www.hnehealth.nsw.gov.au/ethics/Pages/Research-Ethics-and-Governance-Unit.aspx

The Hunter New England Human Research Ethics Committee wishes you every success in your research.

Yours faithfully

For: Ms M Hunter
Chair
Hunter New England Human Research Ethics Committee

Hunter New England Research Support & Development Office
Locked Bag No 1
New Lambton NSW 2305
Telephone: (02) 49214950 Facsimile: (02) 49214818
Email: HNELHD-HREC@hnehealth.nsw.gov.au
http://www.hnehealth.nsw.gov.au/ethics/Pages/Research-Ethics-and-Governance-Unit.aspx

A17. Journal permissions for article: The return of weighing in pregnancy: A discussion of evidence and practice.

Subject: Re: Permission for use of ar/ cle in a thesis disserta/ on [210129-001914]
Date: Saturday, 30 January 2021 at 5:45:26 am Australian Eastern Daylight Time
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From: Administrator
Date: Thursday, January 28, 2021 10:02 PM GMT

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Date: Thursday, January 28, 2021 10:02 PM GMT

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Shanna

A18. Journal permissions for article: Demographic and social-cognitive factors associated with gestational weight gain in an Australian pregnancy cohort.

Monday, February 1, 2021 at 07:47:10 Australian Eastern Daylight Time

Subject: Re: Obtain permission request - Journal (1129405) [210129-002060]
Date: Sunday, 31 January 2021 at 6:07:24 am Australian Eastern Daylight Time
From: Rights and Permissions (ELS)
To: Fealy, Shanna

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Sr Copyrights Coordinator – Copyrights Team
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E-mail: r.lingayath@elsevier.com | url: www.elsevier.com

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Regards,
Permission Granting Team

From: Shanna Fealy
Date: Thursday, January 28, 2021 10:17 PM GMT

Submission ID: 1129405
Date: 28 Jan 2021 10:17pm

Name: Ms Shanna Fealy
Institute/company: Charles Sturt University
Address: 7 Major Innes Road
Post/Zip Code: 2444
City: Port Macquaire
State/Territory: NSW
Country: Australia
Telephone: 0415601169
Email: sfealy@csu.edu.au

Type of Publication: Journal

Title: Eating Behaviours
Auhtors: Shanna Fealy, John Attia, Lucy Leigh, Christopher Oldmeadow, Michael hazelton, Maralyn Coureur, Clare E. Collins, Roger Smith, Alexis Hure
Year: 2020
From page: 1
To page: 7
ISSN: 1471-0153
Volume: 39
Article title: Demographic and social-cognitive factors associated with gestational weight gain in an Australian pregnancy cohort.

I would like to use: Full article / chapter

I am the author of the Elsevier material: Yes
Involvement: lead and corresponding author of the article

In what format will you use the material: Print and Electronic
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Proposed use: Reuse in a thesis/dissertation

Material can be extracted: No

Additional Comments / Information: I am requesting permission for use of the article within my thesis dissertation and an email or statement to that effect for inclusion in my thesis. Thank you for you assistance best wishes Shanna Fealy

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A19. Journal permissions for article: A Revalidation of the Weight-Related Behaviours Questionnaire within an Australian Pregnancy Cohort

Sunday, February 28, 2021 at 15:46:27 Australian Eastern Daylight Time

Subject: Re: Request for Permission to include this article in my thesis [210222-020652]
Date: Wednesday, 24 February 2021 at 3:59:40 am Australian Eastern Daylight Time
From: Permissions Helpdesk
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Date: Monday, February 22, 2021 09:21 PM GMT

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Shanna
