MONASH University

Optimising women's health, lifestyle and digital health engagement during preconception, pregnancy and postpartum

by

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BAppSci; GradCertHumNutr; MHumNutr; GradCertHealthResPract

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Abstract

The increasing prevalence of overweight and obesity that affects approximately 60% of Australian women of reproductive age, presents major public and economic health concern, with associated reproductive, metabolic and psychosocial sequalae. Prior to pregnancy, increased weight and suboptimal lifestyle behaviours may impair fertility and extend time to conception, both naturally and via assisted reproduction methods. In the presence of obesity, miscarriage rates are higher and live birth rates are lower. During pregnancy, overweight and obesity increases the risk of adverse maternal and neonatal outcomes. Maternal risks include gestational diabetes, hypertensive disorders and caesarean section, and for offspring there is increased risk of congenital anomalies, shoulder dystocia, respiratory distress, macrosomia and being born large for gestational age. These risks are independently exacerbated by excess gestational weight gain, which occurs in approximately 50% of pregnancies. In addition to weight related concerns, health, wellbeing and associated behaviours in the weeks, months and years prior to conception significantly influence short- and long-term health outcomes for both a mother and her offspring. As such, strategies to optimise health and lifestyle behaviours during this period are vital, given some of the most important mechanisms for development and factors affecting birth outcomes occur in the very early stages of pregnancy, often before women are aware they are pregnant or commence antenatal care.

The overarching aim of this PhD is to explore women's health and information seeking behaviours to inform digital healthy lifestyle interventions during preconception, pregnancy and postpartum. I also aim to evaluate the impact of a digital lifestyle intervention on preconception health behaviours.

Chapter one presents a cross-sectional exploration of Australian women's health and lifestyle behaviours prior to a planned pregnancy. This project provides critical insights regarding women's alignment with preconception care guidelines and strengthens the rationale for interventions targeting this population. Chapters two to four involve novel methodologies, generating insights from digital communities and tools that women commonly engage with during pregnancy and postpartum. Chapter five reports on the design and evaluation framework of a digital healthy lifestyle intervention, OptimalMe. The subsequent chapter focuses on the evaluation of behaviour change outcomes following preconception intervention. OptimalMe is underpinned by a low intensity, non-prescriptive, behaviour change intervention grounded in social cognitive theory,

which aligns with national dietary and physical activity guidelines. Here, novel adaptation to a digital program targeting women during preconception was informed by evidence I generated in this thesis. While the OptimalMe program extends across preconception, pregnancy and postpartum, this PhD focuses on the preconception intervention phase.

This thesis addresses important knowledge gaps in our understanding of preconception health and lifestyle behaviours, and generates new insights into digital health and web-based communities during preconception, pregnancy and postpartum. It contributes new knowledge to inform an innovative implementation trial with program evaluation to inform translation of evidence on lifestyle interventions at these life stages, into practice. This body of work has important implications for an increasingly resource constrained health sector, through the provision of a low intensity, accessible preconception program to address a critical population-based health issue, with demonstrated efficacy and potential for broader scale-up.

Declaration

This thesis is an original work of my research and contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Print Name: …………Bonnie Brammall…………...

Date: …………21/11/2022…………..…..

Publications during enrolment

(Note that maiden name changed from Chivers to Brammall during the thesis)

1. **Chivers BR**, Boyle JA, Lang AY, Teede HJ, Moran LJ, Harrison CL. Preconception Health and Lifestyle Behaviours of Women Planning a Pregnancy: A Cross-Sectional Study. J Clin Med. 2020 Jun 2;9(6):1701.

   [Chapter 1]

   Journal Citation Reports (JCR) 2022 impact factor 4.96; 23 citations; Altmetric score: 15, *top 25% of all research outputs scored by Altmetric*

2. **Chivers BR**, Garad RM, Boyle JA, Skouteris H, Teede HJ, Harrison CL. Perinatal Distress During COVID-19: Thematic Analysis of an Online Parenting Forum. J Med Internet Res. 2020 Sep 7;22(9):e22002.

   [Chapter 2]

   JCR 2022 impact factor: 7.08; 84 citations; Altmetric score: 38, *top 5% of all research outputs scored by Altmetric.*

3. **Chivers BR**, Garad RM, Moran LJ, Lim S, Harrison CL. Support Seeking in the Postpartum Period: Content Analysis of Posts in Web-Based Parenting Discussion Groups. J Med Internet Res. 2021 Jul 15;23(7):e26600.

   [Chapter 3]

   JRC 2022 impact factor: 7.08; 9 citations; Altmetric score: 8, *top 25% of all research outputs scored by Altmetric*

4. **Brammall BR**, Garad RM, Boyle JA, Hayman MJ, de Jersey SJ, Teede HJ, Hong QV, Carrandi A, Harrison CL. Assessing the Content and Quality of Digital Tools for Managing Gestational Weight Gain: Systematic Search and Evaluation. Journal of Medical Internet Research. 2022 Nov 25;24(11):e37552.

   [Chapter 4]

   JCR 2022 impact factor: 7.08.

5. Harrison CL, **Brammall BR**, Garad R, Teede H. OptimalMe Intervention for Healthy Preconception, Pregnancy, and Postpartum Lifestyles: Protocol for a Randomized Controlled Implementation Effectiveness Feasibility Trial. JMIR Res Protocol. 2022 Jun 9;11(6):e33625.

   [Chapter 5]

   JCR 2022 impact factor: NA; Altmetric score: 13, *top 25% of all research outputs scored by Altmetric*

6. **Brammall BR**, Garad RM, Teede HJ, Harrison CL. Evaluating Preconception Health and Behaviour Change Following a Randomised Type III Hybrid Effectiveness-Implementation Digital Healthy Lifestyle Intervention: The OptimalMe Program.

Submitted 23/11/2022 to NPJ Digit Med

[Chapter 6]

JCR 2022 impact factor: 13.49

Thesis including published works declaration

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

This thesis includes six original manuscripts, five of which are published and one submitted for peer review. The core themes of the thesis are health and lifestyle behaviours during preconception, insights from women's interactions with digital communities, an assessment of publicly available digital tools targeting pregnant women and implementation research. The ideas, development and writing up of five manuscripts in the thesis were the principle responsibility of myself, the student, working within the Monash Centre for Health Research and Implementation, School of Public Health and Preventive Medicine, Faculty of Medicine, Nursing and Health Sciences under the supervision of Dr Cheryce Harrison, Dr Rhonda Garad and Professor Helena Teede. Chapter five includes a second author manuscript, in which I did not have primary responsibility. This manuscript is included in this thesis as I played a significant role in the trial design, methodology, implementation and evaluation.

The inclusion of co-authors reflects the fact that the work came from active collaboration between researchers and acknowledges input into team-based research.

Within chapters 1-6, my contribution to the work involved the following:

Thesis Chapter	Publication Title	Status *(published, in press, accepted or returned for revision, submitted)*	Nature and % of student contribution	Co-author name(s) Nature and % of Co-author's contribution*	Co-author(s), Monash student Y/N*
1	Preconception Health and Lifestyle Behaviours of Women Planning a Pregnancy: A Cross-Sectional Study	Published	Primary responsibility for literature review, data cleaning, analysis and interpretation of results, writing the manuscript 75%	*Contributed to funding, design, interpretation, manuscript drafting* 10% Cheryce Harrison *Design, interpretation, manuscript drafting* 5% Jacqueline Boyle	N N

				Contributed to design, completed data collection, manuscript drafting 5% Adina Lang	Y
				Funding, manuscript drafting 2.5% Helena Teede	N
				Manuscript drafting 2.5% Lisa Moran	N
2	Perinatal Distress During COVID-19: Thematic Analysis of an Online Parenting Forum	Published	Significant contribution to concept and design, primary responsibility for literature review, data cleaning, analysis and interpretation of results, writing the manuscript 60%	*Joint first author: contributed to design, interpretation, manuscript drafting* 25% Rhonda Garad *Contributed to funding, design, interpretation, manuscript drafting* 9% Cheryce Harrison *Contributed to funding and manuscript drafting* 2% Helena Teede *Manuscript drafting* 2% Jacqueline Boyle 2% Helen Skouteris	N (all)
3	Support Seeking in the Postpartum Period: Content Analysis of Posts in Web-Based Parenting Discussion Groups	Published	Significant contribution to concept and design, primary responsibility for literature review, data cleaning, analysis and interpretation of results, writing the manuscript 70%	*Contributed to design, interpretation, manuscript drafting* 15% Cheryce Harrison 12% Rhonda Garad *Manuscript drafting* 1.5% Lisa Moran 1.5% Siew Lim	N (all)
4	Assessing the Content and Quality of Digital Tools for Managing Gestational Weight Gain: Systematic Search and Evaluation	Published	Significant contribution to concept and design, primary responsibility for literature review, data cleaning, analysis and interpretation of results, writing the manuscript	*Contributed to funding, design, interpretation, manuscript drafting* 10 % Cheryce Harrison 5% Rhonda Garad *Contributed to design and data synthesis, manuscript drafting* 3.5% Melanie Hayman 3.5% Susan de Jersey	N N N N

#	Title	Status	Contribution	Co-author contributions	Monash student
			70%	*Contributed to design, manuscript drafting* 2% Jacqueline Boyle	N
				Contributed to data synthesis, manuscript drafting 2% Vinh Hong 2% Lane Carrandi	Y Y
				Contributed to funding, manuscript drafting 2% Helena Teede	N
5	OptimalMe Intervention for Healthy Preconception, Pregnancy, and Postpartum Lifestyles: Protocol for a Randomized Controlled Implementation Effectiveness Feasibility Trial	Published	Intellectual input into the trial design, methodology intervention content and evaluation design. Contributed to trial implementation and manuscript drafting 20%	*First author: Program lead, conceptualised trial, design and methodology, provided funding, primary responsibility for manuscript drafting* 55% Cheryce Harrison *Conceptualised trial, provided funding, intellectual input into the trial design, manuscript drafting* 17% Helena Teede *Provided intellectual input into trial design and methodology, manuscript drafting* 8% Rhonda Garad	N (all)
6	Evaluating Preconception Health and Behaviour Change Following a Randomised Type III Hybrid Effectiveness-Implementation Digital Healthy Lifestyle Intervention: The OptimalMe Program	Submitted	Primary responsibility for literature review, data cleaning, analysis and interpretation of results, writing the manuscript 75%	*Program lead, conceptualised trial, design and evaluation methodology, provided funding, manuscript drafting* 15% Cheryce Harrison *Provided intellectual input into the trial design and evaluation methodology, manuscript drafting* 5% Rhonda Garad *Conceptualised trial, provided funding, intellectual input into the*	N (all)

				trial design, manuscript drafting 5% Helena Teede	

I have not renumbered sections of submitted or published manuscripts in order to generate a consistent presentation within the thesis.

Student name: Bonnie Brammall

Date: 18/11/2022

I hereby certify that the above declaration correctly reflects the nature and extent of the student's and co-authors' contributions to this work. In instances where I am not the responsible author I have consulted with the responsible author to agree on the respective contributions of the authors.

Main Supervisor name: Dr Cheryce Harrison

Date: 21/11/2022

Acknowledgements

Professional

I would like to express my gratitude to Dr Cheryce Harrison, Dr Rhonda Garad and Professor Helena Teede, my supervisors. You have been a wonderful support, which was so critical as we all transitioned into working remotely. I am so grateful for the tremendous opportunity to play a role in OptimalMe program. I have appreciated your insight, experience, confidence and trust. As my supervisors, you have pushed me to learn independently, while guiding me in the right direction and always ensuring I felt supported.

Thank you to Josphin Johnson and Susanne Baker for their contributions to OptimalMe, and for their guidance in project management and IT support. Without the support from Medibank Private, namely Courtney Brown and Catherine Keating, the OptimalMe trial would not have been possible. Thank you for fostering this collaboration and trusting us with your members.

I have immense gratitude to the women who participated in OptimalMe and took me on their reproductive journey. I have gained so much from this experience and I am so grateful for their involvement in our research.

This research was supported by a Monash Graduate Scholarship.

Personal

I am also profoundly grateful to my family and friends for your support over the course of my PhD.

To my partner Jason, you have motivated and encouraged me to stretch myself and inspired me to take whatever path I chose to feel fulfilled. Thank you for supporting my direction and never letting me doubt myself. Your partnership and patience are greatly appreciated.

To my parents. Thank you, mum, for your intellectual and emotional support. You have read and listened to every word I have written. Thank you for supporting Jason and I over the past three and a half years to help me complete this journey. To my dad, thank you for being on my shoulder the whole way, and directing me into a field where I have found passion and value.

To Seema, my friend and mentor, thank you for setting me on this journey and believing in my abilities, and for always being so proud.

Thank you to my wonderful friends and wider family. You are an unwavering cheer squad who don't quite "get it" but support me nonetheless.

Last, but not least, thank you to my beautiful dog and my horse. You are a source of joy and distraction and you always ground me.

Dedications

This thesis is dedicated to my dad, Stephen Chivers, and my cousin, Alexandra Chivers.

Thank you for inspiring me, I wish you were here to see this.

Thesis by publication and PhD journey

Monash University doctoral candidates are encouraged to submit a thesis by publication including manuscripts that have been prepared or accepted for publication. These manuscripts may include more than one author and can be inserted into the thesis in their published format. The thesis must reflect a sustained and cohesive theme, and introductions framing and linking the chapters and manuscripts can be included.

Upon leaving secondary school I completed a Bachelor of Applied Science in Fashion and Textiles Merchandising (RMIT) in 2012. This course taught me great business skills and enhanced my creative abilities and interests. I also had the great opportunity to travel overseas on two incredible integrated learning tours in China and Vietnam. After completing my studies, I lacked the desire to work in the fashion industry, so I took some time off to focus on riding as a horse trainer. Over these years my dad had been battling bowel cancer, and in subsequent years, my younger cousin was also diagnosed. Their journey fuelled an increasing interest in health, wellbeing and preventive lifestyle behaviours. As a result, I enrolled in a Bachelor of Nutrition at Victoria University in 2014. I commenced the course and then shortly before the census date I had a fall at a dressage competition. I was unable to attend university while I recovered, and therefore I had to drop out of the course, much to my disappointment. Midway through the same year I went to Deakin to speak to a course advisor about midyear enrolment in their undergraduate course. The course advisor informed me that, due to having a Bachelor Degree, a Master's Degree in Nutrition was possible, via enrolment into a Graduate Certificate course in Nutrition. Without this insight, I do not believe I would have ever ended up where I am today. This pathway to Masters ignited my interest in research and with the support and influence of Dr Julie Woods, and my tutor Assoc Prof Seema Misra-Thakur, I gained the confidence and knowledge to continue on to undertake a PhD. I obtained a Masters of Human Nutrition in 2016, then enrolled in a Graduate Certificate in Health Research Practice, to support pursuit of a PhD. In 2019 I enrolled in a PhD to broaden my research knowledge and gain new skills in the field of women's health.

My dad passed away in 2015, followed by my cousin in 2017. They were both immensely proud and interested in my nutrition studies, and I am grateful for the impact their tough and confronting journey had on my life and career direction.

This thesis demonstrates the progression of my knowledge and skillset through the development, implementation and evaluation of the OptimalMe program. Throughout my candidature I have advanced as a well-rounded researcher gaining knowledge in women's health and digital health in quantitative and qualitative research. I have developed new skills in public health research, biostatistics, epidemiology, project management, stakeholder engagement, data collection, questionnaire and qualitative interview design and program implementation and evaluation. This has been supported with formal coursework in biostatistics and epidemiology; short courses in leadership, project management and qualitative research; and mentoring by my multi-disciplinary team of supervisors.

I have produced high quality work with impact and practical translation. During my PhD I have received a Monash Graduate Scholarship and an NHMRC Centre of Research Excellence in Health in Preconception and Pregnancy (HiPP) Research Support Grant.

My advancement is demonstrated within the manuscripts I have produced throughout my PhD candidature. My thesis includes seven chapters and six manuscripts exploring women's health behaviours, insights from digital health tools and women's digital interactions, and the implementation and evaluation of a feasibility trial. This thesis represents a knowledge to action project, with the initial manuscripts informing implementation trials for women during preconception, pregnancy and postpartum. The description and evaluation of a digital health intervention for women during preconception and pregnancy, OptimalMe, has formed one published protocol manuscript (second author), in which my role primarily involved informing and developing preconception care resources, delivering the health coaching and evaluating the secondary outcomes. This intervention was based on the extensive background work led by my supervisors and on the original funding proposal.

List of abbreviations, terms and conditions

ABACUS: App Behaviour Change Scale

BMI: Body Mass Index

CDoH: Commercial Determinants of Health

CRE: Centre of Research Excellence

CVD: Cardiovascular Disease

DALYs: Disability Adjusted Life Years

GDM: Gestational Diabetes Mellitus

GWG: Gestational Weight Gain

HiPP: Health in Preconception and Pregnancy

IOM: Institute of Medicine

LGA: Large for Gestational Age

MARS: Mobile App Rating Scale

MCHRI: Monash Centre for Health Research and Implementation

PCC: Preconception care

RCT: Randomised Controlled Trial

SES: Socio Economic Status

SGA: Small for Gestational Age

WHO: World Health Organization

List of conference presentations

Listed below are the candidate's conference presentations and posters regarding research included in this thesis. Due to the significant effect of COVID-19 on travel and conference structure during candidature, the ability to present and utilise funding opportunities to attend was significantly impacted.

Oral presentations

Public Health Association of Australia, *Prevention 2022, Brisbane, Australia, 2022.*

Bonnie Brammall, Rhonda Garad, Jacqueline Boyle, Melanie Hayman, Susan de Jersey, Helena Teede, Quoc V Hong, Alayna Carrandi, Cheryce Harrison.

Assessing the Content and Quality of Digital Tools for Managing Gestational Weight Gain: Systematic Search and Evaluation.

Poster presentations

International Congress on Obesity (ICO), *Melbourne, Australia, 2022.*

Bonnie Brammall, Rhonda Garad, Jacqueline Boyle, Melanie Hayman, Susan de Jersey, Helena Teede, Quoc V Hong, Alayna Carrandi, Cheryce Harrison.

Assessing the Content and Quality of Digital Tools for Managing Gestational Weight Gain: Systematic Search and Evaluation.

International Congress on Obesity (ICO), *Melbourne, Australia, 2022.*

Bonnie Brammall, Rhonda Garad, Helena Teede, Cheryce Harrison. Improving preconception health and lifestyle behaviours through digital health intervention: The OptimalMe Program

Scholarships and funding

Listed below are scholarships and funding that I have received relevant to the period of candidature.

Year	Award/prize
2020	**Monash University Graduate Scholarship** for PhD stipend.
2022	**CRE HiPP PhD Research Support Grant** for travel funding to disseminate PhD findings and collaborate

Coursework and short courses

Listed below are coursework, short courses, training and professional development that I have completed relevant to the period of candidature.

Year	Coursework/ training
2020	**Master of Public Health, Introduction to Epidemiology MPH 5040** Monash University (High distinction)
2019	**Master of Public Health, Introduction to Biostatistics MPH 5041** Monash University (Credit)
2019	**Ethics and Good Research Practice** Short course, Monash University
2019	**Qualitative Research Methods for Public Health** Short Course, Monash University
2019	**Women in Leadership Program** Monash Centre for Health Research and Implementation, Monash University and Monash Partners

Media

June 2020   Article in *Prevention Conversation*, Preconception Health and Lifestyle Behaviours

Sep 2020   Article in *Monash News*, Perinatal distress during COVID-19

Statement of aims

The overarching aim of my PhD is to explore health, lifestyle and information seeking-behaviours during preconception, pregnancy and postpartum to inform evidence-based implementation of digital healthy lifestyle interventions across these reproductive life-phases.

Specific aims

Chapter 1. Preconception health and lifestyle behaviours

To examine the health behaviours of Australian women during preconception (prior to pregnancy recognition), evaluate alignment with PCC recommendations, and determine differential health behaviours according to stages of family planning and intention to conceive.

Chapter 2. Perinatal women's digital information and support seeking during COVID-19

To examine the public discourse of a perinatal cohort in the context of COVID-19 to understand unmet health information and support needs, and the impacts on mothering identity and social dynamics.

Chapter 3. Digital support seeking during the postpartum period

To thematically explore the conversations of new mothers on a web-based parenting forum to investigate what topics or concerns are being discussed to identify women's priorities and information-and-support-seeking needs during the postpartum period.

Chapter 4. Consumer facing digital health tools to monitor gestational weight gain

To evaluate the quality and behaviour change potential of publicly available digital tools (websites and mobile apps) that promote and facilitate GWG tracking during pregnancy.

Chapter 5. Development of the OptimalMe program

To generate key implementation learnings to inform the feasibility of future scale up and determine the effectiveness of intervention delivery methods on engagement, experience, acceptability,

knowledge, risk perception, health literacy, and modifiable weight-related health behaviours in women during preconception, pregnancy, and postpartum periods.

Chapter 6. OptimalMe program evaluation in preconception

To understand the impact of a digital healthy lifestyle intervention on women's preconception health behaviour and preventative care actions.

Background

Overweight and Obesity

Escalating weight and obesity is a significant public health problem in most countries worldwide. Overweight and obesity are defined as abnormal or excessive fat accumulation that presents a risk to health and is considered preventable (1). According to the most recently available World Health Organization (WHO) data, as of 2016 two billion adults 18 years or over were classified as living with overweight or obesity, representing approximately 39% of the global population. Longitudinally, this equates to a three-fold increase in the prevalence of adult obesity over a span of forty years to currently affect over 650 million people (2). Escalating weight is now not only confined to adults, with overweight and obesity increasing greater than tenfold among children and adolescents (5–19 years) across this time from 4% to 18% (2). Likewise, previously a concern predominantly in higher-income developed countries, overweight and obesity is now prevalent in most low- and middle-income countries worldwide, particularly in urban settings (1). Overall, the majority of the world's population now reside in countries where overweight and obesity kills more people than underweight (2).

Body mass index (BMI) is commonly used to define overweight and obesity in adults and is calculated as weight in kilograms divided by the square of height in meters (kg/m^2). According to WHO, BMI is classified as: underweight ($\leq$18.50kg/m^2); normal (or healthy) weight (18.50–24.99kg/m^2); overweight (25.00–29.99kg/m^2); and obese ($\geq$30.00kg/m^2) (3). In adults, co-morbidities associated with a higher BMI include asthma, back and knee pain, musculoskeletal conditions, osteoarthritis, chronic kidney and gallbladder disease, type 2 diabetes, dementia, some cancers and cardiovascular disease (CVD) (4). A definitive study in 2020 reported a BMI above the healthy range attributed to approximately five million deaths globally (2.4 million females and 2.3 million males) and a further 147.7 million disability-adjusted life years (DALYs; 70.7 million females and 77.0 million males (5)); equivalent to a global doubling in both outcomes for males and females across a 27 year timespan to 2017. Cardiovascular disease was the leading cause of high-BMI-related DALYs, followed by diabetes and kidney diseases, and neoplasms; which collectively accounted for 89.3% of all high-BMI-related DALYs in 2017 (5). In children, co-morbidities associated with a higher BMI include a higher risk of breathing difficulties, bone fractures, hypertension, insulin resistance, and

early markers of CVD, including vascular alterations and increased cholesterol (2). Overweight or obesity during childhood is shown to be predictive of obesity in adulthood and earlier onset of associated chronic conditions including type 2 diabetes and CVD (6).

Overweight, obesity and suboptimal lifestyle behaviours that increase the risk of adverse health outcomes are influenced by a complex interplay of individual, environmental, societal and economic factors (4). These factors include the social and physical settings in which people live, work and interact with and the influence of infrastructure, cultural, political and commercial factors that, in combination, promote obesity by forming 'obesogenic environments' (4, 7, 8). Whilst obesogenic environments are fixed and pervasive, individual lifestyle related behaviours are considered more easily modifiable, and centre around energy balance. This includes components related to energy intake such as excessive caloric intake, sub-optimal diets lacking in essential nutrients, excess alcohol consumption (9) and those related to energy expenditure, including insufficient physical activity levels (10) and extended periods of sedentary behaviour (10).

Overweight and Obesity in Australia

In Australia, almost one quarter of children and adolescents, and two-thirds of adults are overweight or obese (4). In 2018, overweight and obesity were responsible for 8.4% of Australia's total burden of disease, surpassed only by smoking as a modifiable risk factor for poor health (8.6%) (11). Illnesses associated with overweight and obesity have a significant impact both directly and indirectly on the Australian economy. Directly, health system burden includes higher costs and demand on health-care services (4). Indirect costs include productivity losses largely related to absenteeism, welfare payments, forgone taxation revenue, as well as costs for carers, aids, respite, and other government programs (4). In 2008, the financial cost of overweight and obesity to Australia was estimated to be $8.6 billion, which was primarily associated with productivity costs ($3.6 billion or 44%), health system costs ($2.0 billion or 24%), and carer costs ($1.9 billion or 23%) (4). More recent estimates of Australian productivity losses due to obesity are up to $14.9 billion, annually (12). It is estimated that if no further action is taken to slow the rise in obesity, there will be $87.7 billion economic burden attributed to obesity between 2015 to 2025 (13).

Overweight and Obesity in Reproductive Aged Australian Women

There has been a marked shift in weight and lifestyle behaviours of Australian women. A quarter of a century ago the majority of Australian women were within a healthy BMI (14), by contrast,

currently 60% are living with overweight or obesity (15). Of great concern are younger adult women (18–36 years) of reproductive age who are gaining weight and progressing more rapidly to obesity than women in other age groups and men generally (16). This, in part, is contributed by high-risk windows for accelerated weight gain that are experienced by younger women, including pregnancy and postpartum (16). During pregnancy, overweight and obesity increases the risk of adverse maternal and neonatal outcomes. Maternal risks include gestational diabetes (GDM), hypertensive disorders and caesarean section, and for offspring there is increased risk of congenital anomalies, shoulder dystocia, respiratory distress, macrosomia and being born large for gestational age (LGA) (17). These risks are independently exacerbated by excess GWG, which occurs in approximately 50% of pregnancies (17).

Pregnancy appears to amplify barriers to healthy lifestyle behaviours that are experienced broadly by women. Currently, 50% and 91% of Australian women of reproductive age do not meet recommended daily fruit and vegetable consumption, respectively (18); 9% consume more than one metric cup of sugar sweetened beverages daily (18); and 18% exceed weekly recommended alcohol intake guidelines (19). During pregnancy, a cross-sectional Australian survey reported that of 857 women included, none met the dietary guidelines for the five main food groups, including vegetables/legumes or beans; fruit; grains; dairy or calcium alternatives, and protein (20). Overall, 56%, 29% and under 10% met the recommendations for the fruit, dairy and other core food groups, respectively (20). National health survey results demonstrate a decline in physical activity during pregnancy, with 17% less pregnant women meeting the recommendations compared to 47% of non-pregnant women (21). As such, there is a critical mandate to address both the external and individual risk factors contributing to overweight, obesity and suboptimal health and their impact on reproductive health in women such as fertility (22, 23), pregnancy outcomes and maternal and child health (24-26).

Optimising Health and Lifestyle Behaviour During Preconception

The optimisation of health and healthy behaviours during the preconception period is increasingly recognised as a window of opportunity to improve health outcomes for both mother and baby and prevent intergenerational sequalae. This rationale is based on life course epidemiology, developmental (embryo) programming around the time of conception, maternal motivation, and the recognition of limited opportunity in intervening during pregnancy to positively influence outcomes given antenatal care commonly commences in the second trimester (24). Further to this,

pregnancy planning is now common in low, middle, and high-income countries (24). Research estimates that estimates that 60% of the 213 million pregnancies worldwide in 2012 were intended (27), thus emphasising a considerable opportunity for prospective preconception health promotion. Preconception care encompasses preventative care strategies that aim to prevent illness, detect specific diseases, and promote and maintain health (28). In women who wish to conceive, the preconception period presents a period of heightened motivation to implement healthy lifestyle changes to benefit conception, pregnancy outcomes and ultimately, the health of their baby (29). A woman who is healthy at the time of conception is more likely to have a successful pregnancy and a healthy child (24). Although previously considered as the three months prior to conception, the preconception period is now recognised as encompassing a broader perspective, across three domains: the biological perspective, which includes the days to weeks before embryo development; the individual perspective, which is a conscious intention to conceive, typically weeks to months before pregnancy occurs; and the public health perspective, encompassing months to years to enable preconception risk factors, such as diet and obesity to be addressed (24).

Given the substantial health and economic burden of suboptimal lifestyle behaviours and escalating weight on fertility, pregnancy outcomes, infant health (24) and health systems (4, 12), finding an effective approach to deliver preconception interventions that promote behaviour change has become a public health imperative. Yet, despite the growing recognition of this critical phase as an intervention opportunity, at the population level, health indicators in women continue to decline, due largely to intervention design and implementation shortfalls that fail to address the needs of women. Preconception interventions are generally limited to interventions focused on a single behaviour or outcome, and mainly target women at higher risk, including those with chronic illnesses or impaired fertility (30, 31). Of the limited evidence available, interventions in higher risk populations demonstrate favourable outcomes, including improvements in knowledge, self-efficacy and optimisation of higher risk behaviours including alcohol consumption and smoking status (32). However, high risk women represent only a small portion of reproductive aged women and therefore this does not address the gap in the provision of effective preconception health and lifestyle care to general populations of women who are planning a pregnancy and are otherwise healthy.

Digital Health and Lifestyle Interventions for Preconception, Pregnancy and Postpartum

A fundamental challenge is how to reach an otherwise healthy population that may not be regularly engaged with the health sector, and who may have limited awareness of both PCC and the attributed

risks of high-risk behaviours (33). Previous research has shown that women may consider conception to be intimate and private, and largely self-managed unless fertility issues arise. For these women, primary methods of engaging with health information regarding conception include the internet, potentially more so rather than health care providers (33). Ninety-one percent of the Australian population are active internet users (34), and it is widely understood and accepted that the internet has become a prominent source to obtain health information, rapidly replacing traditional paper-based health information and supplementing face-to-face health professional consultations (35-38). Digital health platforms, online tools and virtual communities provide unique benefits such as accessibility, convenience, anonymity, and social and peer support (39-43). It is therefore not surprising that interactions with pregnancy-related information via websites, mobile applications, and social media platforms are becoming commonplace among preconception, pregnant and postpartum women (33, 44). Post child-birth, the majority of Australian parents (73%) with children aged less than five years use websites, blogs, and web-based forums to obtain information about infant or child health and parenting (39, 42, 45, 46). Given this growing trend, digital tools such as mobile applications and websites have the potential to impact health and behaviour in the preconception population.

Whist digital health appears to be a promising platform in which to engage women, there is a lack of evidence on what information and support women are seeking online, the quality and safety of information and tools designed to track health information. This includes the availability and quality of freely accessible digital tools, including those to monitor GWG during pregnancy. Given the benefit of self-weighing for weight management during pregnancy (47), and the tendency of consumers to trust digital health information (48), an assessment of digital tools for GWG is important. It is also important to understand the information seeking behaviours of women, and to assess the quality of the health-related information and tools being utilised.

As women are highly engaged with digital platforms during the perinatal period, digitally delivered interventions may provide an effective method to reach, promote, and deliver PCC and lifestyle interventions to women planning a pregnancy. A digital program that engages women prior to pregnancy and provides ongoing health and lifestyle intervention during pregnancy and post-birth would be novel, and has the capacity to address this issue at scale. The formative body of work presented in this thesis informs PCC and digital health innovations.

Adaptation of HeLP-her to a Digital Preconception, Pregnancy and Postpartum Intervention

The Healthy Lifestyle Program (HeLP-her) is a low intensity weight gain prevention program for reproductive aged women, and was one of the first effective, community-based prevention trials in women internationally (49, 50). Monash University's multidisciplinary research team demonstrated that HeLP-her can successfully be translated and implemented in numerous settings (community-based clinics, rural and regional settings), and in different populations (general reproductive aged, pregnant and postpartum women) (49-53). Women who participated in HeLP-her have previously reported health coaching sessions to be a valued method to receiving lifestyle advice (52). However, women suggested at program evaluation that using a mixture of face-to-face and electronic methods (phone coaching and SMS text messaging) would be beneficial to address individual preferences and learning styles (52). Coupled with the imperative need, these HeLP-her findings informed the decision to adapt the program to a digital intervention that can reach women during preconception, called OptimalMe. This intervention is designed to inform women about the importance of PCC, the risks of suboptimal lifestyles and behaviours during preconception, pregnancy and postpartum, and to guide, foster and support self-managed behaviour change. OptimalMe is underpinned theoretically by the Social Cognitive Theory (54) and a behaviour change framework that effectively optimised weight and health related behaviours in HeLP-her (51).

During my PhD I have played a significant role in the design of OptimalMe (Figure 1). This includes input into obtaining ethics and management of subsequent amendments; managing consumer cognitive testing and analysis/application of the findings; co-developing intervention content, screening expressions of interest and delivering the intervention to approximately 350 women across preconception and pregnancy. During the implementation of the trial I have regularly reported preliminary findings and numbers to the chief investigators and stakeholders. I have co-developed and disseminated numerous questionnaires for evaluation, and cleaned and collated all data used to date. Semi-structured interviews have been conducted. I co-developed the guide for these interviews, arranged all appointments and analysed the transcripts. Delivery and evaluation of OptimalMe is ongoing. Upon completion of my PhD I will continue to evaluate secondary aims from the preconception intervention, and the primary aims will be evaluated by my supervisory team.
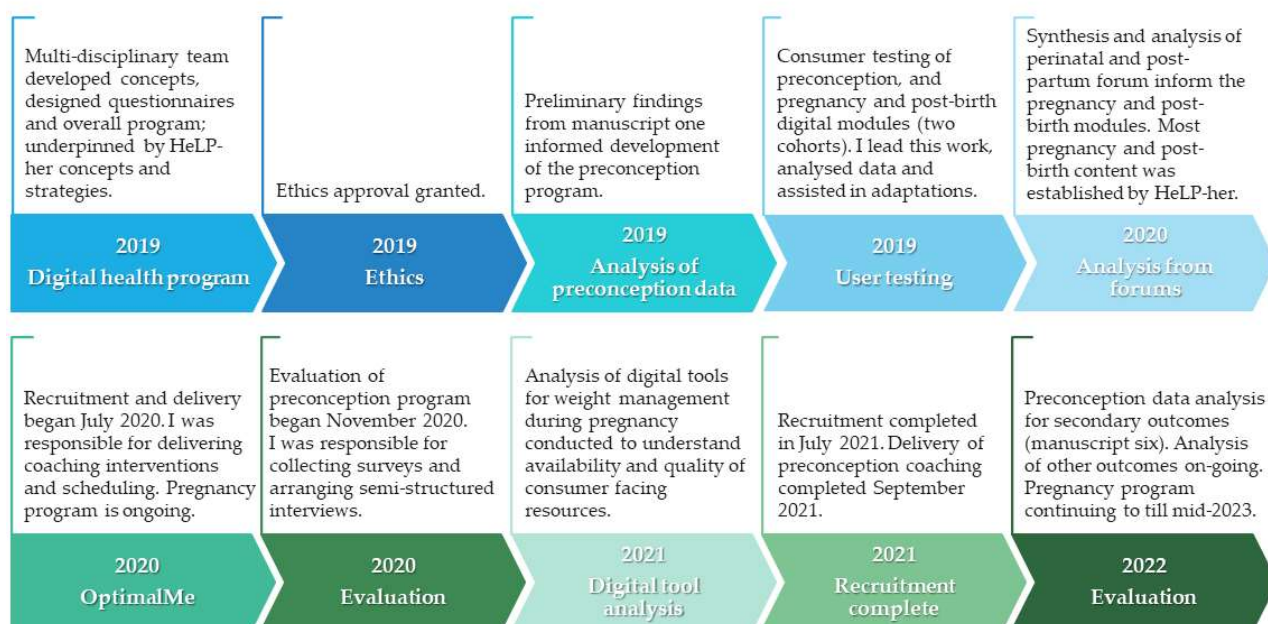
Development of OptimalMe and PhD research insights

Multi-disciplinary team developed concepts, designed questionnaires and overall program; underpinned by HeLP-her concepts and strategies.

2019
Digital health program

Ethics approval granted.

2019
Ethics

Preliminary findings from manuscript one informed development of the preconception program.

2019
Analysis of preconception data

Consumer testing of preconception, and pregnancy and post-birth digital modules (two cohorts). I lead this work, analysed data and assisted in adaptations.

2019
User testing

Synthesis and analysis of perinatal and post-partum forum inform the pregnancy and post-birth modules. Most pregnancy and post-birth content was established by HeLP-her.

2020
Analysis from forums

Recruitment and delivery began July 2020. I was responsible for delivering coaching interventions and scheduling. Pregnancy program is ongoing.

2020
OptimalMe

Evaluation of preconception program began November 2020. I was responsible for collecting surveys and arranging semi-structured interviews.

2020
Evaluation

Analysis of digital tools for weight management during pregnancy conducted to understand availability and quality of consumer facing resources.

2021
Digital tool analysis

Recruitment completed in July 2021. Delivery of preconception coaching completed September 2021.

2021
Recruitment complete

Preconception data analysis for secondary outcomes (manuscript six). Analysis of other outcomes on-going. Pregnancy program continuing to till mid-2023.

2022
Evaluation

Figure 1: Overview of contributions to OptimalMe, and research insights from Preconception Pregnancy and Postpartum

Chapter 1. Preconception health and lifestyle behaviours

1.1   Introduction

Women's health and lifestyle behaviours are critical factors for fertility (22, 23), pregnancy outcomes and infant health (24-26). This manuscript addresses a gap in evidence pertaining to the health and behaviours of women who are prospectively planning a pregnancy, but have not yet conceived. Prior to this analysis our understanding of the health and behaviours of women was limited predominantly to retrospective insights from pregnant women or those from a general reproductive aged population who may not intend to conceive (55, 56). These data are weakened by recall limitations and potential bias (57), and critically, exclude insights from women intending to conceive who do not fall pregnant.

In this cross-sectional study, I advanced the field by strengthening our understanding of women's behaviour and health status during preconception by capturing and reporting findings from women who are planning a pregnancy but are not yet pregnant.

This project aimed to describe women's health and behaviours that are important during preconception and have impacts on conception and pregnancy outcomes. The outcomes reported were guided by the Guidelines for Preventive Activities in General Practice, relating to preconception (28), to determine if women reported health and behaviour in line with best practice recommendations for care. We compared the outcomes of those planning an immediate pregnancy (currently trying to conceive) with those who had longer term pregnancy intentions (1-2 years) to explore the impact of time to intended pregnancy on behaviour and uptake of PCC objectives.

My role in this project was to conceptualise the presentation of this data (alignment with guideline and stratified by pregnancy intention) and conduct an analysis of the data, which had been collected prior to my PhD commencement, by Dr. Adina Lang. I had primary responsibility to write the manuscript, with secondary support from Dr Cheryce Harrison and Assoc Prof Jacqueline Boyle, and the wider author group.

At the time of completion, to the knowledge of the author group, this was one of the first studies to report the health and behaviour of women prospectively planning a pregnancy. Compared to other

studies of preconception health and behaviour that reported on single behaviours, such as cigarette smoking, alcohol or supplementation (55, 56), this extensive cross-sectional study comprehensively examined numerous factors and behaviours.

Overall, in 294 women there were concerning findings in the context of a cohort actively planning for conception, including recent weight gain, alcohol consumption and minimal engagement with healthcare to prepare for pregnancy. Women appeared to be more proactive in self-managed, modifiable aspects of preconception health, including supplementation, weight management and intention to cease higher-risk behaviours including alcohol intake, yet engagement with primary healthcare providers to prepare for pregnancy was suboptimal. Despite positive intentions, modifiable behaviours and self-managed aspects of PCC were suboptimal, with high alcohol intake, incomplete supplementation and cessation of contraceptive use prior to optimising preconception health and behaviours. Preconception care has been shown to improve maternal and child health outcomes for all women, as well as women with particular risk factors such as maternal obesity, diabetes, hypertension, depression, substance misuse, and occupational variables (31, 58, 59). Therefore, efforts are required to improve PCC knowledge, awareness and uptake through strengthened partnerships between women and their healthcare providers.

The impact of this project was extensive in influencing health policy and informing a preconception program that has the potential to address this issue at scale. The project outcomes informed the design of the OptimalMe preconception program and health coaching guide, emphasising the need to address lifestyle behaviours, clinically relevant PCC outcomes and improve awareness of partnership with primary healthcare providers for PCC. In addition, our results demonstrating that preconception alcohol consumption was significant, were used to influence the political consideration of mandating alcohol warning labels in Australia, in partnership with Foundation for Alcohol Research and Education (FARE; see Appendix 1 for relevant Minister's letters and associated media article). In the emerging field of Commercial Determinants of Health (CDoH) (60), the influence of this work on the alcohol industry rather than the individual, and the positive outcomes of lobbying Government to respond to our research is a significant translation outcome for the benefit of women and their children.

1.2 Preconception health and lifestyle behaviours, Australian context

Chivers BR, Boyle JA, Lang AY, Teede HJ, Moran LJ, Harrison CL

Preconception Health and Lifestyle Behaviours of Women Planning a Pregnancy: A Cross-Sectional Study

Article

Preconception Health and Lifestyle Behaviours of Women Planning a Pregnancy: A Cross-Sectional Study

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Abstract: Preconception care and lifestyle behaviours significantly influence health outcomes of women and future generations. A cross-sectional survey of Australian women in preconception, stratified by pregnancy planning stage (active planners (currently trying to conceive) vs. non-active planners (pregnancy planned within 1–5 years)), assessed health behaviours and their alignment to preconception care guidelines. Overall, 294 women with a mean (SD) age of 30.7 (4.3) years were recruited and 38.9% were overweight or obese. Approximately half of women (54.4%) reported weight gain within the previous 12 months, of which 69.5% gained ≥ 3kg. The vast majority of women (90.2%) were unaware of reproductive life plans, and 16.8% over the age of 25 had not undertaken cervical screening. Of active planners (n = 121), 47.1% had sought medical/health advice in preparation for pregnancy and 81.0% had commenced supplementation with folic acid, iodine or a preconception multivitamin. High-risk lifestyle behaviours including cigarette smoking (7.3%), consumption of alcohol (85.3%) and excessive alcohol consumption within three months (56.3%), were frequently reported in women who were actively trying to conceive. Results indicate that women who are actively planning a pregnancy require support to optimise health and lifestyle in preparation for pregnancy to improve alignment with current preconception care recommendations.

Keywords: preconception; health behaviours; pregnancy planning; women's health; clinical care guidelines

1. Introduction

The health status and behaviours of prospective parents before conception, known as the preconception period, is important for the health of women and future generations [1,2]. Initiating strategies to optimise health and lifestyle behaviours during preconception is vital, as some of the most important mechanisms for development and factors affecting birth outcomes occur in the very early stages of pregnancy, often before women are aware they are pregnant or commence antenatal care [3,4]. There are many modifiable health behaviours that can negatively impact outcomes during pregnancy that are difficult to change in the short term [5], and, therefore, addressing these warrants early intervention, during preconception. These include a balanced diet and regular moderate-intensity exercise consistent with recommendations [6,7], weight management, cessation of cigarette smoking, alcohol and recreational drug use, and treatment of sexually transmitted infections (STIs). All of these may also optimise fertility, thereby increasing the likelihood of natural conception [2,5].

The Royal Australian College of General Practitioners (RACGP) Guidelines for Preventative Activities in General Practice [8] recommend a range of preconception care (PCC) strategies, consistent with several other international PCC guidelines [9,10]. Major components of PCC include risk assessment (12), education and health promotion, and medical and psychosocial interventions [11] to enhance knowledge, attitudes and behaviours and improve the health status of prospective parents [10,12]. Understanding whether women seek PCC, what areas of PCC are addressed, as well as their health behaviours during this time, is therefore important, to identify deviation between individual health behaviours and PCC recommendations. This, in turn, can inform and refine PCC recommendations, focus policy and enable targeted PCC strategies where required.

While information is available about the uptake of antenatal care by Australian women [13], little is known about behaviour before pregnancy. Of the available evidence, the majority are retrospective studies of pregnant women [5,14,15]. These studies preclude insight from women who may be planning a pregnancy but do not conceive and are also susceptible to recall bias [16–18]. Further, the majority of research relates to a limited number of health behaviours, predominantly folic acid supplementation, alcohol consumption and cigarette smoking [5,19,20]. A comprehensive and holistic understanding of preconception health and behaviours in women currently planning a pregnancy is lacking. To address these fundamental gaps, this cross-sectional study aims to examine health behaviours of women during preconception, in accordance with Australian PCC recommendations [8]. The secondary aim is to compare the results of women at different stages of family planning, to evaluate any differences in behaviour patterns.

2. Materials and Methods

2.1. Study Design

A cross-sectional questionnaire completed by Australian women in preconception or interconception (between pregnancies).

2.2. Health Setting, Recruitment and Participants

The Australian healthcare system is government-supported via 'Medicare', which provides universal, free or low-cost care to Australian citizens and residents (and others eligible) across most health services. Private health insurance, paid by the individual, enables choice of hospital and/or provider outside of the public system. Insurance is typically characterised by waiting periods for hospital cover, including pregnancy and birth cover with a 12-month average waiting period before some, or all, of the cost of hospital treatment as a patient is covered. Women of reproductive age who have private health insurance pregnancy therefore provide a unique cohort through which to explore preconception health, before conception actually occurs.

In this study, women were recruited via partnership with a large Australian private healthcare insurance provider, Medibank Private Limited (MPL). Eligible women included those aged between 18–40 years, who had joined or upgraded their health insurance in the previous 12 months to include pregnancy and birth cover, were not pregnant at the time of completing the questionnaire and indicated they were planning a pregnancy within the next five years. Those who indicated they were planning a pregnancy beyond five years into the future, were unsure of, or not, planning a pregnancy or had completed their family were excluded.

A co-developed invitation for participation was emailed by MPL to all eligible women explaining the study and the voluntary nature of participation. Women opted in to the study, providing implied consent, by following an electronic link and completing the anonymous online questionnaire.

2.3. Ethics

Ethics approval for this study was obtained by the Monash Health (RES-17-0000-087A) and Monash University (Project no. 10370) Human Research Ethics Committees.

2.4. The Questionnaire

The questionnaire was adapted from existing tools to assess women's pregnancy planning and related health behaviours, risk perception and knowledge. Detailed information about this questionnaire has been published previously [21] and the questions analysed in the current study are provided as supplementary material. It was developed in consultation with multidisciplinary health and medical expertise across obstetrics, public health, social science, dietetics, exercise physiology and endocrinology, with cognitive interviewing and consumer testing performed as previously reported [15]. Information gathered within the questionnaire was aligned with Australian PCC recommendations [8]. This included awareness of a reproductive life plan (a personalised set of goals about pregnancy intention, timing and spacing of intended pregnancies, and associated physical, mental and sexual health considerations [22]); reproductive history; genetic history and screening for genetic conditions; general physical assessment (BMI, cervical screening, STI screening and dental examination history); screening for infectious diseases/immunisation status; folic acid and iodine supplementation; nutrition and exercise; psychosocial factors and substance use (tobacco, alcohol and recreational drugs) [8,23]. General physical assessment, including cervical and STI screening, were analysed in accordance with current Australian guidelines which recommend cervical screening every five years from 2017 for women aged 25–74 years of age that are sexually active (or after two years if last test was prior to 2017, followed by every five years if results are normal) [24]. STI screening recommendations include opportunistic screening of sexually active women under 29 years of age and annual screening for high-risk groups, such as Aboriginal and Torres Strait Islander people, sex workers and women who inject drugs [8].

2.5. Stage of Pregnancy Planning

To establish stage of pregnancy planning, women were asked 'are you planning a pregnancy in the future?'. Women who selected 'yes, I am currently trying to conceive' or 'yes, within 1 year' were classified as 'active planners'. Those who answered 'yes, within 5 years' were classified as 'non-active planners'.

2.6. Demographics

Socio-economic status was estimated according to participant's post code, using the deciles in the Australian Socio-Economic Indexes for Areas (SEIFA) Index of Relative Socio-economic Disadvantage [25]. Deciles 1–3 were classified as higher-level disadvantage, 4–7 as moderate-level disadvantage and decile 8–10 as lower-level disadvantage. Rural/remote or urban locality was determined by post code using the Rural and Remote Postcode List [26].

2.7. Reproductive Health, Family Planning and Genetic Health

Women were asked what form of contraception was used 'every time', 'most of the time', 'sometimes' or 'never' in the last six months when engaging in sexual intercourse. Women could select multiple types of contraception and could select multiple frequencies of use. Selections of 'every time' and/or 'most of the time' were classified as regular use, and 'sometimes' and 'never' were captured as non-regular use. Previous and current use of fertility treatment was assessed by the question, 'have you or your partner been treated for, or are currently undergoing treatment for infertility?', (yes/no).

2.8. Actions to Prepare for Pregnancy

Women were asked if they were currently taking actions to improve their health in preparation for pregnancy, including the following: taking folic acid, iodine, pre-pregnancy multivitamins (analysed individually and combined as a composite) or vitamin D; trying to cut down or stop smoking, cut down or stop drinking alcohol, improve diet, improve exercise level or improve sleep patterns; seeking medical/health advice; not doing any action listed; or taking some other action.

2.9. Lifestyle Behaviours and Modifiable Risk Factors

Current and/or recent behaviour relating to alcohol consumption, recreational drug use and smoking was collected. Women were asked to record their average alcohol consumption from Monday–Thursday and Friday–Sunday, per week, for the previous three months, which was collated into a weekly average. The women were also asked to provide the number of times they had consumed more than four standard drinks in one single occasion (excessive drinking) in the past three months: 'I don't remember/I don't know'; or 'I had stopped drinking alcohol because I was trying to get pregnant' were provided as additional response options. The cohort were asked if they had ever taken recreational drugs; those who answered 'yes' were then asked when the last time they took recreational drugs was. Smoking status was recorded by asking 'are you currently smoking', (yes/no). Participants could choose not to respond to questions regarding cigarette smoking or drug use by selecting 'prefer not to answer'.

Self-reported weight and height were collected and used to calculate BMI (weight/height (m^2)), which was classified according to the World Health Organization definitions: underweight ($\leq$18.49 kg/m^2); normal weight (18.50–24.99 kg/m^2) (herein referred to as healthy BMI); overweight (25.00–29.99 kg/m^2); and obese ($\geq$ 30.00kg/m^2) [27]. Weight-related behaviours were evaluated, including self-weighing behaviour (daily, weekly, monthly (regular weigher) or occasionally, never (non-regular weigher)), weight maintenance behaviours (maintain or lose weight), and weight gain in the previous 12 months (yes, no or unsure; if yes, how much weight gain: 1–2kg, 3–5kg or 6 + kg).

2.10. Statistical Analysis

Data analysis was performed using IBM SPSS Statistics version 25 (Armonk, New York, NY, USA). Descriptive statistics were tested for skewness by using the Shapiro–Wilk test and were presented as mean and standard deviation (SD) for normally distributed continuous variables, and median and interquartile range (IQR) for skewed continuous variables. Frequencies and percentages were presented for categorical variables. The Kruskal–Wallis Test, Mann–Whitney U and the chi-squared test (χ^2 tests) were used to compare the characteristics of women, stratified by pregnancy intention. A subanalysis was performed for fertility treatment, cervical screening, weight-related actions, weight gain within the previous 12 months and amount of weight gain. To perform subanalyses variables were stratified to explore the characteristics of those within the cohort who reported a response of interest. All *p*-values presented are two-tailed; $p < 0.05$ was considered statistically significant. Where a significant p-value was identified in a multiple comparison, the Bonferroni correction was used to examine if the significance remained after adjusting for multiple groups, and, if so, where significance occurred [28].

3. Results

3.1. Demographic Characteristics

In total, 4870 eligible women were invited to participate (2104 did not open the original email and were therefore treated as not contactable); of those who opened the email, 23.8% opened the questionnaire and 18.2% (n = 504) attempted it. Ninety-two women reported being currently pregnant and 118 selected a pregnancy intention that did not meet the inclusion criteria, leaving 294 women who met the inclusion criteria for the current study. Overall, the mean age was 30.7 (4.3) years and median BMI was 23.7 (20.1, 26.8) kg/m2. Overall, 41% (n = 121) of women were classified as actively planning for pregnancy while 59% (n = 173) were not actively planning for pregnancy. Women who were actively planning for pregnancy were more likely to be married/de facto (97.8% vs. 90.7%, *p* = 0.04) compared with non-active planners, with no further significant differences in demographic characteristics found between the two groups (Table 1).

Table 1. Participant characteristics stratified by pregnancy intention.

Characteristic	All (n = 294)	Active Planners (n = 121)	Non-Active Planners (n = 173)	*p*-Value
Age (years) Mean (SD)	*n = 195*	*n = 89*	*n = 106*	
	30.7 (4.3)	31.4 (4.4)	30.2 (4.1)	0.35
BMI (kg/m^2) Median (IQR)	*n = 193*	*n = 88*	*n = 105*	
	23.7 (20.1, 26.8)	24.2 (20.8, 27.7)	23.1 (20.3, 26.0)	0.05
Country of birth	*n = 197*	*n = 90*	*n = 107*	
Australia	135 (68.5%)	56 (62.2%)	79 (73.8%)	0.08
Outside Australia	62 (31.5%)	34 (37.8%)	28 (26.2%)	
Education	*n = 196*	*n = 89*	*n = 107*	
School Only	10 (5.1%)	6 (6.7%)	4 (3.7%)	
Certificate/Diploma/Apprenticeship	69 (35.2%)	36 (40.5%)	33 (30.8%)	0.18
University	117 (59.7%)	47 (52.8%)	70 (65.4%)	
Employment	*n = 196*	*n = 89*	*n = 107*	
Employed	184 (93.9%)	86 (96.6%)	98 (91.6%)	0.14
Unemployed	12 (6.1%)	3 (3.4%)	9 (8.4%)	
Area of residence	*n = 192*	*n = 87*	*n = 105*	
Urban	158 (82.3%)	73 (83.9%)	20 (19.0%)	0.29
Rural/remote	33 (17.7%)	14 (16.1%)	85 (81.0%)	
SEFIA	*n = 191*	*n = 86*	*n = 105*	
Higher-level disadvantage	18 (9.4%)	8 (9.3%)	10 (9.5%)	
Moderate-level disadvantage	59 (30.9%)	26 (30.2%)	33 (31.4%)	0.98
Lower-level disadvantage	114 (59.7%)	52 (60.5%)	62 (59.0%)	
Annual household income (AUD)	*n = 196*	*n = 89*	*n = 107*	
<$40,000	8 (4.1%)	4 (4.5%)	4 (3.7%)	
$41,000–$64,999	17 (8.7%)	9 (10.1%)	8 (7.5%)	
$65,000–$80,000	24 (12.2%)	8 (9.0%)	16 (15.0%)	0.74
>$81,000	135 (68.9%)	62 (69.7%)	73 (68.2%)	
Prefer not to answer	12 (6.1%)	6 (6.7%)	6 (5.6%)	
Relationship Status	*n = 196*	*n = 89*	*n = 107*	
Married/De facto	184 (93.9%)	87 (97.8%)	97 (90.7%)	0.04
Unmarried	12 (6.1%)	2 (2.3%)	10 (9.3%)	

Total *n* for each variable may vary based on the total number of responses.

Compared with key demographic characteristics from available 2016 Australian Census information [29] across ~3.7 million women aged 18–40 years; 68.9% of our cohort reported a higher annual household income than the population median (~$74,446 AUD/year). The frequency of those reporting unemployment (6.1%) was comparable to Australian females aged 15 years and over (6.7% unemployed). We recruited a comparable proportion of women born overseas to the overall Australian population (31.5% vs. 26.7%), while a smaller proportion of our cohort lived in rural/remote areas (17.7% compared to 29.0%).

3.2. Reproductive Health, Family Planning and Genetic Factors

Approximately 90% of women overall were not aware of a reproductive life plan and approximately ~30% reported having a previous pregnancy. Thirty percent of active planners (the participant or their partner) reported currently or previously undertaking fertility treatment compared to 4.1% of non-active planners (*p* < 0.001). A subanalysis showed that those who reported use of fertility treatment were of a similar age (31.7 (4.0) vs. 30.6 (4.3) years *p* = 0.81) with a higher median BMI (25.7 (20.5, 30.9) vs. 23.3 (20.4, 26.2) kg/m^2, *p* < 0.05) compared to those not reporting fertility treatment and a higher proportion were overweight or obese women (58.1% vs. 35.1%, *p* < 0.05). All other outcomes for reproductive health, family planning and genetic factors are displayed in Table 2.

Table 2. Reproductive health, actions and awareness, stratified by pregnancy intention.

Factor or Action	All (n = 294)	Active Planners (n = 121)	Non-Active Planners (n = 173)	*p*-Value
Awareness of reproductive life plan	*n = 255*	*n = 110*	*n = 145*	
Yes	25 (9.8%)	10 (9.1%)	15 (10.3%)	0.74
Previous pregnancy	*n = 57*	*n = 31*	*n = 26*	
Yes	20 (35.1%)	12 (38.7%)	8 (30.8%)	0.53
Regular contraception choice				
No contraception	*n = 232* 87 (37.5%)	*n = 103* 65 (63.1%)	*n = 129* 22 (17.1%)	<0.001
Withdrawal	*n = 213* 41 (19.2%)	*n = 89* 9 (10.1%)	*n = 124* 32 (25.8%)	<0.01
Barrier	*n = 223* 62 (27.8%)	*n = 92* 14 (15.2%)	*n = 131* 48 (36.6%)	<0.001
Hormonal	*n = 233* 85 (25.8%)	*n = 95* 12 (12.6%)	*n = 138* 73 (52.9%)	<0.001
Fertility treatment (previous or current treatment of participant or their partner)	*n = 255*	*n = 110*	*n = 145*	
Yes	40 (15.7%)	34 (30.9%)	6 (4.1%)	<0.001
Personal/family history of genetic condition	*n = 199*	*n = 90*	*n = 109*	
Yes No Unsure	40 (20.1%) 119 (59.8%) 40 (20.1%)	19 (21.1%) 53 (58.9%) 18 (20.0%)	21 (19.3%) 66 (60.6%) 22 (20.2%)	0.95
Tested for genetic conditions	*n = 40*	*n = 19*	*n = 21*	
Yes No Unsure	23 (57.5%) 15 (37.5%) 2 (5.0%)	10 (53.6%) 8 (42.1%) 1 (5.3%)	13 (61.9%) 7 (33.3%) 1 (4.8%)	0.84

Total *n* for each variable may vary based on the total number of responses.

3.3. General Physical Health, Medical Screening and Immunisation Status

General physical health characteristics, uptake of medical screening, routine health checks and testing and immunisation status are presented in Table 3, with no significant differences found between active and non-active planners. Approximately 17.0% of women over 25 years had never undertaken cervical screening for cancer prevention. A subanalysis comparing women those who had commenced screening (n = 159) with those who had not (n = 33), found no significant differences in demographic characteristics, with the exception of SEIFA classification, which indicated they were more likely to reside in an area of higher-level disadvantage (25.0% vs. 5.2%, *p* = 0.002). Twelve (n = 12) of those unscreened and aged over 25 years reported they had sought medical/health advice to prepare for pregnancy, and 6.1% had been tested for an STI within six months.

3.4. Actions to Prepare for Pregnancy, Unhealthy Lifestyle Behaviours and Modifiable Risk Factors

Women actively planning for pregnancy were more likely to report folic acid (75.2% vs. 30.6%, *p* < 0.001), iodine (29.8% vs. 16.2%, *p* = 0.01), pre-pregnancy (44.6% vs. 17.9%, *p* < 0.001) and/or vitamin D supplementation (38.9% vs. 22.5%, *p* = 0.003) compared with non-active planners (Table 4).

Overall, 6.6% were currently smoking, 85.3% had consumed alcohol in the previous three months and 59.0% indicated they had engaged in excessive drinking within the previous three months. Active planners were significantly more likely to report alcohol cessation in the previous three months in preparation for pregnancy, compared with women not actively planning (19.8% vs. 5.3%, *p* = 0.01). Yet, overall, active planners reported a similar median number of alcoholic drinks per week (4.0 (1.0, 7.0) vs. 3.0 (0.5, 5.5)) compared with women not actively planning (*p* = 0.35).

Table 3. General physical health and screening, stratified by pregnancy intention.

Factor or Action	All (n = 294)	Active Planners (n = 121)	Non-Active Planners (n = 173)	*p*-Value
BMI category	*n = 193*	*n = 88*	*n = 105*	
Underweight	7 (3.6%)	4 (4.5%)	3 (2.9%)	
Healthy	111 (57.5%)	45 (51.1%)	66 (62.9%)	
Overweight	39 (20.2%)	21 (23.9%)	19 (18.1%)	0.43
Obese	36 (18.7%)	18 (20.5%)	17 (16.2%)	
Undertaken cervical screening/pap smear	*n = 197*	*n = 90*	*n = 107*	
Yes	159 (80.7%)	73 (81.1%)	86 (80.4%)	
No (aged, >25yrs)	33 (16.8%)	15 (16.7%)	18 (16.8%)	0.97
No (aged, ≤25yrs)	5 (2.5%)	2 (2.2%)	3 (2.8%)	
STI test (within 6 months)	*n = 197*	*n = 90*	*n = 107*	
Yes	57 (28.9%)	31 (34.4%)	26 (24.3%)	0.12
Dental Check Up (within 12 months)	*n = 252*	*n = 110*	*n = 142*	
Yes	181, (71.8%)	81, (73.6%)	100, (70.4%)	0.06
Currently experiencing gum/teeth problem	*n = 252*	*n = 110*	*n = 142*	
Yes	32 (12.7%)	15 (13.6%)	17 (12.0%)	0.69
Up-to-date immunisation	*n = 197*	*n = 90*	*n = 107*	
Measles Mumps Rubella (MMR)	152 (77.2%)	72 (80.0%)	80 (74.8%)	0.38
Hepatitis B	139 (70.6%)	65 (72.2%)	74 (69.2%)	0.64
Chicken Pox (Varicella)	124 (62.9%)	55 (61.1%)	69 (59.8%)	0.63
Tetanus/Diphtheria/Pertussis (whooping cough)	156 (79.2%)	71 (78.9%)	85 (79.4%)	0.92
Influenza	101 (51.3%)	46 (51.1%)	55 (51.4%)	0.97
None of the above	18 (9.1%)	7 (7.8%)	11 (10.3%)	0.54
Unsure	4 (2.0%)	1 (1.1%)	3 (2.8%)	0.40

Total *n* for each variable may vary based on the total number of responses.

Approximately half of all women (54.4%) reported gaining weight in the previous 12 months, with 50.5% of these women reporting an increase of 3–5kg or more, and 19.1% reporting an increase of 6kg or more. Weighing habits, weight gain in previous 12 months, amount of weight gain and weight-related actions between the two groups did not differ significantly.

3.5. Subanalysis of Weight Behaviour and Weight Gain

Most women who reported weight gain in the previous 12 months were a healthy BMI (57.1%), while 21.0% were overweight, 21.0% were obese and 1.0% were underweight. The majority of those who reported a weight gain of 6kg or more within 12 months were obese (65.0%) or overweight (20.0%), with 15.0% a healthy BMI. Smaller weight increases of 1–2kg and 3–5kg in the previous year were most prevalent in women of a healthy BMI (81.3% and 58.5%, respectively), followed by those overweight (12.5% and 3.1%, respectively) and obese (26.4 and 15.1%, respectively).

Seventy-six percent of women who reported that they were currently trying to maintain a healthy weight were a healthy BMI, while 6.7% were underweight, 15.6% were overweight and 2.2% were obese. Of these, 38.9% reported gaining weight in the previous 12 months, while 52.2% had not and 8.9% were unsure.

The majority of women trying to lose weight reported weight gain in the previous 12 months (68.9%) and were an unhealthy BMI (34.4% obese, 25.8% overweight and 1.1% underweight) compared with 38.7% who were a healthy BMI. Most of those who reported no attempt to maintain nor lose weight were a healthy BMI (70.0% vs. 30.0% overweight/obese). Sixty percent of all women taking no weight-related actions reported weight gain within the previous 12 months.

Table 4. Actions to prepare for pregnancy, unhealthy lifestyle behaviours and modifiable risk factors, stratified by pregnancy intention.

Factor or Action	All (n = 294)	Active Planners (n = 121)	Non-active Planners (n = 173)	*p*-Value
Current actions to prepare for pregnancy	*n = 294*	*n = 121*	*n = 173*	
Supplement use:				
Taking folic acid	144 (49.0%)	91 (75.2%)	53 (30.6%)	<0.001
Taking iodine	64 (21.8%)	36 (29.8%)	28 (16.2%)	0.01
Taking a pre-pregnancy supplement	85 (28.9%)	54 (44.6%)	31 (17.9%)	<0.001
Taking folic acid/iodine/pre-pregnancy supplement *	155 (52.7%)	98 (81.0%)	57 (33.0%)	<0.001
Taking vitamin D	86 (29.3%)	47 (38.9%)	39 (22.5%)	<0.01
Taking other supplements	40 (13.6%)	14 (11.6%)	26 (15.0%)	0.40
Diet:				
Improving diet	190 (64.6%)	77 (63.6%)	113 (65.3%)	0.77
Physical activity:				
Increasing exercise	176 (59.9%)	67 (55.4%)	109 (63.0%)	0.19
Psychosocial:				
Improving sleeping patterns/decreasing stress	78 (26.5%)	27 (22.3%)	51 (29.5%)	0.17
Healthcare:				
Seeking medical/health advice	119 (40.5%)	57 (47.1%)	62 (35.8%)	0.05
Other:				
Trying to stop/decrease smoking	18 (6.1%)	7 (5.8%)	11 (6.4%)	0.84
Trying to stop/decrease drinking alcohol	74 (25.2%)	43 (35.5%)	31 (17.9%)	<0.01
Not doing any of the above	26 (8.8%)	5 (4.1%)	21 (12.1%)	0.02
Smoking status	*n = 252*	*n = 110*	*n = 142*	
Yes, current smoker	17 (6.6%)	8 (7.3%)	9 (6.3%)	
Never smoked/quit smoking	235 (91.8%)	100 (90.9%)	131 (92.3%)	0.92
Prefer not to answer	4 (1.6%)	2 (1.8%)	2 (1.4%)	
Consumed alcohol in previous 3 months	*n = 225*	*n = 95*	*n = 130*	
Yes	192 (85.3%)	81 (85.3%)	111 (85.4%)	0.98
Excessive drinking	*n = 227*	*n = 96*	*n = 131*	
One or more times	134 (59.0%)	54 (56.3%)	80 (61.1%)	
Nil	41 (18.1%)	14 (14.6%)	27 (20.6%)	<0.01 **
Unsure	26 (11.5%)	9 (9.4%)	17 (13.0%)	
Stopped drinking for pregnancy	26 (11.5%)	19 (19.8%) **	7 (5.3%) **	
Average alcoholic drinks per week in past 3 months. Median (IQR)	*n = 225*	*n = 92*	*n = 133*	
	3.0 (0.0, 6.0)	4.0 (1.0, 7.0)	3.0 (0.5, 5.5)	0.35
Recreational drug use	*n = 248*	*n = 108*	*n = 140*	
Yes, within 1 month	13 (5.2%)	5 (4.6%)	8 (4.3%)	
Yes, within 1 year	13 (5.2%)	7 (6.5%)	6 (4.3%)	
Yes, but not within 1 year	48 (19.4%)	21 (19.4%)	27 (19.3%)	0.95
Never	169 (68.1%)	73 (67.6%)	96 (68.6%)	
Prefer not to answer	5 (2.0%)	2 (1.9%)	3 (2.1%)	
Weighing habits	*n = 193*	*n = 88*	*n = 105*	
Regular	93 (48.2%)	47 (53.4%)	46 (43.8%)	0.18
Irregular	100 (51.8%)	41 (46.6%)	59 (56.2%)	
Weight gain in previous 12 months	*n = 193*	*n = 88*	*n = 105*	
Yes	105 (54.4%)	43 (48.9%)	62 (59.1%)	
No	74 (38.3%)	38 (43.2%)	36 (34.3%)	0.37
Unsure	14 (7.3%)	7 (8.0%)	7 (6.7%)	
Amount weight gain in previous 12 months	*n = 105*	*n = 43*	*n = 62*	
1–2 kg	32 (30.5%)	14 (32.6%)	18 (29.0%)	
3–5 kg	53 (50.5%)	20 (46.5%)	33 (53.2%)	0.79
6 kg or more	20 (19.0%)	9 (20.9%)	11 (17.7%)	
Weight related actions (trying to..)	*n = 254*	*n = 110*	*n = 144*	
Maintaining a healthy weight	116 (45.7%)	53 (48.2%)	63 (43.8%)	
Lose weight	125 (49.2%)	51 (46.4%)	74 (51.4%)	0.73
Neither of the above	13 (5.1%)	6 (5.5%)	7 (4.9%)	

* Participants who selected one or more of the following options: (currently) taking folic acid/folate/Blackmores I-Folic/iodine/multivitamin for pre-pregnancy or (currently) taking other action (and listed pregnancy/pre-pregnancy multivitamin or similar). ** Significant difference (*p* = 0.001) identified here after Bonferroni correction. Total n for each variable may vary based on the total number of responses.

4. Discussion

We report that less than half of women planning a pregnancy had sought medical or health advice in preparation for pregnancy, and, of those that did, missed opportunities for important components of PCC existed. While uptake of cervical screening and up-to-date immunisation was relatively high, there was no difference between groups, with one in five active planners indicating they have never completed cervical screening and similar or greater proportions not immunised adequately for pregnancy. The intention to cease modifiable high-risk behaviours such as cigarette smoking and alcohol consumption was greater in those actively planning, yet the incidence and frequency of associated behaviours did not vary from those not actively planning a pregnancy. We also report increased weight gain in our cohort, emphasising the burden of accelerated progression to obesity in young, reproductive-aged women. Overall, despite some favourable areas of preconception health and pregnancy planning, including supplementation use, our results highlight several areas of preconception health warranting improved awareness, support and resources for women planning a pregnancy.

Our results show that less than half of women planning a pregnancy had sought health or medical advice as part of their pregnancy planning behaviour. This could be reflective of previous research demonstrating that women in preconception do not view themselves as a distinct group in need of healthcare [30,31]. It is plausible that women may plan for pregnancy individually, only engaging with their primary healthcare provider if difficulty in conceiving occurs [32]. The vast majority of active planners reported efforts to improve diet and increase exercise and had commenced preconception supplementation in line with national recommendations and consistent with previous Australian studies [19,33,34]. Our results indicate increased confidence in adopting self-managed behaviours and potentially lower awareness of aspects of PCC warranting health professional engagement [32,35], including cervical screening, immunisation and genetic testing, emphasising the need for targeted preconception health promotion in these areas in women planning a pregnancy.

Here, we found that approximately 1 in 5 eligible women had not commenced cervical screening. Interestingly, ~40.0% of these had sought medical/health advice to prepare for pregnancy, presenting a missed opportunity to initiate screening. Barriers for cervical screening are most commonly related to embarrassment, not acting on an intention to be screened, fear of pain and fear of results [36]. It is possible that women who had reported seeking advice and had not previously had a cervical screening test were provided with information but did not ultimately complete screening. Here, we found those that had not commenced screening were more likely to reside in areas of higher-level disadvantage compared with those who had performed screening. Given that engagement with a healthcare provider did not vary by screening status, this is likely not reflective of reduced access to healthcare or resources, with other contributory factors not captured by our survey potentially explaining results found. Similarly, 1 in 5 women or above were not adequately immunised for pregnancy and 50.0% of those with a known family history of a genetic condition had not been screened. We also report that approximately 30.0% of our cohort had undertaken an STI test within six months, in line with previous research [37]. Given uptake of all of screening types was similar in both groups, there is opportunity to improve these preventive health measures in primary care settings in all women preconception, irrespective of pregnancy planning. Barriers to PCC reported by GPs include lack of awareness of pregnancy intention and lack of presentation during preconception [38], mirroring results found here. Taken together, results concur with previous research highlighting the need to develop strategies that both encourage women into self-directed partnerships with their primary healthcare provider whilst also addressing barriers health providers experience for enhanced health communication overall [23].

Our findings indicate that women planning a pregnancy are not adhering to recommendations advising abstinence of alcohol during preconception [8], with just 11.5% reporting that they had stopped drinking, comparable to previous findings [39]. We found average weekly alcohol intake was comparable irrespective of planning status, potentially indicating complacency and/or ambivalence

towards drinking in women actively planning for pregnancy. This could be due to the influence of individual and social factors as well as the normalisation of alcohol intake in women presenting as facilitators [18]. This highlights the need for strategies that encourage cessation of alcohol consumption when actively attempting to conceive given the discrepancy between intention and behaviour reported here. This could include leveraging off recent legislative changes on the introduction of warning labels on alcoholic beverages in Australia [40] and elsewhere [41].

Achieving and maintaining a healthy weight is highlighted as crucial in international evidence-based guidelines for preconception, pregnancy and post-pregnancy health [9]. Here, we report that ~55.0% of our cohort reported weight gain in the last 12 months, with 69.5% of these reporting an increase of three or more kilograms within the previous year. Even modest weight gain increases cardiovascular and chronic disease risk [42], whilst simultaneously contributing to obesity risk and conversion to higher BMI categories. Further, pregnancy is a recognised high-risk window for excessive gestational weight gain and postpartum weight retention [43,44]. This reaffirms the critical need for early intervention, prior to pregnancy, for weight gain prevention and/or weight loss where required, given the associated pregnancy and future health risk for mother and child [45]. Overall, approximately half of all women were currently trying to lose weight, and, encouragingly, the majority of active planners reported they had improved their diet and exercise behaviours to prepare for pregnancy, potentially reflective of enhanced motivation to ensure optimised health in pregnancy, as previously reported [46].

Reproductive and fertility behaviours varied, potentially in line with women's pregnancy planning intentions. Women not actively planning a pregnancy were more likely to report hormonal and barrier contraceptive use, which is positive, both decreasing the likelihood of an unplanned pregnancy and enabling opportunities for PCC. Interestingly, one quarter of non-active planners reported using the withdrawal method regularly, potentially indicating complacency and/or lack of awareness, given this is recognised as one of the least effective forms of contraception with a ~20.0% failure rate [47,48]. Conversely, current or previous assisted fertility treatment was reported by a higher proportion of women actively planning for pregnancy compared to non-active planners. There was no difference in age in those who had engaged in fertility treatment compared with those who had not; however, there were higher proportions of overweight or obesity overall. One in six Australian couples experience fertility problems [49], in line with international estimates [50]. Most fertility treatment in Australia is provided in the private health system, and the high rate of fertility treatment reported by active planners in this study may reflect increased likelihood of commencing private health insurance to access treatment (as reported previously) as well as the overall higher socioeconomic status (SES) of participants [51]. Fertility treatment reported in non-active planners is likely reflective of previous treatment; however, this cannot be delineated from current use due to the survey structure. Similarly, we were unable to explore causes of infertility and associated treatment overall.

Strengths and Limitations

Our rigorously developed questionnaire assessed an extensive range of health and lifestyle behaviours in accordance with the majority of national PCC recommendations [21]. Our stratification by stage of pregnancy planning strengthens the understanding of PCC uptake by enabling differences in behaviour to be observed. While the cross-sectional design of our study can explore associations, we are unable to confirm causal relationships and inferential statistics were not possible.

Our cohort consisted of women who had private health insurance, which may limit the generalisability of our results to other populations owing to an overall higher socio-demographic profile. The private health system uniquely provides an opportunity to explore preconception behaviours before conception due to waiting periods, of typically 12-months, before hospital-based healthcare claims can be made. Whilst this study group are of a higher SES, ~50.0% of Australian women of reproductive age have private health insurance and 26.0% birth in private hospitals [13]; hence,

our results are relevant to a significant proportion of Australian women, further emphasized by comparability with Australian population census data.

5. Conclusions

Our results demonstrate significant divergence from PCC recommendations in women planning for pregnancy, with several areas of preconception health that warrant improved health promotion. While women appear to be more receptive to self-managed aspects of preconception health, including supplementation, weight management and intention to cease higher-risk behaviours including alcohol intake, we found minimal variation in behaviour compared with women not actively planning a pregnancy. Given the potential for evidence-based PCC to optimise fertility and reduce adverse maternal and child outcomes, efforts are required to improve PCC knowledge, awareness and uptake through strengthened partnerships between women and their healthcare providers. Future research would benefit from extension into other populations as well as prospective studies examining causal associations between preconception health behaviours and associated outcomes during pregnancy.

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Chapter 2. Perinatal women's digital information and support seeking during COVID-19

2.1   Introduction

The coronavirus disease 2019 (COVID-19) caused by the novel Coronavirus strain SARS-CoV-2 was declared a public health emergency of international concern by the World Health Organization (WHO) in January 2020. At the time of this manuscript, the virus had contributed to the deaths of close to one million people (59) and posed a global mental health threat. Significant individual-and-population-level public health measures were implemented in Australia to limit the spread of the virus. These policies profoundly disrupted all aspects of people's daily lives, including healthcare interaction, with a subsequent cascading effect on behaviour and wellbeing. There was little evidence available at the time to inform the impact of these measures on women who were in the perinatal period defined as those trying to conceive, pregnant or post-birth.

Here I aimed to explore the impact of the virus on women's pregnancy and parenting experiences, and to understand their unmet needs that may be addressed through public health measures and communications. Unmediated conversations about COVID-19 by women on Australia's most popular online pregnancy and birth forum were used to gain insights into key areas of concern and health seeking needs and behaviours. A thematic analysis approach was used, additionally including a word frequency analysis and a sentiment analysis; which aggregated and foregrounded the concerns of women and their perception of the virus and its impact on themselves, and their current, or future families.

My role in this project was to conceptualise the design of the study in tandem with my supervisors. I collected and synthesised data, undertook the analysis and interpreted the results. The sentiment analysis is a novel methodology that had not been used by the research team prior to this project. I was responsible for exploring its application and interpreting the results. This analysis provided insight into area of inquiry, expressed within the data, by computational identification and categorisation of terms and phrases, which in turn, was used to support the findings of our thematic analysis.

Findings revealed significant concerns and uncertainty within the perinatal population across areas such as fear and apprehension about public health safety, concern about entering public health facilities, access to medical care in the pre and post birth life-phases. The results indicated that to remedy these pervasive concerns, direct, targeted communication to pregnant women and new mothers was warranted. In addition, these findings were critical and timely to inform the content design of the OptimalMe platform.

This project was the first of its kind to provide in-depth, unmediated insights into the impact of the COVID-19 virus on a perinatal population. The findings have been frequently cited and amplified within the media and circulated to relevant authorities to highlight the importance of targeted communications and public health measures on this population of women. See Appendix 2 for media and supporting translation work (infographic).

2.2   Perinatal distress during COVID-19

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Perinatal Distress During COVID-19: Thematic Analysis of an Online Parenting Forum

Original Paper

Perinatal Distress During COVID-19: Thematic Analysis of an Online Parenting Forum

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Abstract

Background: The COVID-19 global pandemic has impacted the whole of society, requiring rapid implementation of individual-, population-, and system-level public health responses to contain and reduce the spread of infection. Women in the perinatal period (pregnant, birthing, and postpartum) have unique and timely needs for directives on health, safety, and risk aversion during periods of isolation and physical distancing for themselves, their child or children, and other family members. In addition, they are a vulnerable group at increased risk of psychological distress that may be exacerbated in the context of social support deprivation and a high-risk external environment.

Objective: The aim of this study is to examine the public discourse of a perinatal cohort to understand unmet health information and support needs, and the impacts on mothering identity and social dynamics in the context of COVID-19.

Methods: A leading Australian online support forum for women pre- through to postbirth was used to interrogate all posts related to COVID-19 from January 27 to May 12, 2020, inclusive. Key search terms included "COVID," "corona," and "pandemic." A three-phase analysis was conducted, including thematic analysis, sentiment analysis, and word frequency calculations.

Results: The search yielded 960 posts, of which 831 were included in our analysis. The qualitative thematic analysis demonstrated reasonable understanding, interpretation, and application of relevant restrictions in place, with five emerging themes identified. These were (1) heightened distress related to a high-risk external environment; (2) despair and anticipatory grief due to deprivation of social and family support, and bonding rituals; (3) altered family and support relationships; (4) guilt-tampered happiness; and (5) family future postponed. Sentiment analysis revealed that the content was predominantly negative (very negative: n=537 and moderately negative: n=443 compared to very positive: n=236 and moderately positive: n=340). Negative words were frequently used in the 831 posts with associated derivatives including "worried" (n=165, 19.9%), "risk" (n=143, 17.2%), "anxiety" (n=98, 11.8%), "concerns" (n=74, 8.8%), and "stress" (n=69, 8.3%).

Conclusions: Women in the perinatal period are uniquely impacted by the current pandemic. General information on COVID-19 safe behaviors did not meet the particular needs of this cohort. The lack of nuanced and timely information may exacerbate the risk of psychological and psychosocial distress in this vulnerable, high-risk group. State and federal public health departments need to provide a central repository of information that is targeted, consistent, accessible, timely, and reassuring. Compensatory social and emotional support should be considered, using alternative measures to mitigate the risk of mental health disorders in this cohort.

Introduction

COVID-19, a novel strain of coronavirus, is an acute, highly infectious virus that has affected tens of millions of people and has caused close to 1 million deaths as of August 2020 [1]. The disease is spread directly through respiratory droplets from the mouth or nose. It is estimated that up to 40% of transmission is presymptomatic, with an average incubation period of 5-6 days [2]. The vast majority of those who are infected with COVID-19 experience mild to moderate illness arising from a cluster of mild symptoms including fever, dry cough, and lethargy [3]. Currently, there is no effective COVID-19 medical prophylaxis and limited treatment, mandating a rigorous individual-, population-, and system-level public health policy and behavioral change response to minimize transmission [4].

COVID-19 originated in Wuhan, China, with the first cases reported in December 2019 [5], and was officially declared as a public health emergency of international concern on January 30, 2020, by the World Health Organization. The first Australian confirmed case of COVID-19 was on January 25, 2020, in Victoria, originating from Wuhan, China, subsequently resulting in the closing of Australian borders to all nonresidents in March [6]. Physical distancing rules were imposed on March 21, 2020, with the associated closure of all *nonessential* services including retail outlets, cafés, restaurants, schools, recreational facilities, and playgrounds [7]. To assist in physical distancing, additional measures including working, studying, or completing school from home were imposed; social gatherings were banned, and stringent restrictions on individual movement were put in place [7]. These public health policies profoundly impacted individual- and population-level health, disrupted normal social interactions, and contributed to economic insecurity.

As COVID-19 continues to disrupt human interactions, published data on the risk, transmission, and health outcomes of specific populations, including women in the perinatal period and their neonate, are evolving, yet are currently inconclusive [8-10]. Women within the perinatal period are a vulnerable population, both physiologically, with changes during pregnancy that reduce immunity [11], and psychologically, with increased risk of psychological distress including stress, anxiety, and depression [12-15], all of which may increase maternal and neonatal morbidity [16]. Consequently, it is recognized that women during this period require unique and specific health, support, and information needs to avoid stress [17]. Currently, the impact of COVID-19 on such needs and associated levels of distress is poorly understood, yet is critical in ascertaining adverse implications, as well as in identifying strategies to protect and optimize women's psychosocial health during this time. Therefore, this study aims to understand the sentiment and impacts to emotional well-being as well as the unmet information and support needs arising from changes to social dynamics and support in a perinatal cohort during the COVID-19 pandemic.

Methods

Overview

We conducted an observational, qualitative analysis of online discussions within a leading Australian forum for new or expecting parents. The most popular Australian pre- and postbirth forum was identified by searching the term "new mum forum" in Google. The top 10 (first page) results were assessed, and all websites with publicly available forums (n=7) were analyzed using a website analytics tool (Alexa, Amazon.com). This software was used to determine the global page views, global rank, and Australian rank of the 7 websites with publicly available forums. The highest ranked website for Australian users was identified and used as the sampling platform for this study. To confirm this website's suitability for this study, member requirements were assessed to ensure forum users were new or expecting mothers.

Within the selected forum, the search function was used to identify user-generated content relating to COVID-19. No date restrictions were applied in the search with posts collected on May 12, 2020. We searched for website content using key search terms including "COVID," "corona," or "pandemic." The search identified articles, comments, and posts, which was then narrowed to posts. All posts were extracted in a deidentified format into a Word (Microsoft Corporation) document, which included the post title, date, and content. The inclusion criteria were posts related to COVID-19 up until May 12, 2020 (inclusive). The exclusion criteria were posts that included a title only (content had been deleted), that did not relate to COVID-19, and that were duplicate posts (original post was collected once).

Analysis

Data was processed using NVivo Pro 12 (QSR International) software [18]. Analysis comprised three phases, including thematic analysis, sentiment analysis, and word frequency calculations of stemmed words. Thematic analysis was undertaken using a modified grounded theory approach that was informed by Braun and Clarke's [19] six phase approach. A single researcher (BC) became familiar with the data, generated initial codes, and searched for themes. The team then collaborated to discuss themes and a >25% check of themes was conducted by two additional researchers (CH and RG). To support the themes identified, NVivo Pro 12 automatic sentiment analysis and a text frequency search were run to identify emotional indicators. NVivo searched for expressions of sentiment in the source material then used predefined scores for words classified as containing sentiment [20]. Words are considered in isolation, and the program then determines the sentiment of the paragraph as a calculation of each word containing the sentiment. Sentiment results include the number of references (paragraphs with sentiment) that are categorized as very positive (VP), moderately positive (MP), moderately negative (MN), and very negative (VN). A single researcher

(BC) conducted a >10% cross-check of the sentiment results. Word frequency calculations were used to identify all stemmed words (minimum 3 letters) used 50 times or more. These words were screened by a single researcher (BC) to identify negative words. The frequency of key terms used was divided by the number of total posts to derive an overall percentage, and a weighted percentage on the total word count was calculated by NVivo Pro 12.

Ethics

Ethics approval for this study was granted by the Monash Health (RES-19-0000-291A) and Monash University (Project no 20196) Human Research Ethics Committees. Although ethical oversight of publicly available data is not strictly required, the authors sought approval as per Monash University protocol.

Results

Overview

A total of 960 posts were identified using the search terms ("corona" n=589, "COVID" n=257, and "pandemic" n=114). As per the exclusion criteria, 114 posts were excluded, resulting in a final sample of 831 unique posts. The first relevant post identified was dated January 27, 2020.

Thematic Analysis

We identified five themes from the analyzed content: (1) heightened distress related to a high-risk external environment; (2) despair and anticipatory grief due to deprivation of social and family support, and bonding rituals; (3) altered family and support relationships; (4) guilt-tampered happiness; and (5) family future postponed.

Theme 1: Heighted Distress Related to a High-Risk External Environment

Women expressed concerns and unease due to a range of factors such as the lack of access to particular information on risk (eg, risk during pregnancy, risk to baby in utero, risk to a new born baby, risk from the hospital environment, risk to mental health from reduced social supports). They asked questions within the discussion forum, such as should pregnant women cease working, what is the risk of COVID-19 to unborn or newly born babies, should working partners isolate from their pregnant spouse or from new babies, are pregnant women at increased risk, or should I be leaving the house? Many women were unable to locate information to fully answer these concerns and sought confirmation of both their concerns and their risk reduction actions from their peers within the forum.

Women who stated they were close to giving birth demonstrated significant levels of worry in relation to the safety of antenatal appointments and the hospital environment. Some indicated they were considering a home birth, and others stated they were considering not attending antenatal visits due to fear of contracting COVID-19.

> I am due to get my NT scan done...I am getting nervous about having to travel there from a small rural town to have it done. I am considering whether I should get it done or not worry.

One woman stated that, although she did not want to be "alarmist" the lack of information on hospital safety made her feel "vulnerable." Others stated that "being pregnant during this time is so scary...it's certainly not how I envisioned it to be going or to end," and another woman said, "I almost don't want to give birth right now."

Women said they found it difficult to disengage with the constant worry and concern about COVID-19 with one woman stating that

> ...all I'm thinking and dreaming about is COVID-19! I'm super paranoid, I feel like even getting groceries, I have anxiety.

Many women said they had disengaged with mainstream news sources as they found these to be fear inducing. Posts reflected heightened levels of worry and stress in this cohort. One woman stated, "I feel the most anxious, overwhelmed, isolated, out of control as I've ever felt before."

Theme 2: Despair and Anticipatory Grief due to Deprivation of Social and Family Support, and Bonding Rituals

Due to the unforeseen restrictions from the pandemic, usual perinatal social rituals such as baby showers, celebrations, or gender reveals were not possible. In addition, areas where women heavily rely on social support, such as multiple support persons during birth and postbirth, and family or social support providing physical, psychological, and social care, were denied to this group of women. When one woman was told she was not allowed to have her partner with her during a routine scan she said, "I am really sad as it's our first pregnancy and these scans are small ways where our husbands can take part in our pregnancy." Many expressed a range of feelings such as sadness, anger, and a sense of loss. One woman stated "the happiest time in our lives is being over shadowed by this virus." Another said "I've played many times over, my siblings and parents coming to hospital to meet my first child and that was a once in a life time moment for me; something I think very special that I won't get anymore." Upon reading about the COVID-19–related grief, one woman said:

> totally made me realise that I'm grieving the loss of a normal pregnancy...I checked out the five stages of grief, and I'm definitely going through the emotions they list! Anger and bargaining - hopefully I'll move on to true acceptance soon.

Theme 3: Altered Family and Support Relationships

Customary ways of strengthening relationships with family and social networks during pregnancy and early motherhood were denied to this group of women due to the demands of isolation. Many of the women discussed conflicts with family members over interpretations of physical distancing rules. This conflict was expressed by one woman as:

> I don't understand how they whinge that they can't see their grandson yet continue to do all the things THAT ARE THE REASON we don't want our son around them...Has anyone else had to deal with family not taking this virus seriously?

The impact of COVID-19 isolating new mothers from their support and family networks, and the unique need to protect the health of grandparents reduced social support for new mothers and resulted, in some cases, in unanticipated interfamily conflict. This had the effect of dividing some families rather than the bonding experiences that many may have anticipated.

Theme 4: Guilt-Tampered Happiness

Many women expressed feelings of guilt due to the contrast between the positivity and happiness they were experiencing at the news of their pregnancy or arrival of their child, and the difficult situation of many others in the community.

> I feel a bit guilty about wanting to share my good news. I...have been looking forward to sharing about our baby especially after I was told I would not be able to have kids at all.

Other women identified guilt relating to their wishes to experience baby showers or events that their peers have formerly enjoyed:

> this might sound a little selfish but it's our first and I was looking forward to the gifts and games etc. I hope by August maybe we can have a small gathering.

Although another woman stated she was feeling guilty for thinking about her pregnancy plans. "I hope everyone is coping with the current covid crisis - I feel a bit guilty thinking about IVF."

Theme 5: Family Future Postponed

Many women discussed their concerns about family planning and of wanting to postpone plans to extend their family. "I've heard so much information (and misinformation) the last few weeks it's really made me fearful about trying to conceive with all the madness around." Another posed the questions:

> [is anyone] temporarily pausing trying to conceive whilst our world is being rattled by corona? Has it changed your timeline in terms of when you want baby to born? Have you decided to wait or maybe not even have anymore?

Sentiment and Word Frequency Analysis

There were 1556 references of sentiment. Of these, most were found to be within the negative range, with 980 (63.0%) references classified as negative (VN: n=537 and MN: n=443) compared with 576 positive references (VP: n=236 and MP: n=340). A cross-check of sentiment results found that less than 10% of sentiment references were coded to incorrect categories.

A list of words used 50 times or more (n=189) was examined to screen for negative words. Multiple negative emotive stem words (n=7) were identified (Table 1). Percentages derived from the total number of posts provide an indication of the spread of these words within the data set.

Table 1. Word frequency in total posts (N=831).[a]

Word	Similar word	Frequency, n (%)	Weighted percentage (%)
Worrying	Worried, worries, worry	165 (19.9)	0.32
Risk	Risking, risks	143 (17.0)	0.27
Anxiety	Anxieties, anxious, anxiousness	98 (11.7)	0.19
Concerns	Concern, concerned, concerning	74 (8.8)	0.14
Stress	Stressed, stressful, stressing	69 (8.2)	0.13
Struggling	Struggle, struggled	59 (7.0)	0.11
Scare	Scares, scared, scaring	55 (6.6)	0.11

[a]Percentage calculations were derived based on the word count in context of the total posts (identifying an approximate number of posts including these words; however, this cannot account for words used multiple times in one post) and as a weighted percentage of the total word count.

Discussion

Principal Results

The rapidly evolving COVID-19 pandemic is a global emergency, requiring unprecedented public health policy changes and behavioral adherence to limit viral spread. This vital public health response comes at significant health, societal, and economic cost, and is anticipated to have a profound effect on emotional well-being and mental health. During the perinatal period, women have specific health care and emotional needs, and are vulnerable to mental health challenges. Understanding the unique perinatal information needs and impact of losing support networks is, therefore, critical in informing public health and health care system's interventions for the well-being of women and their families.

Our results demonstrate a significant response to the pandemic within this cohort, with an average of 275 posts per month directly related to COVID-19 across the evaluation period. Thematic analysis captured five themes: heightened distress related to a high-risk external environment; despair and anticipatory grief due to deprivation of social and family support, and bonding rituals; altered family and support relationships; guilt-tampered happiness; and a family future postponed. Sentiment analysis showed heightened negativity with high frequency use of negative terms including "stress," "anxious," "worry," and "risk," with emergent qualitative themes identified related to anxiety, grief, guilt, social support, and disrupted family planning.

To enable rapid evaluation and dissemination of findings, we chose to examine a leading online Australian perinatal forum,

accessed broadly by reproductive-aged women across preconception, pregnancy, postpartum, and into early parenting and childhood. Online support groups have previously been shown to be commonly accessed by women during this period. They provide an accessible, peer-to-peer opportunity for information sharing, individualized information seeking, and social and emotional support from women in a comparable life stage [21,22]. Accessibility and anonymity provided by online forums facilitates a disinhibited expression of feelings without concern of consequences or conflict from close connections. Engagement with and preference for interacting with peers in an online forum may reduce engagement with other forms of media. Indeed, this is supported by our thematic analysis showing many women reporting disengagement with mainstream news sources, as they found these to be fear-provoking.

Anticipatory grief for loss of social and family affirming opportunities during the perinatal period was emphasized as a consequence of physical distancing measures in this cohort. Pregnancy and birth are often a celebratory period for women and are associated with joy experienced by both the parents and close family members. Traditional rituals and milestones including the early pregnancy growth and development scans, baby shower celebrations, and hospital visits by family and grandparents were all effectively denied in accordance with physical distancing and personal safety measures. Such milestones present significant opportunities for social support and likely play a role in strengthening family and partner relationships, in turn increasing well-being, self-efficacy, and coping during this time. Disruption or removal of these milestones is, therefore, likely to impact well-being, potentially increasing feelings of isolation and consequently driving conflict due to anger and frustration, exacerbating pre-existing negativity within the wider external environment.

Conversely, many women also expressed guilt as a result of feeling joy and happiness related to their pregnancy or impending birth. This *paradox of guilt* in the context of COVID-19 is reportedly similar to the phenomenon of survivor's guilt, an experience of immense guilt toward surviving a traumatic event that others in a given population did not [23]. Here, women felt happiness yet felt exclaiming such feelings were inappropriate in the context of widespread illness, grief, and loss at a population level. Although this may not be directly termed as survivor's guilt, a correlation is plausible. Women may also be disproportionately affected by feelings of guilt in this context, with research showing increased concern for the health of others including older family members and children, rather than the health and well-being of themselves [24].

Our results show an interruption in family planning as a consequence of COVID-19. This may be due to several factors including economic and employment insecurity or fear of direct health impacts. The sudden closure of many sectors has profoundly impacted the economy, contributing to the largest rise in unemployment rate since the depression, with women disproportionately impacted [25]. Hesitancy related to health outcomes during pregnancy may also impact family planning. Although women are generally more resistant to viral infections than men, physiological changes that occur during pregnancy increase vulnerability to severe infections due to a reduced immune response. A recent systemic review of the first 108 pregnant women infected with COVID-19 found a majority of case reports occurred in the last trimester with associated severe maternal morbidity [8]. This included a cesarean section rate of 91% across cases, predominantly due to fetal distress, with 1 intrauterine and 1 neonatal death recorded. Despite the majority of women recovering without major complication, the authors concluded that mother-to-baby transmission of COVID-19 remains unclear [8], with similar reports published elsewhere [9,10].

Our sentiment analysis revealed increased negativity during the evaluation period, reflected by ~60% of posts related to distress including anxiety, worry, and risk. These results are similar to recent research evaluating user sentiment on Twitter during the COVID-19 pandemic [26]. Following a brief analysis of daily tweets related to four key emotions, the authors concluded fear was most strongly represented, followed by anger; joy; and, lastly, sadness. Increased negativity on social media is likely to be indicative, in part, of the broader population's overall sentiment. Indeed, this is supported by recent population-based research by the UK Office of National Statistics, reporting a doubling in high levels of anxiety between October 2019 to April 2020, compared with an earlier reference period [27]. Notably, women appear disproportionately affected, with 24% higher frequency of anxiety than men overall. Authors postulated that increased anxiety in women may be related to financial impacts, including a reduced likelihood of employment due to child rearing and gender inequities in salary. Increased anxiety and depressive symptoms in women are also common during pregnancy [15], and recent preliminary research reported a two-fold increase during COVID-19 [28]. The impact of social isolation was reported as a significant predictor of increased depression on a regression analysis [28]. Pregnancy, birth, and the postpartum periods are life stages requiring increased levels of social support, and reduced support at this time has been shown to have detrimental impacts on maternal mental health outcomes [29]. Women in this cohort frequently reported having reduced access to social support networks such as partners (ie, essential workers or those requiring quarantine due to business-related travel), family members, significant others, social networks, mothering groups, and health care professionals. In turn, this may have increased engagement with the forum as a source of like-minded support and comfort.

The women using the discussion forum demonstrated reasonable understanding and knowledge of relevant public health restrictions. This is encouraging with respect to behavior changes in response to the COVID-19 pandemic, as it indicates successful public health communication to the general community. However, women in the perinatal period are highly motivated to seek nuanced information that reduces risk to the mother, unborn child, or new baby. This includes information relating to self-isolation and safety while pregnant, employment implications if unable to work from home, the risks of COVID-19 infection at health facilities during perinatal medical visits, restrictions on birthing supports, and isolation from working partners. Women indicated information was sought from multiple sources but indicated, however, that it did not

meet their current needs and was either general in nature, ambiguous, or inconsistent. It is critical that the information needs of this cohort are understood and met to reduce the risk of mental health disorders in an already high-risk group and to reduce the risk of avoidance of health care monitoring. This is particularly imperative during pregnancy with some women indicating they would postpone or avoid antenatal visits, which may lead to negative health outcomes for both mother and baby. State and federal public health departments need to provide a central repository of information for this cohort that is accessible, timely, and reassuring. It is also important to understand that women are using discussion forums as their primary source of information in lieu of official sources.

Limitations

The following limitations should be considered when interpreting these findings. Anonymized data was interrogated and, therefore, demographical and geographical information about the user could not be obtained that may influence the user's engagement with the forum, as well as their perception and reaction to the COVID-19 pandemic. However, in accessing real-world nonidentified data, information is less likely to be influenced by social desirability or recall bias. We cannot confirm all posts were written by women in the perinatal period, however, forum users must enter an expected due date, child's birth date, or declare that they are trying to conceive to become a member of the forum.

Additionally, the real-world implications of users' online posts are unclear, and detrimental effects may be overemphasized in the absence of sufficient data pertaining to real-world behavior and state of mind. Due to early inconsistency in pandemic-related terminology, users may have used other keywords to describe COVID-19 that were not collected in this study. Finally, due to site management and restrictions relating to the seeking or provision of medical advice via the forum, posts may have been deleted before data was collected. In addition, the limitations of the software used in the sentiment analysis must be acknowledged, such as the inability to recognize sarcasm, double negatives, slang, dialect variations, idioms, and ambiguity. However, to address this limitation, we cross-checked the results and determined less than 10% were incorrectly classified. We believe this to be one of the first evaluations of the social impacts of COVID-19 in mothers or pregnant women in Australia [24,30-33]. This paper provides critical insights into the unanticipated impacts of this pandemic on a high need's perinatal cohort.

Conclusion

The perinatal period involves a major life transition requiring increased levels of social, emotional, and health professional support. Our results demonstrate pregnant women and new mothers are uniquely impacted by the COVID-19 pandemic. General information on COVID-19 safe behaviors does not appear to meet the needs of this population. The lack of nuanced and timely information appears to have exacerbated the risk of psychological and psychosocial distress in this vulnerable group who demonstrate heightened distress, reduced social and emotional support, anticipatory grief, increasing interfamily conflicts, and direct impacts on family planning behaviors. These findings suggest the need for targeted, consistent, accessible, and timely information on risk and risk aversion strategies, and adoption of strategies to de-escalate anxiety and concern. It also suggests that support strategies are needed to compensate for the loss of family, social support, and health professional contact, and lastly, that mental health interventions tailored to the unique needs of this cohort are likely important during the pandemic and for related public health policies.

Conflicts of Interest

None declared.

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Abbreviations

MN: moderately negative
MP: moderately positive
VN: very negative
VP: very positive

XSL•FO
RenderX

Chapter 3. Digital support seeking during the postpartum period

3.1   Introduction

As women transition into the role of early parenthood, they undergo significant physical, social and psychological changes which can present challenges and increased support needs (39, 60). While this topic has been extensively researched and close attention is paid to women's postpartum psychological wellbeing in Australia, unmediated insight into their concerns, support needs and priorities had not been previously extensively explored. Digital forums are a popular communication network for new mothers (40), and provide a helpful and pragmatic database to explore women's conversations with their peers. Analysis of online forum conversations has been used to explore the needs of women during pregnancy (61), but our study examining a post-birth population was the first of its kind. The post-birth period is a challenging time as the physical demands of parenting a newborn baby may place the mother under considerable stress. Women have particular support needs that may not be raised or noticed in clinical or health care settings, and therefore concerns and distress may not be identified and addressed.

In this project we aimed to explore the unmediated conversations of women during the first year of motherhood using Australia's leading birth and parenting forum. Internet discussion forums provide a unique platform through which peer-to-peer information sharing gives women access to first-hand accounts of others with similar experiences. Birth clubs, which are associated with women's due date or delivery date were used to collect data from women within one year of childbirth. We endeavoured to explore the topics of conversation to determine if there were themes of significant interest or concern to new mothers. Within a research setting, such as semi-structured interviews or focus groups, women may be susceptible to recall bias (55), particularly regarding concerns and priorities from earlier postpartum periods. Furthermore, research suggests that some women do not discuss self-sourced pregnancy related information with health care providers (36), which may extend into research centred approaches during postpartum. The outcomes of this analysis were quantitative (word frequencies and sentiment analysis) and qualitative (thematic analysis of post content).

My role in this project was to conceptualise the design of the study, alongside my supervisors. I collected and synthesised data, completed the analysis and interpreted the results. Here we used the novel sentiment analysis, which I implemented and interpreted. This analysis allowed insight into the overall attitude expressed within the forum posts, by computational identification and categorisation of terms and phrases. The sentiment analysis was used to support the findings of our thematic analysis.

The analyses found that infant care was the most prominent overarching topic discussed, with feeding and sleep being the primary subtopics. Discussions about maternal care were much less frequent, demonstrating a focus on infant needs over personal, maternal concerns. This is an important finding, providing insight into the well-established concept of reduced engagement and compliance in maternal postpartum healthy lifestyle interventions (64). Our findings regarding a central focus on infant needs and the paucity of effective strategies to engage women in optimising postpartum health and lifestyle behaviours emphasise a need for novel approaches to enhance maternal health following pregnancy. Such approaches could deliver maternal healthy lifestyle strategies alongside infant care or incorporate holistic lifestyle interventions including infants to improve feasibility and engagement for new mothers. A secondary finding was a pattern of behaviour that resembled a cycle of learning across five phases: help seeking, solution ideation, testing and skill development, consolidation, and empowerment and improved mental well-being. The majority of posts belonged to the earlier phases of the learning cycle, indicating that women were potentially more likely to use the forum to seek help and reassurance, rather than to share positive experiences. This suggests that, for those engaged with the forum, it is a significant source of support seeking during early motherhood. The findings of this project were utilised in the development of the post-birth program of OptimalMe, in the coaching guide and correspondence sent to women nearing the end of the program and their pregnancy. The results demonstrated a need to communicate the importance of prioritising one's own health during the postpartum period, and to encourage women to utilise the goal setting component of the program to set some goals to focus on their wellbeing.

3.2   Support seeking in the postpartum period

Chivers BR, Garad RM, Moran LJ, Lim S, Harrison CL

Support Seeking in the Postpartum Period: Content Analysis of Posts in Web-Based Parenting Discussion Groups

Original Paper

Support Seeking in the Postpartum Period: Content Analysis of Posts in Web-Based Parenting Discussion Groups

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Abstract

Background: The transition from pregnancy to motherhood is a major developmental phase that can be challenging for both women and their families. For new mothers, the postpartum period is recognized as a critical period for increased risk of both physical and mental health concerns. For this reason, it is imperative that women receive accurate, evidence-based information during this time.

Objective: This study aims to explore the conversations of new mothers on a web-based parenting forum to investigate what topics or concerns are being discussed.

Methods: A leading Australian web-based support forum for women before and after birth was used to obtain a sample of posts from the mothers of infants aged 0-12 months. Quantitative data (word frequencies and sentiment analysis) and qualitative data (post content) were extracted from discussion threads and examined to determine sentiments and theoretical storylines.

Results: In total, 260 posts were sampled. Infant care was the most prominent overarching topic discussed, with feeding and sleep being the most discussed subtopics. Discussions about maternal care were much less frequent but included questions about birth recovery, breastfeeding concerns, and interconception. A pattern of behavior emerged within the posts. This pattern resembled a cycle of learning across five phases: help seeking, solution ideation, testing and skill development, consolidation, and empowerment and improved mental well-being. A dynamic interplay was observed as mothers navigated new concerns or developmental changes.

Conclusions: Engagement in web-based forums to seek help and support during the postpartum period was common, with infant health and well-being being the primary concerns for new mothers during this time. The identification of a maternal learning cycle within the forum underscores the contributory role of web-based communities in maternal peer social support, information seeking, and early parenting practices.

Introduction

The transition from pregnancy to motherhood is a major developmental phase that is recognized as a challenging time for both women and their families [1]. Early parenting and infant care are often prioritized over the health of the mother, presenting as significant barriers to self-care in the early postpartum period [2-4]. These barriers inhibit efforts to maintain or improve overall health, mental health, and healthy lifestyle behaviors [2-4], such as adequate diet quality and

regular physical activity [5]. For these reasons, the postpartum period is recognized as a critical period for an increased risk of adverse health. Weight retention after pregnancy is common [6,7] and is associated with excessive gestational weight gain [8], which is a strong predictor for the development of future obesity and chronic diseases [7]. Furthermore, mental health disorders, including anxiety and depression, affect up to 20% of women following pregnancy [9,10]. Postpartum anxiety and/or depression can exert significant effects on the health and well-being of mothers, their partners, and other children and can exert a negative impact on infant development [11]. Therefore, given the vulnerability to adverse physical and mental health, new mothers are a unique population with specific health needs that require increased support as well as accurate and trustworthy health information and care.

During the postpartum period, almost three-quarters (73%) of Australian parents with children aged less than 5 years use websites, blogs, and web-based forums to obtain information about infant or child health and parenting [12-14], with similar findings reported internationally [15]. Australian households have a considerably high internet use, with 97% of households with children having internet access [16]. Previous research evaluating the drivers of internet use during this time reported convenience, anonymity, and social and peer support as facilitating factors [13,17,18]. Web-based parenting forums are a common platform in which women can connect with peers for emotional support; alleviate feelings of isolation; and facilitate the discussion of sensitive topics that are otherwise difficult to address with friends, family, or health care providers in face-to-face encounters [18]. Yet, although reasons for engagement are clear [1,12,13,18], there is limited evidence showing what information and support women seek during the postpartum period and how they interact within such forums. An improved understanding of the information and support needs of women during this significant life phase is crucial to ensure that health and information needs of the mothers are met.

To address this research gap, this paper examines the unmediated user-generated content from web-based forum discussions of women in the postpartum period to identify early parenting information and emotional support–seeking behaviors.

Methods

Overview

An observational analysis of web-based discussions was conducted within a leading Australian internet discussion forum for new or expecting parents. The most popular Australian pre- and postbirth forum was identified by searching the term *new mum forum* on Google. The top 10 (first page) results were assessed, and all the websites with publicly available forums (n=7) were analyzed using a website analytics tool (Alexa, Amazon). This software was used to determine the global page views, global rank, and Australian rank of the seven websites with publicly available forums. The highest ranked website for Australian users was identified and used as the sampling platform for this study. To confirm the suitability of this website for this study, member requirements were assessed to ensure that forum users were new or expecting mothers. The second

highest ranked site did not have an open access forum, and those ranked 3-10 had a significantly lower rank than the first and second highest ranked sites. Therefore, the first site was retained, with the remainder deemed insufficient for sampling. This approach is comparable with previous research that used discussion forums [19,20].

The selected forum allows members to interact with their *birth club*, which corresponds to their child's due date (month and year). Birth clubs are a subforum of the wider forum community, and they are nonspecific in the nature of discussion topics. In total, 13 birth clubs (January 2019 to January 2020) were selected as the sampling platform to represent 1 calendar year and therefore one cross-section of the postpartum period across this time (ie, <1 month to 12 months postpartum).

Included posts were sampled by selecting the first 20 posts or threads from each birth club at the time of collection. Posts were collected between January 6, 2020, and January 13, 2020. The exclusion criteria included posts that enquired about or discussed an elder sibling (not the infant aged 0-12 months), other people's child or children, extended family such as grandparents or in-laws, or products or shopping (unless the post also discussed infant care such as feeding product advice). Posts in the January 2020 birth club were excluded if the forum user indicated that they had not yet given birth. Posts were collected sequentially, as they appeared on the day of sampling, and if a post met the exclusion criteria, the following post was selected until 20 posts were obtained. Posts were extracted in a deidentified format into an Excel (Microsoft) document that included the post title, date, and content, comparable with previous research [19,20].

Analysis

Data were processed using NVivo Pro 12 software (QSR International) [21]. A modified grounded theory analysis was conducted, which was informed by the six-phase approach by Braun and Clarke [22]. Due to the understudied nature of parenting forums, a grounded theory approach is well suited to add depth and breadth to this investigation [23]. A single researcher (BRC) generated initial codes and then grouped them into core categories. Three authors agreed on initial and intermediate codes and conducted a narrative overview of the discussions (BRC, RMG, and CLH). A >10% (26/260) check was conducted after initial coding and during theme conceptualization by 2 additional researchers (RMG and CLH). As the themes were conceptualized, the research team developed a theoretical storyline, which could be observed beyond *what* was being discussed.

To support these findings, NVivo Pro 12 text frequency search was used to identify the common terms, thereby identifying prominent conversation topics. Word frequency calculations identified all stemmed words (minimum three letters). NVivo Pro 12 automatic sentiment analysis was performed to identify the emotional indicators. NVivo searched for the expressions of sentiment in the source material (forum posts) and used predefined scores for words classified as containing sentiment [24]. Words are considered in isolation, and the program then determines the sentiment of the paragraph as a calculation of each word containing the sentiment. Sentiment results include the number of references (paragraphs with sentiment) that are

categorized as very positive, moderately positive, moderately negative, and very negative [24].

Ethics

The Monash Health (RES-19-0000-291A) and Monash University (project no. 20196) Human Research Ethics Committees granted ethics approval for this study. Although the ethical oversight of publicly available data is not strictly required, the authors sought approval as per the Monash University protocol.

Results

Overview

In total, 260 posts were extracted and analyzed. The 13 birth clubs had an average of 3013 members in each club (n=39,163 forum members overall).

Analysis of User-Generated Content

The analysis of posts through open coding identified 432 references at the intermediate coding stage. Various posts discussed multiple topics; therefore, the number of topic references exceeded the number of posts. Infant-focused references were the most frequent (237/432, 54.8%), with 12.5% (54/432) of references relating to sleep and naps. References to infant health (46/432, 10.6%) and feeding were frequent (68/432, 15.7%), and 7.6% (33/432) of references were related to breastfeeding. Forum use to seek help, support, advice, or reassurance was frequent (71/432, 16.4%). Discussion topics relating to infant care commonly centered on health (eg, nappy rash, cracked lips, and cradle cap) and development (eg, common milestones including teething and sitting, crawling, or walking). Both first time and mothers with older children were active in these discussions. Women regularly used the forum to ease concerns and to assist them in times of need or confusion during their first year of motherhood.

Maternal health needs and/or well-being were less frequent, with the overall identification of 21.1% (91/432) of references. Most maternal health discussions were observed in the early postpartum period and became less frequent further on from the birth experience. Topics pertaining to maternal health included birth recovery, breastfeeding difficulties, mastitis or breast discomfort, pelvic floor health, and resumption of menstruation. There was limited discussion about modifiable health factors, including the mother's weight, exercise, or diet. The evidence of mental distress was observed with some women discussing the feelings of anxiety, birth trauma, or unhappiness (Table 1).

The discussion forum was used in tandem with care or advice from health professionals, not in place of it. Women appeared to use the forum to confirm a health issue, seek out the experiences of other mothers, or share their experiences. There was no evidence of disregarding the health advice from the health professionals.

Mothers reached out to other forum users when they were unsure about how to manage something and sought a similar experience from others in their birth club commonly asking the following: "Has anyone else had this?," "Has anyone else been told this?," "Can anyone else relate?," and "Anyone going through the same thing?" These inquiries match efforts to normalize experiences or to confirm a problem. Mothers were often observed describing a problem to ask others if this was *normal* and to determine if they should seek advice from health professionals: "Should I be concerned?," "What do I do? Should I take him to the doctor?...or is this normal?," and "Is this something I should be worried about at this age." Some mothers used the forum to allay worries as they bridged time until they could reach their doctor: "I am taking him to the doctors tomorrow but I just wanted to know if anyone has experienced this."

Table 1. Intermediate coding references (N=432).

Topic, subthemes, and references	Codes, n (%)
Infant	237 (54.9)
Sleep	54 (12.5)
Daytime or nighttime sleep routine	30 (6.9)
Bad sleeper	5 (1.1)
Hunger and sleep relationship	4 (0.9)
Cosleeping	3 (0.7)
Sleep regression or changes	4 (0.9)
Sleep training	3 (0.7)
Clothes or swaddle for sleep	2 (0.5)
Not sleeping due to teething	2 (0.5)
Sleep safety	1 (0.2)
Infant health	46 (10.6)
Skin concerns or topical treatments	15 (3.5)
Miscellaneous	12 (2.7)
Weight concerns	4 (0.9)
Bowel movements	4 (0.9)
Immunizations	4 (0.9)
Blood or mucus in nappy	3 (0.7)
Common cold	2 (0.5)
Tongue tie	2 (0.5)
Routines	39 (9)
Daytime nap routine	15 (3.5)
Nighttime sleep routine	15 (3.5)
Feeding routines	9 (2.1)
Feeding	35 (8.1)
Feeding solids	12 (2.7)
Formula amount or recommendations	6 (1.4)
Feeding routines	6 (1.4)
Refusing bottle	3 (0.7)
Unusual food-related behavior	3 (0.7)
Feeding cow's milk	2 (0.5)
Unable to burp or upset tummy	2 (0.5)
Dad wanting to help feed	1 (0.2)
Breastfeeding	33 (7.6)
Milk supply	20 (4.6)
Breastfeeding routines	3 (0.7)
Pain or discomfort	3 (0.7)
Breastfeeding in subsequent pregnancy	2 (0.5)
Weaning	2 (0.5)
Drinking alcohol and breastfeeding	1 (0.2)
Feeding aides, that is, shields	1 (0.2)
Number of breastfeeds	1 (0.2)

Topic, subthemes, and references	Codes, n (%)
Development	19 (4.4)
Teething	7 (1.6)
Leap	5 (1.1)
Crawling	3 (0.7)
Talking	2 (0.5)
Walking	2 (0.5)
Infant behavior	6 (1.4)
Behavioral problems or concerns	6 (1.4)
Miscellaneous	5 (1.2)
Haircuts or ear piercing	2 (0.5)
Travel	2 (0.5)
Car seats	1 (0.2)
Maternal	156 (36.1)
Help seeking	71 (16.4)
Seeking emotional support	15 (3.4)
Seeking advice or reassurance	56 (12.9)
Psychosocial health	30 (6.9)
Emotional well-being	17 (3.9)
Anxious about something	4 (0.9)
Feeling lost or guilty	4 (0.9)
Lack of support	3 (0.7)
Changes and challenges	2 (0.5)
Interconception	25 (5.8)
Sleep deprived	6 (1.4)
Menstrual cycle returning	6 (1.4)
Subsequent pregnancy announcement	6 (1.4)
Becoming pregnant again (views or concerns)	4 (0.9)
Birth control	2 (0.5)
Irregular periods	1 (0.2)
Birth recovery or physical health	24 (5.6)
Natural birth recovery	12 (2.8)
C-section recovery	4 (0.9)
Weight loss	4 (0.9)
Birth experience	2 (0.5)
Stretch marks	1 (0.2)
Pelvic floor	1 (0.2)
Socializing	6 (1.4)
Networking	6 (1.4)
Medical	39 (9)
Health provider advice	23 (5.3)
Querying the advice of health provider (general physician or maternal child health nurse) with forum community	13 (3)
Discussing concern before seeking professional advice	10 (2.3)

| Topic, subthemes, and references	Codes, n (%)
Questioning	16 (3.7)
Clinically relevant questions	16 (3.7)

Overview of Advanced Coding

An emerging cross-cutting pattern through posts was observed while examining web-based discussions in the cohort. Although the discussion topics identified remained consistent, the mother's approach to discussing these concerns, how the concern was expressed, and level of support sought varied. This pattern was reflective of a cycle of learning across five phases: (1) help seeking, (2) solution ideation, (3) testing and skill development, (4) consolidation, and (5) empowerment and improved mental well-being (Figure 1). As mothers moved through the stages of parenting and learning, confidence among forum members increased and confusion, uncertainty, and the need for reassurance decreased. During the final stages of the learning process, women often presented as more empowered and self-assured, with some sharing stories of reassurance and others assuming the role of peer support providers to mothers in the early postpartum period. Although we describe a process model, in practice, we believe that early parenting experiences and parental skill development by mothers are characterized through a dynamic interplay within the model. Mothers may interact with different phases simultaneously, as they encounter new challenges that cause stress and uncertainty; yet, they are further progressed and more confident in other aspects of early parenting. For example, a mother may feel confident about infant feeding (later phases) and yet be anxious and uncertain about how to manage teething (earlier phases).

There appeared to be a temporal relationship between the length of time parenting and increased confidence. This is presumed and cannot be confirmed by this study; however, early postpartum mothers expressed greater levels of uncertainty and concern than those interacting with the forum during the later postpartum period. Overall, the vast majority of posts were from women expressing phases one or two, women who portrayed distress and uncertainty, and women who were more likely to seek support and advice from others. A minority of posts belonged to the later phases of the learning cycle, indicating that women were potentially more reassured and less inclined to engage with the forum specifically to share positive experiences.

Figure 1. Schematic of the learning cycle.
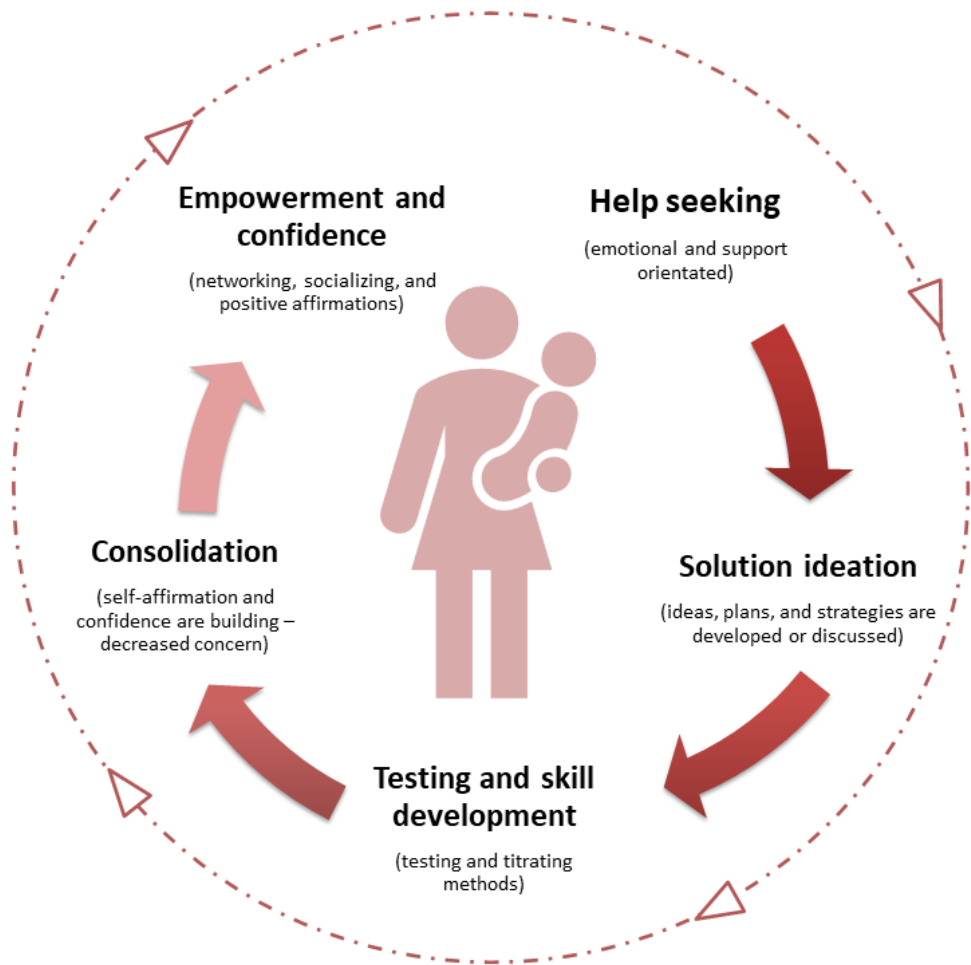
Five-Phase Learning Process (Drawn From Advanced Coding)

Phase One: Help Seeking

Women using the forum initiated discussions on an issue, need, or problem relating to their child or children or parental experiences. Conveying emotional experiences was common in this phase, as was maternal uncertainty. Women regularly stated that they were feeling *anxious*, *stressed*, *worried*, or *exhausted*. The forum acted as an outlet for these emotions and an opportunity to receive social and emotional support from other women:

> *our little miss is the worst sleeper ever [...] I am up and down all night we are lucky to get 3 hours [...] please any book ideas, throw them at me. I'm physically, emotionally and mentally drained.*

> *I'm really down at the moment [...] My 8-month-old doesn't sleep through, she doesn't show me any affection and is quite sooky and demanding. I [...] just feel like I'm waiting for the stage to pass so I can be happier and feel some sort of motivation.*

> *my little one is 9 weeks old and I still feel so clueless, does anyone else? [...] I just feel a bit lost.*

In the early postbirth period, many women used this stage to discuss their experiences before seeking health professional's advice or while bridging the time until they can seek help:

> *[I have the symptoms of an] episiotomy hematoma. Has anyone had any experiences with this? I'm checking in with my OBGYN tomorrow.*

Phase Two: Solution Ideation

Following the initial requests for help and/or information, women discussed potential solutions. Discussing or testing strategies or ways to resolve their concerns with their peers in the forum was common to this phase:

> *I need your help. My poor little baby is super constipated [...] Nothing has worked! I have tried pear and prunes, water, pear juice, Coloxyl, brown sugar and water.*

Solution ideation was also used by women building confidence to make changes:

> *for those of you who have started snacks for baby. What are you offering? Need ideas. Also breastfeeding mamas do you still offer a boob [breast] feed before putting baby down for a nap?*

Phase Three: Testing and Skill Development

In this phase, women started to implement strategies and test solutions. Using a trial-by-error approach, mothers titrated methods to obtain the best outcomes related to their concern. They discussed their results with their peers while seeking reassurance and guidance during this process:

> *recently increased my 16-week-old to 150ml and 5 bottles [...] she's struggling to take even 90ml at a time?! I [have] stretched to 4 hours thinking she might not be hungry but still no difference working. [...] she*

> *missing out on around 300 of the total, should I be worried? she's seems her usual happy self maybe napping a little more.*

During this phase, women have the confidence to try things or rationalize their experiences, yet require reassurance from their peers:

> *...is that too ambitious even for an 8-month-old? Does anyone else's baby not babble at all at 8 months? and/or what sounds are your babies making by now?*

Mothers often seek insight from the past experiences of others or their peers with a child of comparable age.

Phase Four: Consolidation

During this phase, women consolidated their new skills and practices. This phase was often coupled with an increased confidence and decreased uncertainty. It was common for women to post step-by-step outlines of their daily routines to compare with those at a similar stage. Women who anticipated that they were approaching a successful outcome were seen to reaffirm what they had tried or achieved, such as:

> *breastfeeding has never been easy, [...] however I was told to just persist. [...] He is already feeding a lot better than he was previously. Fingers crossed it gets better and better so I can go back to exclusively breastfeeding.*

A common process observed during this phase was the consolidation of advice received from health professionals:

> *she said that from 9 months, milk is secondary and food is to be offered first always. Has everyone else been told this? I'll follow her advice. Was just checking.*

Phase Five: Empowerment

In this final phase, women displayed a degree of empowerment characterized by an increased confidence in the use of acquired knowledge or skills. Many assumed the role of information provider to other mothers, which could be viewed via the responses to original posts, characterizing somewhat of a team working together to share ideas and support those in need. Within the original posts, we viewed women at this stage reaching out for connections, such as "how are all the mummas doing? just checking in," or networking "any mums living close to [...] who would like to connect." Those with the confidence to do so shared their experiences to support and guide others:

> *I wanted to create a thread in case you're feeling a bit down and want some encouragement from other women navigating their first/second/third/tenth time through the postpartum recovery journey. [...] It's not pretty, let's say that. [...] I'm tired but [...] I'm wandering around like an elderly lady, blissfully happy with our third born child [...] and feeling the pains, irks and exhaustion.*

Sentiment and Word Frequency Analysis

A word frequency calculation supports the findings of our open coding with *baby*, *sleep*, *feeds*, three of the five most frequently used words (Multimedia Appendix 1). There were 335

references of sentiment. Of these, most were found to be within the negative range, with 64.2% (215/335) of references classified as negative (very negative: n=126 and moderately negative: n=89) compared with 120 positive references (very positive: n=48 and moderately positive: n=78). A cross-check of sentiment results revealed that less than <10.1% (34/335) of the sentiment references were coded as incorrect categories.

Discussion

Principal Findings

This observational study examined unmediated peer-to-peer web-based discussions during the postpartum period, providing important insights into the information- and help-seeking needs of new mothers. We used the largest digital platform for new parents in Australia, which was representative of approximately 9.8% (30,000/305,832) of women giving birth annually [25], in line with engagement to opt in survey-based methods evaluating health behaviors [26]. Our results demonstrate a predominant focus on infant health needs, including feeding, breastfeeding, and sleep, during early parenting, with maternal health and well-being being a minor focus. Sentiment analyses revealed that the posts were more likely to be negatively portrayed, supporting the finding that the forum is commonly used to express a problem, seek information or help, and gain support or reassurance, consistent with previous literature [20]. The thematic analysis of posts revealed a pattern of behavior resembling a learning process whereby topics remained consistent, but how the concern was expressed and the level of support required varied. This process revealed several phases that commenced with help seeking through consolidation and empowerment. Overall, our findings provide critical insight into the concerns of new mothers and underscore the contributory role of web-based communities in maternal peer social support, information seeking, and the development of early parenting practices.

We report a central focus around the care and development of the infant, with a minority of posts about maternal well-being and fewer again centered on preventive health, including weight gain prevention or modifiable lifestyle factors. This finding is significant, given that the risk of adverse health is high, suboptimal lifestyle behaviors and weight gain are common, and barriers to health optimization exist during the postpartum period [2-4]. Previous studies have reported that time constraints are the most prominent barrier to healthy lifestyle changes, including physical activity engagement, at both 3 and 12 months after pregnancy [3]. In addition to reaffirming these barriers, our results provide additional insights and findings that personal health and well-being were not prominently discussed by mothers, suggesting that this is not a central priority during early parenting compared with that of infant health. This is potentially reflective of reduced engagement and compliance in postpartum healthy lifestyle interventions, as reported previously [27]. Subsequently, there is a paucity of effective strategies to engage women during this life phase for optimized health. Taken together, this emphasizes the need for novel approaches to enhance the awareness of, and engagement in, maternal preventive health during this period. This could

potentially include maternal healthy lifestyle promotion delivered alongside infant care or design of holistic lifestyle programs including infants and wider family members to improve feasibility and engagement for new mothers. Alternatively, the implementation of healthy lifestyle programs during pregnancy when women are regularly engaged with health care providers has been shown to increase compliance in the postpartum period [28] and may better optimize lifestyle behaviors if practiced and maintained before birth.

Our results identified that discussion themes were underpinned by a learning development process, not dissimilar to those previously described, such as Becoming a Mother and Maternal Role Attainment theories [29-31]. The findings of this study emulate the concepts outlined in previous theories regarding maternal development (psychological adjustments and acquisition of a new role; acquaintance, learning, and physical restoration, which are both assumed and learned; and internalization of the maternal role, competence, and confidence). The crucial developmental processes at play within the forum emphasize the importance of the internet during this period and illustrate the influence forum communities may have on maternal decision-making and experiences. Lupton [18] previously identified that women use forums and web-based social networks to connect with other women and to gain guidance and insight through others' experiences and knowledge. We note that the majority of posts were in the early phases of the learning cycle, in which mothers were uncertain, requiring an increased emotional support or solution seeking from their peers. This is also reflected in the sentiment analysis results, with higher proportions of negative sentiment compared with positive sentiment. Our results show that an increasing maternal confidence potentially coincides with the skill and knowledge acquisition sought within web-based communities. Although not all knowledge and skills may be obtained through the forum, and the de-escalation of stress and uncertainty may be influenced by many factors, the forum community is clearly an important platform during early parenting knowledge acquisition for many women and, therefore, plays a significant role in the postpartum journey for new mothers.

Supporting parents to meet the challenges of their caregiving role has consistently been identified as a public health priority [32,33]. Despite this widespread recognition [34], knowledge gaps still exist regarding effective ways to promote positive parenting practices, and little evidence is available that clearly depicts how parents learn and develop [32]. Ensuring health professionals are aware of the support requirements of women during this phase as well as their information priorities, as identified here, is essential. Furthermore, the understanding that acquisition of knowledge and skills during early parenting is fluid and follows a learning cycle is important in enabling the provision of individualized information and support. Similarly, assisting women in recognizing these learning processes may alleviate postpartum stress [35] and anxiety experienced during the initial phases and, in turn, facilitate more rapid progression toward knowledge acquisition and confidence and possible improvements in mental well-being.

To our knowledge, this is the first study to assess the unmediated web-based conversations of mothers during the first year of the

postpartum period. Our findings portray parental experiences and perceptions without the influence of researchers or controlled research settings [36]. This design enables insight into the communication and output of emotions that women may experience at any time of the day, which may be lost to recall or have subsided when sought in a research or clinical setting.

Limitations

The following limitations should be considered while interpreting these findings. Anonymized data were interrogated, and therefore, demographic and geographical user information could not be obtained. User demographics may influence engagement with the forum as well as postpartum needs and experiences. Although users cannot be demographically profiled, the anonymous nature of the forum allows for uninhibited discussion, providing rich data on the needs of participating women. Due to site management and restrictions relating to the seeking or provision of medical advice via the forum, posts may have been deleted before data were collected.

Conclusions

The postpartum period involves a major life transition that requires increased levels of social, emotional, and health professional support. Our results demonstrate that engagement in web-based forums to seek help and support during the postpartum period is common, with infant health and well-being being primary concerns for new mothers during this time. A lack of discussion about maternal health was observed, emphasizing the need for improved awareness and novel engagement strategies. The identification of a maternal learning cycle at play within the forum demonstrates the significant role of web-based communities in maternal social support and in defining parenting. Further exploration is needed to understand how health care professionals can provide targeted and personalized support to women in postpartum period, where infant needs are prioritized above their own, particularly for those experiencing increased levels of distress and uncertainty.

Authors' Contributions

Conceptulization and study design: CLH, BRC, RMG. Data extraction, collation, and analysis: BRC. Thematic analysis and interpretation: CLH, BRC, RMG. Manuscript preparation: BRC. All authors reviewed the manuscript for intellectual content and approved the final version.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Frequently used words in forum user-generated content (word cloud).
[PNG File , 77 KB-Multimedia Appendix 1]

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Chapter 4. Consumer facing digital health tools to monitor gestational weight gain

4.1 Introduction

Reproductive aged women are a high risk group for accelerated weight gain, with pregnancy and postpartum recognised as key contributory life-stages to obesity development (63). During pregnancy, global epidemiological data in over one million pregnancies reported 50% of women gain weight in excess of recommended thresholds advised by the National Academic of Medicine (previously, Institute of Medicine), while 20% had inadequate GWG (64). Associated risks of GWG below recommendations include preterm birth and delivery of a small for gestational age (SGA) infant, whilst excessive GWG above recommendations is associated with caesarean section, macrosomia and delivery of a large for gestational age (LGA) infant (64-66). Digital health, including internet-based information and mobile 'mHealth' applications (apps) have become a popular and widely used source of health information for pregnant women (33-36). Given the tendency of consumers to trust digital health information (46), which is not always reliable or current (36), it is critical to know what tools and information are available to those searching for such applications, and to assess their quality.

Here my role was to design and perform a systematic search for mobile applications and websites targeted towards, and allowing, gestational weight gain tracking. I then performed an extensive evaluation of the tools, using validated scales, (the Mobile App Rating Scale (MARS) (67) and App Behaviour Change Scale (ABACUS) (68)) and criteria developed specific to evidence-based information (69) and GWG. The outcomes were four analyses, providing an in-depth understanding of the tools, from practical aspects such as usability, functionality and appearance, through to health information quality and behaviour change capacity.

My role in this project was to conceptualise the design of the study, alongside my supervisors and deliver the body of work in this project. I conducted the search, with cross-checks performed by my supervisors. I was responsible for managing data collection across the author group. Tools were allocated to two reviewers and all questions and criteria were disseminated and collected via an online questionnaire to allow ease for the author group. I analysed the results, and led the writing of the manuscript.

This chapters provides an overview of digital tool quality, features and functionally; behaviour change potential; the credibility, quality and safety of the health-related information provided; and the ability of the tool to highlight the importance of optimising GWG. Across 19 eligible digital tools, we found the majority were marketed as having features for pregnancy related education, advice, monitoring and tracking of GWG. Yet the quality of information related to GWG was poor, lacking an evidence base with little underpinning expertise and there was limited ability to guide behaviour change for optimised GWG. We found minimal likelihood of resources to alert, provide support or direct women into partnership with their healthcare provider, if GWG was outside of recommended thresholds.

The findings of this study emphasise a missed opportunity in information provision and support to safely optimise health behaviours and GWG for women, and a critical need to improve the quality and regulation of publicly accessible online resources targeted towards health and weight management during pregnancy. Collaboration between the health and commercial sectors is warranted to improve safety of publicly available tools, and to ensure that women are receiving credible, high quality health information. These findings have been presented at two public health and obesity conferences, and translated into a short communication piece disseminated by the Health in Preconception, Pregnancy, and Postpartum Early-and Mid-Career Researcher Collective International (HiPP EMR-C International). See Appendix 4 translational work and conference presentations related to this work.

4.2 Content and quality assessment of digital tools for managing gestational weight gain

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Assessing the Content and Quality of Digital Tools for Managing Gestational Weight Gain: Systematic Search and Evaluation

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Abstract

Background: Digital health resources have the potential to assist women in optimizing gestational weight gain (GWG) during pregnancy to improve maternal health outcomes.

Objective: In this study, we aimed to evaluate the quality and behavior change potential of publicly available digital tools (websites and apps) that facilitate GWG tracking.

Methods: Digital tools were identified using key search terms across website search engines and app stores and evaluated using the Mobile App Rating Scale, the App Behavior Change Scale, as well as criteria to evaluate the rigor and safety of GWG information.

Results: Overall, 1085 tools were screened for inclusion (162 websites and 923 apps), and 19 were deemed eligible. The mean Mobile App Rating Scale quality score was 3.31 (SD 0.53) out of 5, ranging from 2.26 to 4.39, and the mean App Behavior Change Scale score was 6 (SD 3.4) out of 21, ranging from 19 to 0. Of the 19 items used to evaluate rigor of GWG advice, most tools (n=11, 57.9%) contained ≤3 items.

Conclusions: This review emphasizes the substantial limitations in current digital resources promoting the monitoring and optimization of GWG. Most tools were of low quality, had minimal behavior change potential, and were potentially unsafe, with minimal linkage to evidence-based information or partnership with health care.

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Introduction

Gestational Weight Gain: An Overview

During pregnancy, gestational weight gain (GWG) is essential to ensure the development of a healthy fetus [1]. However, GWG below or above the recommendations is associated with an increased risk of negative pregnancy outcomes and neonatal conditions or complications [1-6]. Epidemiological data in over 1 million pregnancies globally reported GWG below or above the recommended thresholds in 23% and 47% of all pregnancies, respectively [7]. The associated risks of GWG below recommendations include preterm birth and the delivery of a small-for-gestational-age infant, whereas excessive GWG above recommendations was associated with cesarean section, macrosomia, and the delivery of a large-for-gestational-age infant [6-8]. Long-term, excessive GWG is associated with intergenerational adverse health risks, including obesity, cardiovascular disease, and type 2 diabetes [1-5]. Therefore, optimizing GWG during pregnancy in line with recommendations is a global health priority.

Digital Health Engagement During Pregnancy

Digital health, including internet-based information and mobile Health (mHealth) apps, have become popular and widely used sources of health information for pregnant women, often replacing traditional paper-based and supplementing face-to-face health professional consultations [9-12]. However, the attainment of credible internet health or mHealth information is reliant on consumer health literacy and the ability to judge the quality and accuracy of information. Given the tendency of consumers to trust digital health information [13], this is problematic, as health information is not always reliable or current and can be confusing, overwhelming, and at times potentially harmful [12].

During pregnancy, freely accessible web-based resources, including trackers, calculators, or graphs, to record and self-monitor GWG have the potential to assist women in identifying whether weight gain is outside the recommended thresholds. In conjunction with the promotion of healthy lifestyle behaviors, these web-based resources have the potential to assist women in achieving healthy GWG [14-16]. However, there is currently limited information about the type of tools available, their format (ie, web-based application or mobile app) and functionality, credibility of the information provided, or their ability to guide behavior change to positively impact GWG. Evaluating digital tools that are publicly available to women to monitor GWG during pregnancy is a critical gap to address, given the risk of complications associated with excessive or inadequate GWG and the need to ensure credible and reliable self-monitoring tools for women during this time. Previous research in this area is limited to evaluations of mobile apps only and is primarily based on functionality [17] or a narrow evaluation of selected apps based on predefined pregnancy topics [18].

In this study, we aimed to evaluate the quality and behavior change potential of publicly available digital tools (websites and apps) that facilitate GWG tracking. Given the benefits of self-weighing for weight management [16] and the high use of digital health information during pregnancy [9-11], there is a need to examine and review what is currently available to ensure that pregnant women are being provided with evidence-based information and tools that align with GWG recommendations.

Methods

The methods of this study have been informed by previous reviews exploring the quality, features, functions, behavior change capacity, and quality of digital applications and resources [19-23].

Systematic Search

Searches were conducted in an Australian web browser using website search engines (Google, BING, and Yahoo) and mobile app stores (Apple AppStore, iOS and Google Play, Android) using a combination of search terms emulating terms likely used by end users, including *pregnancy weight, pregnancy weight tracker, pregnancy weight gain calculator, pregnancy weight graph* (website searches), and *pregnancy weight, pregnancy weight tracker,* and *gestational weight tracker* (app searches). Search terms were developed by a multidisciplinary team comprising obstetrics and gynecology (O&G), midwifery, nursing, dietetics and nutrition, and exercise physiology. Each search term combination was entered individually in the search engine. For websites, the first 2 pages of results for each search term were screened for inclusion, similar to previous studies [19,24,25]. For apps, searches were entered into the Google Play and Apple App Store databases without any specified search categories. All the retrieved app search results were screened for inclusion. One reviewer (BRB) independently reviewed all results, with a 100% cross-check of websites and 50% cross-check of apps completed by 2 additional independent reviewers (CLH and RMG).

Inclusion Criteria and Selection Process

Websites and apps were included according to the following criteria: publicly available or ability to download (free or paid, but with free discovery capacity); written in or available in English; title or description suggested inclusion of tools or advice or resources relating to pregnancy weight gain; and weight-tracking tool enabled multiple logs or entries of weight across pregnancy (ie, not just 1 static weight log).

Apps that met the inclusion criteria were further filtered using the following app-specific inclusion criteria: updated within 18 months from the search date, May 2021; user rating of ≥4.0 stars if ≥6 months old (apps <6 months were included irrespective of user rating) as a proxy for app popularity per previous research [21]; incorporation of a graph or chart or illustration of GWG (ie, does not merely display the weight as a numerical value); and presence of surrounding content about pregnancy health and well-being. Apps that required downloading to complete this step were screened for inclusion by 2 researchers (BRB and RMG). If the apps available on Google Play and Apple AppStore had contrasting user ratings, the higher rating was carried forward and documented in the app description results.

Resource Evaluation

Overview

Eligible websites and apps were randomly allocated to 2 reviewers and independently reviewed on a mobile device. All reviewers (AC, BRB, MJH, QVH, RMG, and SJdJ) have expertise in public health and form a multidisciplinary team (ie, O&G, midwifery, nursing, dietetics and nutrition, and exercise physiology). Where the same app was available on both Google Play Store and Apple App Store, app details and descriptions were reviewed to ensure consistency across the 2 platforms and downloaded for review on an Apple device. The reviews were conducted from June to July 2021. Apps were user tested for evaluation using numerous validated scales and relevant questions (Multimedia Appendices 1-4) using a mock user profile. Each app was explored until the reviewer had familiarized themselves with the functionality and features of the app, with a user experience consistent with other studies [21]. Reviewers noted whether the app stopped functioning or whether the features were not accessible. Following the review, if there was a contradiction in reviewer responses, a third independent reviewer was assigned to resolve item or items of disagreement and establish consensus (BRB, CLH, and RMG).

Collections of user demographic and pregnancy-specific data were recorded, including username; contact details (name, email, phone, or other); date of birth or age; country of origin; gestation (due date, last menstrual cycle, or date of conception); type of pregnancy (singleton, twin, triplet, etc); parity (first, second, third, etc); and preconception weight and height.

GWG Criteria

To evaluate the rigor and safety aspects of GWG management information, GWG-specific criteria were developed by a multidisciplinary team (Multimedia Appendix 1). The criteria encompassed 19 items, including reference to published international guidelines for GWG (ie, National Academy of Medicine, previously Institute of Medicine [26]) with personalization according to BMI; warnings, notifications, or alerts for weight gain detected outside of recommendations; direction or advice to consult a health professional if logged GWG was outside of the recommendations; and dietary and physical activity content and the development of content in consultation with relevant health professionals (O&G, midwifery, allied health, etc).

Mobile App Rating Scale

The Mobile App Rating Scale (MARS) is a 23-item evaluation tool comprising 6 domains (Multimedia Appendix 2): *engagement, functionality, aesthetics, information quality, subjective quality*, and *health topic specific* [27,28]. Each item is scored using a 5-point ordinal scale, with a mean score derived for each domain. The first 4 domains, including *engagement* (ie, incorporation of interesting, customizable, and interactive—eg, sends alerts, messages, reminders, and feedback and enables sharing—features targeted at the audience); *functionality* (ie, ease of use, navigation, flow logic, and gestural design); *aesthetics* (ie, graphic design, overall visual appeal, color scheme, and stylistic consistency); and *information quality* (ie, contains high-quality information from a credible source),

are combined and averaged to provide an overall app quality score out of 5. A *subjective quality* score between 0 and 20 is allocated by each reviewer. This section requires the reviewer to rate whether they would recommend the app to people who may benefit from using the app, how many times over 12 months they would use the app if it was relevant to them, whether they would be willing to pay for the app, and their overall app star rating. The *health topic–specific* domain is an optional 5-item section that can be adjusted to suit the topic area researched (ie, GWG). This domain aims to assess whether the app is likely to *increase awareness of the importance of addressing GWG, increase knowledge or understanding of GWG, change attitudes toward improving GWG, increase intention or motivation to address GWG,* and *encourage further help seeking for GWG.*

The MARS also includes an App Classification section to obtain information about technical features (Multimedia Appendix 2). These items were recorded for descriptive purposes but did not form part of the functionality rating. These features include the app rating, obtained via the Google Play or Apple App Store; the number of app downloads (derived from the Google Play Store only as of August 2021; the Apple App Store does not provide app download information, so this information is precluded); whether the digital tool presented or required agreement to terms and conditions or a disclaimer; required log-in; allowed password protection; allowed sharing to social media; allowed data export; had an app community; sent reminders; required web access to function; and whether the digital tool sent push notifications. All applicable criteria were used for website evaluation, excluding ratings and downloads.

The App Behavior Change Scale

The App Behavior Change Scale (ABACUS) is designed to evaluate the behavior change potential of smartphone apps and websites across 4 domains (Multimedia Appendix 3) [22,23]. These include knowledge and information (ie, customized and personal features, collection of baseline information, and consequences for continuing or discontinuing behavior); goals and planning (ie, goal setting, goal reviewing, updating or changing, and willingness for behavior change); feedback and monitoring (ie, easy-to-use self-monitoring tools and data exporting or rewards or incentives); and actions (ie, reminders, prompts or cues, planning for barriers, and assistance with distractions or avoidance).

Quality Evaluation

Criteria to evaluate the quality of the health-related digital tools were developed (Multimedia Appendix 4) and modified from app review studies in the field authored by our group [19,20]. The criteria include statement of purpose of the app or website; contact details provided (email, phone, or fax); ownership disclosure (who owns the app or website); copyright; general disclosures; general disclaimers; advertisement disclosures; sponsorship disclosures; author or developer disclosures; author or developer credentials (credentials and affiliations); independence of sponsors or funders; references provided; and type of references provided (a list of types provided, including meta-analysis, randomized controlled trial, media, government guideline, or option piece).

Statistical Analysis

Descriptive statistics (mean and SD) and frequencies (numbers and percentages) were calculated for all scales applied. The reported percentages were rounded to the nearest whole number. Intraclass correlation (ICC) scores were calculated to determine the agreement between the MARS rating using SPSS statistical software (version 25; IBM Corp). All analyses were conducted using SPSS for Windows, with a significance level set at $P<.05$. The following previously established categories for expressing levels of reliability for ICC results were used: high reliability, 0.90 to 0.99; good reliability, 0.80 to 0.89; fair reliability, 0.70 to 0.79; and poor reliability, 0.69 or less [29].

Ethical Considerations

This study does not meet the criteria for human research and thus did not require oversight from the authors' institutions.

Results

A total of 1085 digital tools were screened for inclusion across 162 websites and 923 apps. After excluding duplicates, 89 digital tools were retained for potential inclusion with 19 digital tools eligible for analysis (Figure 1).

Figure 1. Flowchart of gestational weight gain (GWG) digital tool selection.
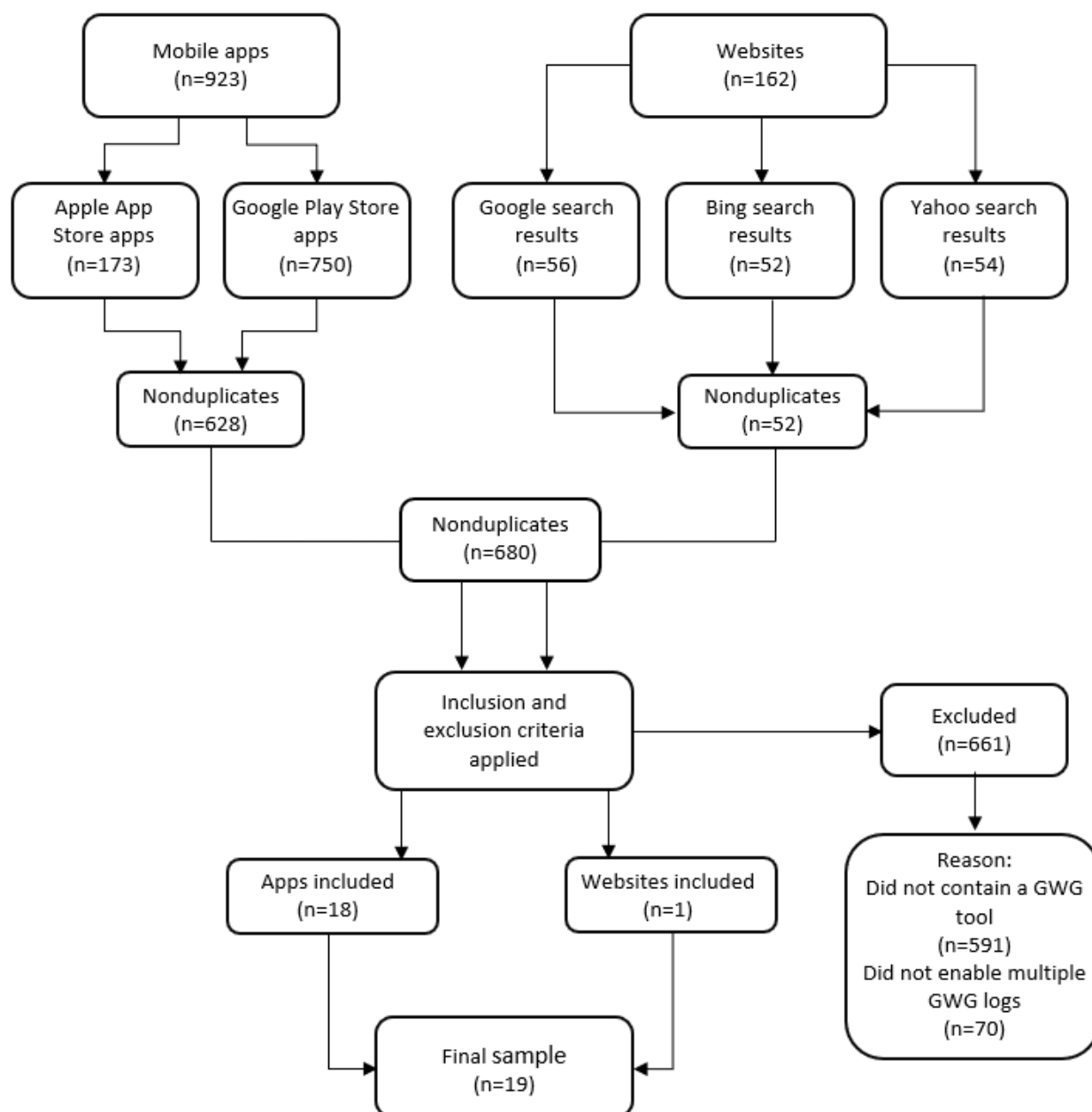
Characteristics and Overview of Digital Tools

Table 1 presents the main characteristics of the websites and apps included in this study; further descriptions of tools are available in Multimedia Appendix 5. All apps (n=18) were available on the Google Play Store and 9 were available on both the Google Play and Apple App Store. The 18 apps had a Google Play or Apple App Store user-rating score ranging from 4.10 to 4.90, with a mean score of 4.64 (SD 0.22), and had been

downloaded over 25 million times from the Google Play Store alone. Most digital tools were associated with commercial enterprises (17/19, 89%), whereas few were affiliated with government services (1/19, 5%) and universities (1/19, 5%). All apps had a free discovery capacity (ability to download and use without payment), with total downloads per app ranging from >500 to >10,000,000. Overall, 50% (9/18) of apps had costs for app subscription and in-app purchases ranging from Aus $1.99 to $79.99 (US $1.49 to $59.99; Multimedia Appendix 5); however, this did not impact the discoverability of content or tools reviewed. The website (1/1, 100%) was free to access.

All digital tools were based on information or education (19/19, 100%) and monitoring or tracking (19/19, 100%), and the majority included advice, tips, and strategies (15/19, 79%). A small number of tools used assessment (3/19, 16%), feedback (3/19, 15%), and goal setting (1/19, 5%). Technical aspects included reminders (11/19, 58%), log-in requirements (11/19, 58%), app communities (5/19, 26%), password protection (4/19, 21%), and sharing options (eg, social media, app to app, or email; 3/19, 16%). Only the website required web access to function, with all apps able to be used offline. All collected information about gestation (19/19, 100%) and most, but not all, collected preconception weight (16/19, 84%) and height (14/19, 74%; Table 1).

Table 1. Technical aspects and characteristics of digital tools for GWG management.

	Value, n (%)	App[a]																		Web[b]
		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	01
Theoretical background or strategies																				
Advice or tips or strategies or skills training	14 (74)	✓[c]	✓			✓	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓
Assessment	4 (16)			✓			✓													✓
Feedback	4 (16)						✓											✓		✓
Goal setting	1 (5)																			
Information or education	18 (95)	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Monitoring or tracking	19 (100)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Technical aspects																				
Allows sharing (social media, app to app, or email)	4 (21)				✓		✓						✓							✓
App community	5 (26)					✓	✓	✓		✓						✓				
Needs web access to function	1 (5)																			✓
Password protected	3 (16)					✓	✓									✓				
Requires log-in	10 (53)		✓	✓		✓	✓					✓	✓			✓	✓	✓	✓	
Sends reminders	11 (58)		✓	✓	✓	✓	✓		✓	✓	✓		✓		✓		✓			

	Value, n (%)	App 01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	Web 01
Information collected																				
Contact details	9 (47)	✓		✓	✓	✓	✓		✓			✓	✓			✓		✓		
Country or location	4 (21)				✓	✓	✓		✓				✓							
Date of birth or age	6 (32)		✓			✓	✓		✓				✓		✓					
Name	11 (58)	✓	✓		✓	✓	✓		✓				✓			✓	✓	✓	✓	
Pregnancy-related information collected																				
Gestation	19 (100)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Height	14 (74)	✓		✓		✓	✓		✓	✓	✓	✓		✓		✓	✓	✓	✓	✓
Pregnancy number (ie, first or second etc)	4 (21)		✓			✓	✓		✓											
Pregnancy type (single or twins etc)	3 (16)					✓	✓													✓
Preconception weight	15 (79)	✓	✓	✓		✓	✓		✓	✓	✓	✓		✓		✓	✓	✓	✓	✓

[a]App: apps included in ths study.

[b]Web: website included in this study.

[c]✓: indicates technical aspects or characteristics present in the digital tool.

GWG Criteria

Gestational weight tracking was a major feature of most digital tools, displayed prominently to users (15/19, 79%), in line with our inclusion criteria (Multimedia Appendix 6). In total, 58% (11/19) of digital tools provided weight recommendations based on preconception weight and height. All other criteria were present in less than half of the digital tools. Overall, 47% (9/19) of tools encouraged an unspecified, healthy diet for optimal GWG, and 37% (7/19) encouraged nonspecific, regular moderate physical activity for optimal GWG. Very few (2/19, 11%) tools alerted the user when their weight gain was outside of the recommended range, and none directed the user to consult a health professional if their weight entry was outside the recommended range. Overall, of the 19 criteria, the majority (11/19, 58%) contained ≤3 items, with 11% (2/19) having 0 items. The tool that met the most criteria for GWG was Web01 (9 of 19 criteria), followed by App17 (7 of 19 criteria) and App06 (6 of 19 criteria); the name and description of tools can be viewed in Multimedia Appendix 5. Refer to Multimedia Appendix 1 for the complete GWG criteria and definitions.

MARS Results

The specific MARS scores for each digital tool are presented in Table 2. The overall mean MARS quality score (comprising engagement, functionality, aesthetics of tool, and the quality of

general pregnancy-related information domains) ranged from 2.26 (lowest-rated app) to 4.39 (highest-rated app), with a mean score of 3.17 (SD 0.75). Subjective ratings (ie, reviewer recommendations, rating, and perceived monetary value) ranged from mean 3.25 (SD 0.00) to mean 15.50 (SD 0.71), from a potential score of 20; app-specific ratings (ie, GWG awareness, knowledge, and understanding of GWG; attitudes toward improving GWG; intention and motivation to address GWG; and help seeking for GWG) ranged from 1.00 to 4.50, with most (15/19, 79%) scores being 2.50 or less. Overall, the best-rated section was functionality (mean 3.94, SD 0.63), followed by aesthetics (mean 3.61, SD 0.69) and engagement (mean 3.19, SD 0.63), compared with app-specific (mean 2.24, SD 0.84) and information (mean 2.49, SD 0.68) domains, which scored the lowest. ICC scores ranged from 0.671 (95% CI −0.169 to 0.946) to 0.996 (95% CI 0.076-0.999). Most ICC results showed either high (10/19, 53%) or good (6/19, 32%) reliability.

Table 2. Mobile App Rating Scale (MARS) scoring.

App or website name	Overall MARS quality score (A-D), mean (SD)	A (engagement), mean (SD)	B (functionality), mean (SD)	C (aesthetics), mean (SD)	D (information), mean (SD)	E (subjective), mean (SD)	F (app specific), mean (SD)	ICC[a] (95% CI)
App06	4.39 (0.54)	4.50 (0.71)	4.50 (0.71)	4.50 (0.24)	4.07 (0.51)	15.50 (0.71)	2.70 (2.40)	0.935 (0.615 to 0.991)
App12	4.07 (0.15)	3.80 (0.57)	4.75 (0.35)	5.00 (0.00)	2.72 (0.40)	13.00 (0.00)	2.30 (0.42)	0.973 (0.824 to 0.996)
Web01	4.00 (0.18)	3.20 (0.28)	5.00 (0.00)	4.00 (0.47)	3.79 (0.91)	12.50 (3.54)	4.50 (0.14)	0.836 (0.222 to 0.975)
App08	3.60 (0.04)	4.10 (0.14)	4.00 (0.00)	4.00 (0.00)	2.29 (0.00)	3.25 (0.00)	2.60 (0.57)	0.996 (0.976 to 0.999)
App02	3.56 (0.11)	3.30 (0.42)	4.13 (0.88)	4.34 (0.47)	2.50 (0.51)	8.00 (1.41)	2.00 (0.57)	0.858 (0.349 to 0.981)
App01	3.54 (0.01)	3.10 (0.14)	4.25 (0.00)	4.00 (0.00)	2.79 (0.10)	8.50 (0.71)	2.50 (0.42)	0.972 (0.817 to 0.996)
App14	3.51 (0.24)	3.50 (0.14)	3.50 (0.35)	4.34 (0.94)	2.72 (0.21)	10.00 (2.83)	2.30 (0.99)	0.856 (0.285 to 0.978)
App05	3.41 (0.06)	3.70 (0.14)	3.88 (0.18)	3.33 (0.00)	2.72 (0.21)	11.50 (0.71)	3.20 (0.28)	0.972 (0.999 to 0.817)
App03	3.39 (0.27)	3.10 (0.42)	4.25 (0.35)	4.00 (0.00)	2.22 (0.30)	7.50 (2.12)	1.70 (0.42)	0.873 (0.349 to 0.981)
App17	3.38 (0.06)	3.60 (0.00)	4.00 (0.00)	3.50 (0.24)	2.43 (0.00)	12.50 (0.71)	3.50 (0.14)	0.995 (0.962 to 0.999)
App09	3.34 (0.08)	3.20 (0.57)	3.63 (0.53)	3.33 (0.00)	3.22 (0.30)	9.50 (0.71)	2.60 (0.57)	0.957 (0.729 to 0.994)
App15	3.25 (0.10)	3.50 (0.71)	3.50 (0.00)	3.50 (0.24)	2.50 (0.10)	10.00 (1.41)	1.60 (0.28)	0.950 (0.693 to 0.993)
App07	3.14 (0.41)	3.20 (0.28)	3.88 (0.18)	3.50 (1.17)	2.00 (0.00)	7.00 (1.41)	1.60 (0.57)	0.859 (0.296 to 0.979)
App11	2.96 (0.69)	2.90 (0.71)	3.50 (0.71)	3.00 (0.95)	2.43 (0.40)	5.50 (2.12)	1.70 (0.14)	0.711 (−0.095 to 0.954)
App10	2.85 (0.62)	2.10 (0.14)	4.38 (0.88)	3.33 91.41)	1.57 (0.00)	6.00 (2.83)	1.30 (0.42)	0.713 (−0.090 to 0.954)
App13	2.84 (0.01)	2.60 (0.57)	3.88 (0.18)	3.00 (0.00)	1.86 (0.40)	7.00 (0.00)	1.90 (0.14)	0.972 (0.815 to 0.996)
App16	2.75 (0.02)	2.80 (0.00)	3.13 (0.18)	2.84 (0.23)	2.22 (0.50)	5.50 (0.71)	1.50 (0.71)	0.864 (0.315 to 0.980)
App18	2.60 (0.83)	2.50 (0.99)	3.63 (0.53)	2.50 (0.71)	1.79 (1.11)	6.50 (3.54)	2.00 (1.13)	0.671 (−0.169 to 0.946)
App04	2.26 (0.26)	2.00 (0.57)	3.13 (0.18)	2.50 (0.24)	1.43 (0.40)	4.00 (0.00)	1.00 (0.00)	0.938 (0.627 to 0.991)

[a]ICC: intraclass correlation; agreement between reviewers (A-F).

ABACUS Results

The overall ABACUS score was 6 (SD 3.6) of 21 (Table 3). Four behavior change techniques were most prominent, which were included in >50% of the apps. These techniques or functions included the ability to customize and personalize some features (19/19, 100%), the collection of baseline information (ie, user information or personal details; 16/19, 84%), allowing the user to easily self-monitor behavior (13/19, 68%) and providing instructions on how to perform a behavior (10/19, 53%). These and other didactic or simple techniques such as instructions, data export, and sending of reminders were much more frequent than interactive functions such as goal setting (1/19, 5%), encouragement (0/19, 0%), providing material or social rewards (0/19, 0%), and ascertaining willingness to change (0/19, 0%). The top tools for behavior change potential were App06 (scoring 16/21), App08 (scoring 11/21), App17 (scoring 9/21), and Web01 (scoring 9/21).

Table 3. Performance on App Behavior Change Scale (ABACUS) criteria (most to least frequently used).

Behavior change technique[a]	Value, n (%)
Customize and personalize some features	19 (100)
Baseline information	16 (84)
Allow the user to easily self-monitor behavior	13 (68)
Provide instruction on how to perform the behavior	10 (53)
Reminders or prompts or cues for activity (on app)	8 (42)
Data export	7 (37)
Information provided about the consequences of continuing or discontinuing behavior	7 (37)
Give user feedback (person or automatic)	5 (26)
Allow or encourage practice or rehearsal in addition to daily activities	4 (21)
Created with expertise or information consistent with national guidelines	4 (21)
Restructure the physical or social environment	4 (21)
Encourage positive habit formation	3 (16)
Provide the opportunity to plan for barriers	3 (16)
Share behaviors with others or allow for social comparison	3 (16)
Understand the difference between current action and future goals	3 (16)
Distraction or avoidance	2 (11)
Review goals, update, and change	2 (11)
Goal setting	1 (5)
Provide general encouragement	0 (0)
Material or social reward or incentive	0 (0)
Willingness for behavior change	0 (0)

[a]App Behavior Change Scale average score: mean 6 (SD 4) out of 21.

Quality Evaluation

Most (16/19, 84%) digital tools had a statement of purpose and all, with the exception of one (18/19, 95%), provided developer or author contact details. Ownership disclosure and copyright statements (14/19, 78%), advertisement disclosure (13/19, 68%), and author or developer disclosure (12/19, 63%) were present in most of the digital tools. No tool provided information to ascertain the independence of sponsors or funders (0/19, 0%); 5% (1/19) provided a sponsorship disclosure and 11% (2/19) outlined author or developer credentials, which included academics and O&G. Overall, 21% (4/19) of digital tools contained references (Multimedia Appendix 7). App06 met the most quality criteria (14 of 21), followed by App05 (9 of 21), and Web01 (9 of 21).

Discussion

Principal Findings

Women are increasingly engaging with digital resources for health guidance, including healthy lifestyles and weight gain during pregnancy. A systematic search approach identified current and publicly available websites and mobile apps that contain tools and resources to monitor GWG. Those included were reviewed based on their quality, features and functions; behavior change potential; the credibility, quality, and safety of the health-related information provided; and their ability to highlight the importance of optimizing GWG. Across 19 eligible digital tools, we found that the majority reported features including pregnancy-related education, advice, monitoring, and tracking of GWG. Despite this, the quality of information related

to GWG was poor, and limited ability to guide behavior change for optimized GWG was found. Advice related to achieving healthy GWG was present in ≤50% of the apps. Overall, this advice was nonspecific in nature and unlikely to be associated with evidence-based information. We found minimal likelihood of resources to alert, provide support, or direct women into partnerships with their health care provider if GWG was outside the recommended thresholds. These results emphasize a missed opportunity in information provision and support to safely optimize health behaviors and GWG for women. There is a critical need to improve the quality and regulation of publicly accessible web-based resources informed by health care, policy, and consumer needs during pregnancy.

Pregnancy presents a unique opportunity in which women are motivated to optimize lifestyle behaviors to ensure favorable health outcomes for themselves and their baby [30]. Optimizing diet, physical activity, and ultimately GWG during pregnancy reduces adverse outcomes for mother and baby and confers protective maternal and intergenerational benefits [30-32]. Our results support a mobilization of women during this time in engagement with health resources, with over 25 million downloads observed across the 18 apps included in this review. Associated consumer user ratings for apps were very high; however, it is not clear what aspects were most appealing and why. Recent qualitative research exploring consumer preferences and experiences with mHealth apps for maternal health reported that functionality and technical ability features were perceived to be of highest value to women [33]. Consumers reported an increased likelihood to use apps that were free or low-cost, aesthetically pleasing, and with minimal technological barriers [33]. However, little emphasis was placed on the quality or credibility of information by consumers when prompted, and there was little desire to obtain and ensure evidence-based information was received [33]. This may potentially explain the high user ratings of the apps included here. On evaluation, MARS domains related to visual appeal, engagement, and functionality scored the highest overall compared with domains related to content specificity, in line with previous research evaluating pregnancy-related apps [18]. Interestingly, although not captured on the scales applied in this study, we observed that functionality was impeded in several apps by mandatory viewing of advertisements contingent on accessing free features, information, or moving between pages. However, it is unclear whether this impacted the highly scored user ratings overall.

In the absence of availability of a framework to evaluate safety features within web-based resources, we built on our previous research [19,20] and included a checklist to rigorously evaluate the presence of features related to GWG management. These included consultation with relevant health care providers in content development, linkage to clinical practice guidelines for pregnancy care and guidelines for GWG, evaluation of surrounding content to promote healthy GWG, and in-built alerts if GWG entries are outside of the recommended range. Overall, we found that only 10% disclosed development in consultation with O&G expertise, 10% used adequate referencing for GWG guidelines, 10% included an alert for GWG outside of recommendations based on preconception weight and height, and none advised health care consultation

if GWG was outside of recommendations. These results emphasize a near-complete absence of components related to safety within currently available web-based resources, mandating a critical need to improve regulatory control in this field [34,35]. Previous research in over 1 million pregnancies worldwide demonstrated an increase in adverse outcomes for both mother and baby when GWG is below or above international recommendations, compared with GWG within recommended thresholds [7]. Level 1 evidence demonstrates optimized GWG and improved maternal outcomes following antenatal lifestyle intervention, and there is now a strong mandate for the implementation of effective strategies in routine care [36]. With increased engagement in and availability of resources to monitor GWG, it is essential that evidence-based information and recommendations are made available to support women, with effective translation of health information congruent with the current guidelines to minimize potential harm.

Using the validated ABACUS framework, we evaluated the capacity of the included apps to guide and support behavior change [23] toward the optimization of GWG. Our results demonstrate that beyond the ability to personalize adaptable features within apps with user information or personal data, scores for the capacity to change behavior were poor overall. Behavioral techniques common to healthy lifestyle change [37], including goal setting, problem solving, provision of consequences related to the target behavior, habit formation, and social and environmental antecedents of behavior, were rarely present. This is reflective of findings within previous non–pregnancy-related research [38] and pregnancy-related research specific to exercise and physical activity [21]. Further research is needed to fully elucidate which behavioral components embedded within web-based resources are effective in changing behavior [38]. This is particularly significant in the context of the burgeoning availability and use of health apps, yet for developers minimal evaluation of efficacy in changing health behaviors or improving health outcomes is required [38].

Altogether, our results highlight several areas of concern, culminating in a missed opportunity to support and guide women during this formative life phase of increased health care needs. First, despite increasing awareness, there is little regulatory control currently in place for digital health resources that are publicly available, which is an area warranting improvement. A recent Australian review highlighted the complexities between developer and consumer considerations and the involvement of multiple, siloed sectors, traversing medical, privacy, advertising, finance, and digital content as barriers to improving regulations to ensure consumer safety [39]. Of the policy documentation available, the review found a focus on the commercial loss or gains related to regulation over and above consumer safety, with consumers ultimately assigned as the primary evaluator in selecting safe and credible apps [39]. Given that women may base their engagement on functionality and aesthetics aspects within apps [33], there is a need to develop resources that can inform women about the quality, credibility, and safety of apps in a reliable, easy, and transparent way. This could include independent certification or endorsements not dissimilar to currently available entities, such as Health on the Net or similar

[21,40]. Second, given that resources were likely to be more based on function and aesthetics, it is not unreasonable to conclude that entertainment and gamification came at the expense of credible information and support for women. Frequent exposure to advertisements highlights the potential for exploitation of women when using resources with exposure to potentially harmful information and imagery, underscoring the need for improved regulation and distinction between apps for entertainment and those for health information provision. Finally, in improving content quality within apps, improved partnership among commercial developers, policy makers, the health care sector, and with women, the consumers, at the forefront is required. Co-design of resources must occur to ensure a balance between the valued consumer attributes of apps alongside evidence-based information and effective behavior change techniques delivered in a way that women value as engaging, trustworthy, and safe. Previous research suggests that involving relevant expertise in app development does not compromise user downloads of apps, suggesting that quality can be optimized without compromising popularity [41].

Strengths and Limitations

This study had several strengths and limitations. To ensure that we captured the available digital health resources for GWG, we used a robust search strategy across both websites and mHealth apps with minimal exclusion criteria, reflective of our search results. By reviewing current digital tools using the validated MARS and ABACUS tools, questions specific to GWG as well as evaluation of credibility of health-related information, we were able to evaluate technical features and quality as well as the behavior change potential and health information. We applied safety criteria specific to GWG management based on our previous publications [19,20] and tested all weight trackers for their ability to digitally summarize GWG, provide personalized feedback according to GWG, and alert and direct women to health care provision if GWG was outside recommendations. Owing to inconsistent search terms used for pregnancy and weight management across Google Play Store and Apple App Store, it is possible that some apps may have been inadvertently missed. Furthermore, a search for digital resources cannot be replicated due to the rapidly changing market and time-dependent popularity, which warrants the need for the development of validated search frameworks in this field.

Conclusions

This review emphasizes the substantial limitations in publicly available consumer-facing digital resources for monitoring and optimizing GWG. Most tools reviewed were of low quality overall, had minimal ability to support behavior change, and were potentially unsafe, with minimal linkage to evidence-based information or partnership with health care. When women require increased support for health optimization, these results emphasize the minimal likelihood of currently available resources to positively influence GWG or, ultimately, health outcomes during this time. Owing to the extensive use of publicly available digital tools, these findings underscore the critical need for better linkage among health, research, and commercial sectors to design apps that are high quality across visual appeal, functionality, credibility, safety, and effectiveness in lifestyle modification and self-management of GWG.

Authors' Contributions

BRB, CLH, JAB, and RMG conceptualized and refined the research idea. CLH and HJT were responsible for funding to support the work. BRB, CLH, MJH, JAB, and RMG designed the study. BRB, CLH, and RMG conducted the literature search and screening of tools. BRB, MJH, SJdJ, AC, QVH, RMG, and CLH conducted data extraction and preparation; BRB synthesized data and conducted statistical analyses. All authors assisted in the interpretation of the analyses, had intellectual input into manuscript and reviewed and approved the manuscript. BRB prepared the manuscript. CLH and RMG supervised this work and CLH has overall responsibility for the work and is the corresponding author.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Gestational weight gain criteria.
[DOCX File , 18 KB-Multimedia Appendix 1]

Multimedia Appendix 2

Mobile App Rating Scale.
[DOCX File , 50 KB-Multimedia Appendix 2]

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Multimedia Appendix 3

App Behavior Change Scale.
[DOCX File , 23 KB-Multimedia Appendix 3]

Multimedia Appendix 4

Quality evaluation criteria.
[DOCX File , 22 KB-Multimedia Appendix 4]

Multimedia Appendix 5

Description of digital tools for gestational weight gain management (results table).
[DOCX File , 15 KB-Multimedia Appendix 5]

Multimedia Appendix 6

Performance on gestational weight gain (GWG) quality questions (inclusion of GWG-specific tools or features; results figure).
[PNG File , 67 KB-Multimedia Appendix 6]

Multimedia Appendix 7

Performance on quality evaluation (results table).
[DOCX File , 14 KB-Multimedia Appendix 7]

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Abbreviations

ABACUS: App Behavior Change Scale
GWG: gestational weight gain
ICC: intraclass correlation
MARS: Mobile App Rating Scale
O&G: obstetrics and gynecology

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Chapter 5. Development of the OptimalMe program

5.1   Introduction

OptimalMe is a randomised, hybrid implementation effectiveness study of an evidence-based healthy lifestyle intervention aimed to address modifiable lifestyle factors and excess weight before, during and after pregnancy. OptimalMe is delivered to women planning a pregnancy, and provides tools, resources and coaching to women prior to and during pregnancy. Women receive the same intervention, yet are randomised into two groups for remotely delivered health coaching (phone vs video conferencing). Evidence comparing the impact of different remotely delivered consultations is limited, therefore feasibility, engagement, adherence, acceptability and effectiveness of delivery methods will be compared to inform future digital health intervention. The program has been made possible due to a collaborative partnership with Medibank Private, one of Australia's largest health insurers, who facilitated connection with women planning a pregnancy by inviting members, who joined or upgraded with pregnancy and birth cover, to take part in our program. This partnership is an example of a positive partnership to address to CDoH (71) and enabled us to engage a hard-to-reach population. The program will include an evaluation of intervention penetration and reach and the feasibility, acceptability, adoption and fidelity of the intervention implemented into, and in partnership with, private healthcare. Secondary outcomes include evaluation of individual health outcomes associated with implementation delivery mode, which are included in the following chapter of this thesis.

This chapter outlines the design of the program, the intervention underpinning, outlines the primary and secondary outcomes and details the evaluation frameworks used. This protocol enables insight into the program, and replication of effective elements to benefit the wider population. Upon completion of the evaluation of OptimalMe, this research protocol will serve as a valuable example of the program strategies and methodologies for our research group and others working in the field of lifestyle management, and preconception through to post-birth engagement, especially in the context of digital health. In addition to my outlined contribution to the development and management of the program (refer to Background page 30-1), here I drafted some of the

methodological components and figures and provided overall intellectual contribution to the manuscript.

5.2 OptimalMe intervention for healthy preconception, pregnancy, and postpartum lifestyles

Harrison CL, **Brammall BR**, Garad R, Teede H

OptimalMe Intervention for Healthy Preconception, Pregnancy, and Postpartum Lifestyles: Protocol for a Randomized Controlled Implementation Effectiveness Feasibility Trial

JMIR Res Protocol. 2022 Jun 9;11(6):e33625.

Protocol

OptimalMe Intervention for Healthy Preconception, Pregnancy, and Postpartum Lifestyles: Protocol for a Randomized Controlled Implementation Effectiveness Feasibility Trial

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Abstract

Background: Reproductive-aged women are a high-risk population group for accelerated weight gain and obesity development, with pregnancy recognized as a critical contributory life-phase. Healthy lifestyle interventions during the antenatal period improve maternal and infant health outcomes, yet translation and implementation of such interventions into real-world health care settings remains limited.

Objective: We aim to generate key implementation learnings to inform the feasibility of future scale up and determine the effectiveness of intervention delivery methods on engagement, experience, acceptability, knowledge, risk perception, health literacy, and modifiable weight-related health behaviors in women during preconception, pregnancy, and postpartum periods.

Methods: This randomized hybrid implementation effectiveness study will evaluate the penetration, reach, feasibility, acceptability, adoption, and fidelity of a healthy lifestyle intervention (OptimalMe) implemented into, and in partnership with, private health care. Individual health outcomes associated with implementation delivery mode, including knowledge, risk perception, health literacy, self-management, and health behaviors, are secondary outcomes. A total of 300 women aged 18 to 44 years, who are not pregnant but wish to conceive within the next 12 months, and with access to the internet will be recruited. All participants will receive the same digital lifestyle intervention, OptimalMe, which is supported by health coaching and text messages during preconception, pregnancy, and postpartum periods. We will use a parallel 2-arm design to compare telephone with videoconference remote delivery methods for health coaching. Methods are theoretically underpinned by the Consolidated Framework for Implementation Research and outcomes based on the Reach, Engagement, Adaptation, Implementation and Maintenance framework.

Results: The study was approved on August 16, 2019 and has been registered. Recruitment commenced in July 2020, and data collection is ongoing. Results are expected to be published in 2022.

Conclusions: The study's design aligns with best practice implementation research. Results will inform translation of evidence from randomized controlled trials on healthy lifestyle interventions into practice targeting women across preconception, pregnancy, and postpartum periods. Learnings will target consumers, program facilitators, health professionals, services, and policy makers to inform future scale up to ultimately benefit the health of women across these life-phases.

Trial Registration: Australian and New Zealand Clinical Trial Registry ACTRN12620001053910; https://www.anzctr.org.au/Trial/Registration/TrialReview.aspx?id=378243&isReview=true

International Registered Report Identifier (IRRID): DERR1-10.2196/33625

(JMIR Res Protoc 2022;11(6):e33625) doi: 10.2196/33625

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Introduction

Background

Obesity is a major global public health and economic burden. In an increasingly obesogenic environment, young women are a high-risk population group with suboptimal lifestyle behaviors [1], accelerated weight gain, and rising obesity prevalence across early to middle adulthood [2,3]. Prior to pregnancy, excess weight affects fertility [4] and independently increases the risk of adverse maternal and neonatal outcomes [5]. During pregnancy, up to 50% of women exceed international gestational weight gain recommendations [6], which increases their risk of complications, such as gestational diabetes, cesarean section delivery, and having a large-for-gestational-age infant, compared with those whose weight gain is within recommendations [6,7]. Independent of maternal prepregnancy BMI, excessive gestational weight gain increases subsequent childhood [8,9] and maternal obesity by 3-fold [10]. Excessive gestational weight gain superimposed on preexisting overweight or obesity further exacerbates risks and perpetuates a cycle of weight gain in women across their reproductive lifespan [11].

Pregnancy is a critical window in which maternal health behaviors and lifestyle should be optimized to benefit the future health of both mother and child [11]. Consequently, most research to date has concentrated on efficacy-based antenatal lifestyle interventions for improving outcomes [12,13]. A recent systematic review and meta-analysis [12] by the US Prevention task force of 68 trials that involved a total of 25,789 women reported a reduction in gestational weight gain after behavioral lifestyle interventions (mean difference −1.02 kg, 95% CI −1.30 to −0.75; 55 studies; n=20,090), with an associated reduction in gestational diabetes (relative risk 0.87, 95% CI 0.79 to 0.95; 43 trials; n=19,752) and emergency cesarean delivery (relative risk 0.85, 95% CI 0.74 to 0.96; 14 trials; n=7520) risks [12]. This level 1 evidence on antenatal healthy lifestyle intervention efficacy is supported by findings of cost-effectiveness and potential cost savings [14], mandating translation into policy and practice [12,15].

However, vital implementation gaps remain [16]. Weight management guidelines for preconception and pregnancy periods lack quality, consistency, and translation of effective intervention strategies into practice with extended reach that is in line with real world experience [17]. Barriers in the preconception period include identifying and engaging women who intend to become pregnant and who are, otherwise, not regularly engaged with the health care system [18]. In pregnancy, identifying broad reach, feasible intervention delivery methods, including remote delivery options, remains unclear [12,13]. Barriers in the postpartum period include engagement, penetration, and uptake of healthy lifestyle interventions with very limited reach and impact to date [19]. To leverage the substantial investment in efficacy trials and deliver health impacts, these barriers must be addressed.

We previously designed a low-intensity, low-cost healthy lifestyle program, called HeLP-her, that has engaged thousands of reproductive-aged women and has an extensive evidence base [16,20-24]. The program effectively prevents progressive weight gain in reproductive aged women [22,23], estimated to be between 0.625 kg and 1.2 kg per year [25], depending on the population studied [2,26]. During pregnancy, HeLP-her optimized gestational weight gain (intervention: mean 6.0, SD 2.8 kg; control: mean 6.9, SD 3.3 kg; *P*<.05) and postpartum weight retention (intervention: mean 0.51, SD 4.48 kg; control: mean 1.96, SD 5.74 kg; *P*<.05) overall, with the greatest efficacy demonstrated in nonobese women [20,21,27]. HeLP-her is theoretically underpinned and improves self-management behaviors through health coaching supported by intervention resources and self-management tools. It has been contextually adapted successfully across delivery methods, settings, and life stages, retaining core components to ensure fidelity [16,20,21,23].

Our formative work has included extensive evidence synthesis to systematically evaluate the efficacy of lifestyle interventions incorporating diet, physical activity and weight- and self-management behaviors during preconception [28], pregnancy [13], and postpartum [19] periods, to integrate key intervention components and inform study design. We have developed and integrated health-related content based on best practice clinical guidelines [29,30] and have identified facilitators and barriers to healthy lifestyle– and weight-related behaviors, information preferences, and health professional engagement across these life stages [31-34]. We have engaged consumers and health professionals to iteratively adapt our evidence-based intervention for broader reach, with translation of the intervention content, resources, and tools to a dedicated web-based digital platform, and have performed extensive consumer testing to evaluate and iteratively optimize acceptability, relevance, and engagement of intervention content in a representative target population of women.

Overall Aim

Applying a hybrid effectiveness-implementation study, we aim to generate key implementation learnings to inform the feasibility of future scale up and determine the effectiveness of intervention delivery methods on engagement, experience, acceptability, knowledge, risk perception, health literacy, and modifiable weight-related health behaviors in women during preconception, pregnancy, and postpartum periods.

Specific Objectives

Our objectives are as follows:

1. Determine implementation feasibility with 1) process evaluation (ie, measure of process used to implement the program and any variation experienced; facilitators and barriers to intervening events impacting implementation), 2) the RE-AIM framework to assess Reach, Effectiveness, Adoption, Implementation and Maintenance of the intervention and 3) cost effectiveness analysis.

2. Evaluate intervention participation (ie, engagement and adherence to program) and engagement (ie, degree of online module completion, frequency, and duration of time spent on the platform).

3. Determine intervention effectiveness on health related outcomes measured at the individual level including health knowledge, health literacy, and self-management behaviors.

4. Determine any discrepancy according to the health coaching delivery method.

Hypotheses

We hypothesize as follows:

1. The intervention will be feasible to implement and can effectively reach and engage women prior to pregnancy through co-designed strategies that are acceptable to women and the implementation partner with demonstrated cost-effectiveness.

2. Participation and engagement with intervention resources will be greater for participants who complete the intended intervention dose compared with those who do not.

3. The intervention will improve preconception and pregnancy health knowledge and self-management.

4. Phone and videoconference health coaching delivery will be equally feasible and cost-effective, yet engagement, adherence, and effectiveness will be greater with videoconference compared with phone-based health coaching.

Methods

Implementation

Design

OptimalMe is a type 3 hybrid effectiveness-implementation study [35] with an active intervention phase (2 years) and a passive observation phase (up to 5 years). Type 3 hybrid implementation designs are those in which implementation outcomes are primary, and individual or population outcomes are secondary [35]. The primary outcome of the project includes overall intervention penetration and reach and the feasibility, acceptability, adoption, and fidelity of the delivery of OptimalMe. Secondary outcomes include evaluation of individual health outcomes associated with implementation delivery mode, including knowledge, risk perception, health literacy, self-management, and health behaviors. The study design is a parallel, two-arm, randomized trial at the level of the individual utilizing a pragmatic philosophy, working within real-world conditions to assess overall effectiveness. All individuals will receive the same evidence-based lifestyle intervention, and implementation delivery methods will be compared.

Setting

The Australian health care system is government supported via Medicare, which provides universal free care to Australian citizens and residents (and others who are eligible) and is supported by a subsidized private health system. Private health insurance, paid by the individual, allows patients to choose hospitals and health care providers from outside of the public

system, with a 12-month waiting period before some, or all, of the cost of hospital treatment is reimbursed. Overall, approximately 54% of Australian adults have a form of private health insurance [36], and 27% of births in Australia occur in private hospitals [37]. Women who give birth in private hospitals attend ambulatory private obstetric care and have limited contact with hospitals prior to delivery.

Women who upgrade private insurance to include, or join with, pregnancy and birth coverage, comprise a unique population, prospectively signaling future intention for a pregnancy. In a sample of 294 women who had recently upgraded or obtained insurance for pregnancy and birth coverage, 41% intended to conceive within the next 12 months [33].

The implementation partner in this research program is Medibank Private, which is one of Australia's largest insurers (funding approximately 20,000 births annually). Feasibility scoping shows approximately 7800 women join with, or upgrade to, pregnancy and birth coverage with this insurer nationally each year.

Framework

This implementation research is underpinned by the Consolidated Framework for Implementation Research [38], which provides a pragmatic framework, informed by *translation into practice* theories, that is designed to guide complex implementation projects and generate knowledge across settings and studies [38]. The framework consists of 5 domains [38]: Domain 1 consists of the unadapted intervention to be implemented and assumes the intervention is composed of core or fundamental components, essential to efficacy, surrounded by peripheral components that are adaptable to the local context, without altering the integrity of the intervention. The adaptable components are informed by domain 2 (the outer setting, ie, policy, guidelines, population needs), domain 3 (the inner setting, ie, the organization's structure, culture, readiness to change), and domain 4 (the individuals within the outer or inner setting involved in the intervention as influencers of implementation. The implementation process (domain 5) works across all domains to achieve implementation through an iterative change process of executing and evaluating implementation activities [38].

The fundamental core components of our intervention include theoretical underpinning; simple diet; physical activity and self-management messages; low-intensity delivery format; individual health coaching sessions focused on goal setting, problem solving, and self-management delivered by a qualified health professional; and ongoing intervention support via text messaging (Domain 1). Core components were informed by our extensive intervention evidence base [16,20,21,23] and were consistently applied to setting, population, intervention tools, resources, and delivery method and format. The integration of peripheral intervention components was undertaken to incorporate best practice clinical guidelines and systematic review lifestyle intervention evidence (Domain 2) and using an intervention co-design process with the implementation partner, Medibank Private (Domain 3) experts in obstetric and lifestyle delivery and reproductive women in this life stage (Domain 4). This included the incorporation of health education resources

within the intervention and the development of a consumer-tested web-based digital platform for remote delivery and comanaged participant engagement. The efficacy of health coaching delivery methods (phone and videoconference) will be compared. A governance process has been established to enable responsive and pragmatic adaptations to peripheral components in partnership with the implementation partner (Medibank Private), yet designed and managed by the clinician academic research group (Monash University). The primary outcomes form Domain 5, which includes overall intervention feasibility, reach, acceptability, and adoption as well as fidelity of the delivery of OptimalMe as planned.

Study

Design

The study will be conducted in accordance with Consolidated Standards of Reporting Trials [39] and Template for Intervention Description and Replication frameworks [40].

Eligibility Criteria

The target intervention population will include Medibank Private members who have joined or upgraded with pregnancy and birth coverage within the 3 months prior to recruitment (to align with likely planned conception based on insurance uptake and wait times). Eligibility criteria focus on inclusiveness and includes those who are not pregnant, who wish to conceive within 12 months of recruitment, who are aged 18 to 44 years, with any BMI, who read and speak English, and who have access to an internet-capable device will be included.

Sample Size

Given the implementation effectiveness study design, sample size has not been powered on a clinical outcome because the primary outcome is to determine implementation learnings to inform feasibility. Available funding enables intervention delivery to approximately 300 women, which is approximately 10% of the eligible population with intention to conceive, based on our formative research [33].

Randomization

Participants will be randomized to receive health coaching either by telephone or via videoconference. An external senior statistician will provide computer-generated randomization codes to the research coordinator only, who will sequentially allocate all participants but will have no role in intervention delivery. Researchers involved in intervention delivery and data collection will be blinded to the allocation sequence; however, due to the nature of the intervention, they will not be blinded to participant allocation. Researchers responsible for data analysis and reporting will be blinded to both allocation sequence and participant allocation. Randomization performed external to the implementation setting is designed to reduce bias. Due to the nature of the intervention, participants will not be blinded to group allocation.

Recruiting Strategy

A co-designed process, using an opt-in design, was developed with the implementation partner to facilitate Australia-wide recruitment. We will use direct email communication (approximately 500 members every month, to be varied based on response rates and historical trends in email engagement observed during specified periods, including seasonal holiday periods) to recruit women (randomly selected to receive a targeted invitation by system generated mailing lists) who meet initial eligibility criteria (insurance coverage and age) with a link to the landing page of the web-based intervention platform. The page contains introductory information about the healthy lifestyle intervention, including a video. Individuals who wish to take part will be required to confirm remaining eligibility criteria, including pregnancy status and intention to conceive within 12 months, provide informed consent electronically, and register via a digital interface. The researcher coordinator will then contact the Medibank-managed integrated voice recognition system to confirm the potential participant's membership (using first and last name, membership ID, date of birth, and postal code) and pregnancy and birth coverage status to confirm eligibility. An email with an activation link to an account for the intervention will be sent to participants, at which time, they are randomized to 1 of the 2 coaching delivery methods. Recruitment will continue until target numbers (n=300) are reached. This pragmatic approach enables management of participant flow into the intervention and will not disqualify those who may be unaware of pregnancy status at point of recruitment or who may re-evaluate their intention to become pregnant after recruitment (Multimedia Appendix 1).

Intervention

Theoretical Underpinning

This intervention is based on our previous healthy lifestyle program—HeLP-her [16,20-23,27]). HeLP-her is a low intensity, behavior change program, grounded in social cognitive theory [41]. HeLP-her is nonprescriptive and provides health coach–delivered simple messages on healthy lifestyle behaviors aligned with national dietary and physical activity guidelines [30,42,43]. These are reinforced by behavior change strategies including identifying individual health priorities and facilitators and barriers for change. Realistic achievable goals are prioritized and developed by participants, and a behavioral action plan that outlines goals and timeframes is established. Individual barriers, strategies for change, and social supports are identified and discussed, and self-monitoring is practiced and encouraged [27].

Delivery

Co-design of intervention delivery with the implementation partner prioritized remote delivery to ensure equitable accessibility to the intervention across Australia by using a dedicated web-based digital platform, supported by health coaching (delivered via phone or videoconference), with ongoing text message support (Figure 1).

Figure 1. OptimalMe program design and delivery.
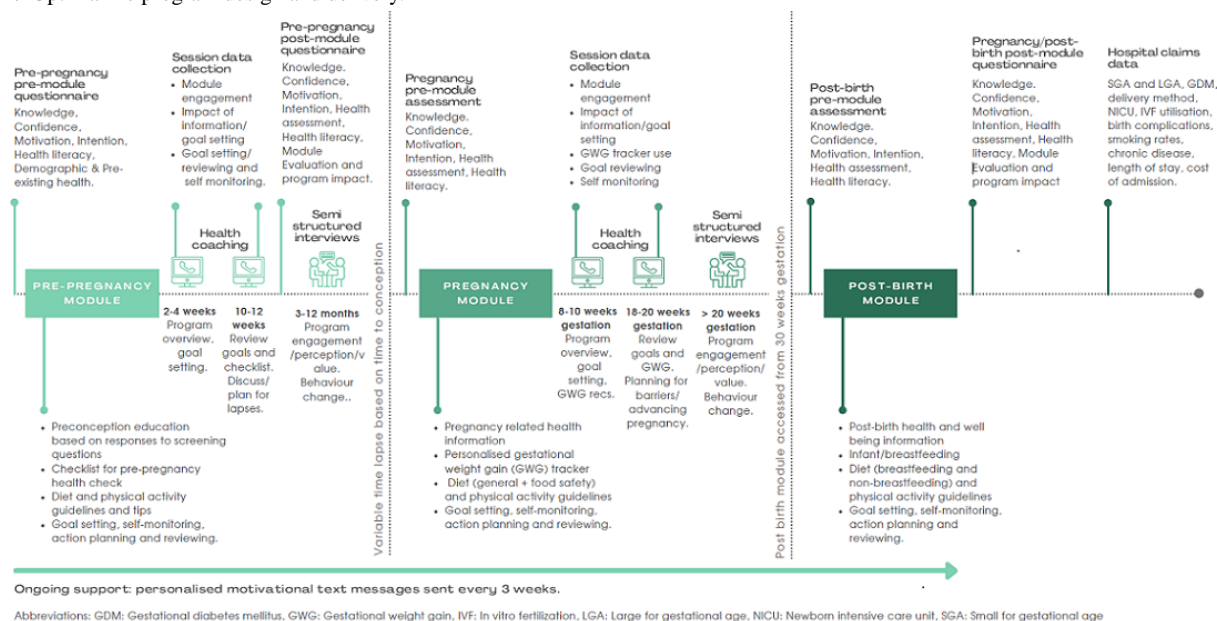
Platform

The secure web-based platform can be accessed via desktop and mobile apps. The platform contains preconception, pregnancy, and postpartum modules. Participants are provided access to the preconception module at the outset from the dashboard (Figure 2). The pregnancy module is accessible to participants when they update their personal profile on the dashboard (pregnancy status and estimated due date). In addition to the 3 modules, the dashboard contains an interactive BMI (and gestational weight gain, if pregnancy is reported) calculator, a checklist, and activities to review behavioral action plans.

All modules have a similar format—each has a health information (education) section and a healthy lifestyle behavior change (self-management) section. The health information section contains health, medical, and screening information and the healthy lifestyle section contains diet and physical activity recommendations, as well as an interactive behavior change section. Health, medical, and screening information are presented as a suite of fact sheets specific each reproductive phase (Multimedia Appendix 2). Information provided is based on the Royal Australian College of General Practitioners Red Book [29], Australian Government Clinical Practice Guidelines for Pregnancy [30], and our formative research [33,34]. A series of health screening questions at module commencement based on these guidelines will inform the presentation of fact sheets according to relevance. For example, preconception participants will be asked when their last cervical screen was completed. If a participant indicates a cervical screen outside of a guideline-specified timeframe, the relevant cervical screening fact sheet will be presented under *Essential information* at the top of the screen. Conversely, if a participant indicates a cervical screen within a guideline-specified timeframe, the fact sheet will be presented under *Other recommended reading*. This design feature ensures that participants are directed to the information that is most relevant to their health needs (based on their responses to screening questions) while minimizing the burden of information, which has previously been identified as a barrier to receiving health information [31].

Fact sheets have a similar structure—each fact sheet has 3 to 4 key messages, followed by detailed topic information and links to other websites for additional evidence-based information. Each fact sheet is supported by an interactive component that enables the user to populate a checklist item summarized on the platform dashboard (Figure 2). For example, opening a fact sheet about cervical screening will populate the *Check my cervical screening status with my GP* item. Health literacy is tested at the top of each fact sheet with a true or false question, with corresponding information that explains the correct answer.

Healthy lifestyle resources include fact sheets related to weight gain prevention and infographics that are based on Australian adult pregnancy [30] and breastfeeding [42] dietary guidelines and physical activity guidelines [43]. Additional resources include information on how to read food labels, how to estimate food portion sizes, healthy snack and food substitution ideas, and calories consumed using various food choices versus those burned from walking. Behavior change is supported by an interactive goal-setting section that guides the user to develop a personalized goal through action planning, which includes an activity to self-select modifiable health behaviors for improvement (eg, packaged or convenience food consumption, alcohol intake, physical activity, fruit and vegetable intake, and sleep). Areas of relevance are selected and prioritized by each participant (ie, areas are ranked in order of importance). Participants are guided through goal-setting using free text to specify what they would like to achieve identify motivating factors and social support pathways, barriers to behavior change and specific strategies to overcome barriers that are time dependent and identification. An action item to review goals will be automatically added to the digital platform, which is encouraged 2 weeks after goal planning and commitment (Figure 2).

The platform was consumer-tested using a quantitative survey for functionality (ie, ease of navigation across the platform),

acceptability (ie, usefulness of the information, presentation and aesthetics, ease of understanding content) and relevance (ie, appropriateness of information, potential for the platform to assist in optimizing health behaviors, peer recommendation). The survey contained a series of statements requiring response on a 5-point Likert scale that ranged from strongly disagree to strongly agree, with an opportunity to provide free text. Responses were transformed to a binary representation (0, disagree and neutral; 1, agree). Overall, 36 women were recruited from the community with advertisements across all modules using both computer (19/36, 53%) and mobile phone or tablet (17/36, 47%) devices. Women were aged between 25 and 38 years old, and the majority were university educated (33/36, 92%). Most women agreed that they could navigate to different areas of the platform and return to the dashboard with ease (23/30, 77%); they found the platform to be aesthetically appealing (25/36, 69%), and the amount of information to be appropriate (28/36, 78%) and easy to understand in its presentation (29/30, 97%). The majority believed that the information would assist them in improving their health-related behaviors (25/30, 83%) and considered the platform relevant to recommend to women of the same life stage (24/36, 67%).

Figure 2. Platform user dashboard.
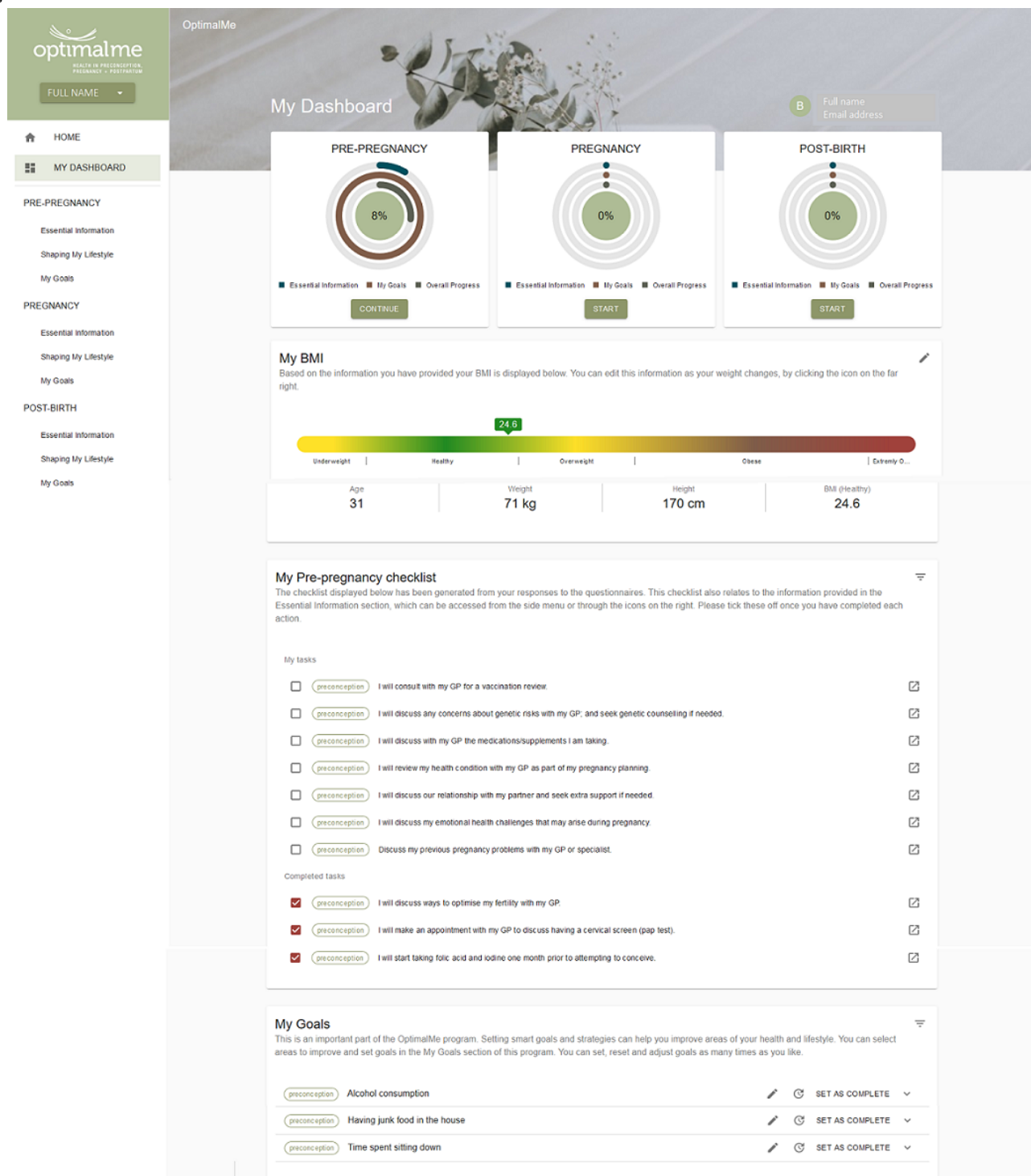
Health Coaching Sessions

Health coaches with a tertiary qualification in health sciences (ie, dietetics, nutrition, exercise physiology, or allied health) will deliver the program and aim for continuity wherever possible to maintain rapport. The purpose of the individual health coaching sessions is to build rapport with participants, reiterate program objectives, enhance engagement, practice goal setting and self-management skills, support participants with lifestyle modules, and provide personalized feedback on behavior change. Any module components that have not been accessed or completed by participants at the point of health coaching will be flagged for completion by the participant during or after the session.

All participants will be offered 2 personalized preconception health coaching sessions (approximately 20 minutes in duration, delivered either be phone or videoconference according to randomization) 2 to 4 weeks after program entry and 6 weeks later.

During pregnancy, 2 additional 20-minute health coaching sessions will be scheduled (8-10 weeks gestation or 1-2 weeks after starting the pregnancy module commencement and 19-20 weeks gestation).

Ongoing Program Support

SMS text messages will be sent every 3 weeks as a reminder to practice healthy behaviors.

Fidelity

Intervention fidelity will be maintained by facilitators using a checklist after health coaching sessions to reduce potential reporting bias. The checklist will include planned discussion points, deviation in delivery of session with reasons, and duration of session. Coaching sessions will be periodically recorded with participant consent to monitor fidelity.

Intervention facilitators will complete program-specific training on the intervention, including health coaching delivery. Facilitators will be required to have a sound knowledge of evidence-based practice; an understanding of health behaviors, nutrition, and physical activity; and a tertiary qualification in a health-related discipline. Program-specific training includes both theory and practical components and motivational interviewing techniques [20-23,44].

Outcome Measures

Outcome measures (Table 1) are underpinned by the RE-AIM (Reach, Effectiveness, Adoption, Implementation and Maintenance [45]). Both quantitative (recruitment and intervention delivery fidelity checklists [46]) and qualitative (semistructured interviews) data collection methods will be used (Multimedia Appendix 1 and Multimedia Appendix 2).

Table 1. Description of outcome measures.

Outcome	Description
Implementation feasibility (primary)	Program evaluation and feasibility for future scale up
Reach	• Proportion of the target population that were invited and participated in the program and intervening factors
Implementation fidelity	• Delivery according to design and any variation experienced • Facilitators and barriers: identification and description of intervening events
Adoption of the program by the implementation partner	• Contextual events or factors influencing implementation within the setting, variation in any co-design implementation component
Cost-effectiveness	• To answer questions about overall feasibility of implementation
Intervention effectiveness (secondary)	Exploratory evaluation of the effectiveness of intervention delivery across preconception and pregnancy (Figure 1)
Participation	• Adherence and engagement measures to intervention dose including health coaching sessions and web-based platform interaction including degree of module completion, frequency and duration of time spent on the platform
Acceptability	• A set of questions relating to the influence of the program in changing health behaviors, the usefulness and relevancy of the information provided, valuable aspects of the program and areas for improvement • Qualitative data analysis of insights, participation factors, intervention reach, adoption and maintenance of behavior change, intervention delivery format, and areas for improvement until thematic data saturation
Effectiveness	• On individual health behaviors including self-reported weight, health literacy [47], self-management [48], diet [49], and physical activity [50] using validated questionnaires • Collected at the start of the intervention, after preconception health coaching sessions and module, and at the start of the pregnancy module
Pregnancy and birthing outcomes	• In vitro fertilization utilization (restricted to only hospital component visibility of this process such as retrievals and transfers); gestational diabetes diagnosis, delivery type (ie, vaginal or cesarean section), birth complications and neonatal intensive care unit admission, length and cost of hospital stay and ancillary utilization (ie, physiotherapy, dieticians, dental) • Captured via encrypted data linkage with Medibank Private for health outcomes up to and including 5 years after the start of the study as observational study phase data

Statistical Analysis

Deidentified quantitative and qualitative databases will be maintained on encrypted Monash University servers and managed by research staff involved in data collection. We will use descriptive approaches to evaluate primary outcomes measures. Quantitative data collected for secondary outcome measures will be exported to STATA (version 17.0; StataCorp LLC). Descriptive statistics (means with standard deviations or frequencies with ranges) will be used to characterize intervention effectiveness and the recruited sample by demographic characteristics (age, BMI, country of birth, education, socioeconomic status, and parity), preexisting health, and health-related behaviors (ie, self-management, diet, and physical activity). Logistic and linear regression models will be used to explore associations between before and after the intervention. Additionally, factors known to influence secondary outcomes, including weight, such as diet, physical activity, breastfeeding status, and parity will be adjusted for a priori. Mixed-effects regression models, with the individual specified as the random

effect, will be investigated to account for repeated measures. Missing data will be examined, and multiple imputation will be used to generate complete data, if data are not found to be missing at random. Sensitivity analyses will be performed to explore robustness. A *P* value <.05 will be considered statistically significant.

Transcripts of semistructured interviews will be independently analyzed and coded by 2 researchers using NVivo software (version 12; QSR International). Data will be searched for concepts in relation to participatory factors and program evaluation, with codes generated and grouped into themes using an inductive approach. Quantitative data will be analyzed first, to inform thematic analyses. The definitions of themes will be determined by consensus (between 2 researchers).

Economic Evaluation

The economic evaluation will be designed to identify the costs associated with implementation, and the net costs to health care funders. Costs of the OptimalMe implementation package will

be identified from the trial data, including the costs of platform maintenance, staff time (in providing the coaching sessions), and SMS text messages. Fixed and variable costs will be identified, allowing cost per woman to be estimated at different scales of the intervention. The net costs to health care funders will be identified by quantifying the costs associated with birth type, birth complications, neonatal intensive care unit admissions, hospital stay, and ancillary utilization. Costs to Medicare Benefits Schedule will be identified based upon item numbers [51] associated with birth type and complications. Costs to private health insurers associated with hospital stay will be identified directly from the study. Costs to public hospital funders from neonatal intensive care unit admissions or any public hospital transfers will be identified from the National Hospital Cost Data Collection produced by the Independent Hospital Pricing Authority [52]. The total cost per woman will be calculated, and generalized linear models will be utilized to identify differences in costs between delivery methods. We will use these models to estimate the net cost impacts to different funders at different levels of the population reached.

Ethical Approval

The Monash Health Human Research and Ethics Committee approved the study (RES-19-0000291A), and the study has been registered (using predefined study description classifications; as such, the trial was registered as an efficacy trial in the absence of a feasibility study descriptor) on the Australian and New Zealand Clinical Trial Registry (ACTRN12620001053910).

Results

The project is supported with funding from Medibank Private Ltd. Recruitment commenced in July 2020 with results expected to be published in 2022.

Discussion

Prevention of weight gain and obesity is a global health priority. Increased emphasis is placed on high-risk populations [53,54], including reproductive-age women with accelerated preconception, pregnancy, and postpartum weight gain [6]. Lifestyle interventions can be used to optimize weight and reduce maternal and neonatal adverse outcomes [12,55], yet translation of effective interventions into real-world settings remains critically limited. We address this gap and leverage extensive investments in efficacy research by undertaking implementation research to inform feasibility, acceptability, applicability, effectiveness, and sustainability of an evidence-based weight gain prevention intervention for preconception, pregnancy, and postpartum periods. Implementation research leverages investment in efficacy-based randomized trial knowledge to study methods that promote the systematic uptake of evidence-based interventions into practice and policy to improve health [35].

Our study design aligns with best practice implementation research; focuses on system-level outcomes; and is underpinned by evidence from efficacy trials, systematic reviews, meta-analyses, and guidelines. Additional health information, specific to preconception, pregnancy, and postpartum life stages, has been integrated, with checklists and resources. Evidence on core and peripheral components has been integrated to adapt the intervention with stakeholders across women, multidisciplinary clinicians, and partners. Novel delivery strategies, including sophisticated digital platform and remote health coaching delivery methods, while retaining core intervention features including low-intensity individual health coaching and ongoing text message support. This work has integrated, and been supported by, robust implementation and intervention frameworks and theories.

We anticipate that the OptimalMe intervention will demonstrate feasibility and directly provide evidence to inform scaled intervention delivery. Learning will not only inform future implementation design but translation of evidence targeting consumers, program facilitators, health professionals, services, and policy makers to inform future scale up of healthy lifestyle interventions to ultimately benefit the health of women.

Authors' Contributions

CLH and HT conceptualized the trial. CLH, BRB, RG, and HT provided intellectual input into the trial design and methodology. CLH, BRB, and RG designed and wrote the intervention content. CLH and BRB implemented the trial. CLH, RG, and BRB designed the evaluation methodology and data collection. CLH drafted the manuscript. All authors reviewed the manuscript for intellectual content and approved the final version.

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Conflicts of Interest

None declared.

Editorial Notice

This feasibility randomized study was not registered, explained by authors that this is part of an efficacy randomized study that is registered. The editor granted an exception from ICMJE rules mandating prospective registration of randomized trials, because the risk of bias appears low and the study for which this protocol is reported was considered formative. However, readers are advised to carefully assess the validity of any potential explicit or implicit claims related to primary outcomes or effectiveness.

Multimedia Appendix 1

Co-designed recruitment strategy.
[PNG File , 158 KB-Multimedia Appendix 1]

Multimedia Appendix 2

OptimalMe health-related content (fact sheets) within preconception, pregnancy, and postpartum modules.
[PNG File , 146 KB-Multimedia Appendix 2]

Multimedia Appendix 3

CONSORT eHEALTH Checklist (V 1.6.1).
[PDF File (Adobe PDF File), 736 KB-Multimedia Appendix 3]

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Abbreviations

BMI: body mass index

Chapter 6. OptimalMe program evaluation in preconception

6.1   Introduction

Prior to the design of OptimalMe, there was a lack of prospective evidence regarding women's health and lifestyle behaviour during preconception, and engagement with interventions prior to pregnancy. This manuscript addresses a critical gap in evidence pertaining to the prospective health and behaviours of women planning a pregnancy. The lack of insight and population level efforts to improve women's health and lifestyle behaviour prior to pregnancy impacts the health of women, their ability to fall pregnant, and, if pregnancy occurs, the health and outcomes and of their pregnancy and children. OptimalMe responds to this evidence gap, by engaging women approaching a prospective pregnancy. OptimalMe provide the opportunity to improve lifestyle behaviour and health outcomes in the lead up to pregnancy, allowing sufficient time to address risk factors and improve outcomes. Through information provision, health and lifestyle coaching and goal setting, women autonomously determine what improvements they would like to make and are encouraged to independently engage with healthcare as they approach a pregnancy.

The aim of this chapter is to explain the impact of OptimalMe on behaviour during preconception. Here we compare women's baseline data with post-intervention data, that was collected on average 4.5 months after completion of the preconception program. I have evaluated overall cohort characteristics, as well as individual participant change. Phone and video delivery modalities are compared, allowing insight into the impact of delivery modes on behaviour change, a timely and significant finding as the uptake and interest in remotely delivered interventions and digital health is increasing.

I present favourable findings relating to self-reported behaviour change from the OptimalMe preconception program, these include the uptake of clinical screening and healthcare engagement, as well as modifiable lifestyle factors such as alcohol consumption, which was shown to be of significance in the first analysis of this PhD. Encouragingly, the delivery mode of coaching interventions had minimal difference on behaviour change, which is a positive finding suggesting that both phone and video intervention is effective for behaviour change programs.

Preliminary results from this study have been presented at the International Obesity Congress. Upon publication, this manuscript will be a novel example of prospective preconception intervention in women planning and pregnancy, and digital health engagement.

6.2 Improving preconception health and lifestyle behaviours through digital health intervention: the OptimalMe program

Bonnie R Brammall, Rhonda M Garad, Helena J Teede & Cheryce L Harrison

Evaluating Preconception Health and Behaviour Change Following a Randomised Type III Hybrid Effectiveness-Implementation Digital Healthy Lifestyle Intervention: The OptimalMe Program

Evaluating preconception health and behaviour change following a randomised type III hybrid effectiveness-implementation digital healthy lifestyle intervention: The OptimalMe Program

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Abstract

OptimalMe is a digital healthy lifestyle intervention for women planning a pregnancy, with remotely delivered coaching. This follow-up study, stratified by coaching delivery mode (phone vs. video conferencing), assessed alignment to preconception care guidelines and self-reported behaviour change. Overall, 308 women enrolled with a mean ± (SD) age of 31.7 (4.3) years and BMI 25.7 (6.1) kg/m². Suboptimal preconception behaviours were reported at baseline including alcohol consumption (57.1%), infrequent weighing (38.1%), and incomplete cervical cancer screening (14.0%) and prenatal supplementation (38.5%). At follow-up (n=220) a significant shift towards desired behaviours was reported for alcohol consumption (non-drinker) (z=-2.638, *p*=0.008), prenatal supplementation (taking supplement) (z=-2.573, *p*=0.010) and weighing behaviour (frequent weigher) (z=-16.442, *p*<0.00001). Results indicate that women who are actively planning a pregnancy require support to optimise health and lifestyle in preparation for pregnancy. Post-intervention outcomes suggest that remotely delivered preconception interventions improve lifestyle behaviours and engagement with clinical preconception care objectives.

Introduction

The health of women and their partners prior to pregnancy significantly influences fertility, pregnancy and intergenerational health outcomes (1-5) and is an increasing area of public health focus. Preconception care (PCC) comprises counselling and interventions that aim to detect and change biomedical, behavioural and social risks to optimise the health of women and their partners prior to pregnancy to improve maternal and neonatal health outcomes (6). The preconception period and associated care encompass three domains (6). Firstly, the biological perspective, which includes the days to weeks before embryo development (6). Secondly, the individual perspective, which comes after a decision to conceive, typically weeks to months before pregnancy occur (6). Finally, the public health perspective, which encompasses longer periods of months or years to enable adequate time to address preconception risk factors, such as diet and obesity (6).

Many preconception risk factors that influence pregnancy outcomes can be prospectively optimised in women with an intention to conceive. This includes folate, or folic acid, and iodine supplementation, substance use, alcohol consumption, medication review and factors related to

weight and energy expenditure imbalance including excessive energy intake, physical inactivity and sedentarism (1, 6). Increased weight prior to conception is associated with adverse risk of maternal and neonatal outcomes that are independently exacerbated by excess gestational weight gain during pregnancy including gestational diabetes mellitus, caesarean section, macrosomia and delivery of a large for gestational age infant (4, 7). Due to the detrimental impacts these risk factors have on reproductive health and maternal and child health outcomes (1, 4, 5, 7-9) identifying effective strategies to deliver interventions that promote behaviour change to optimise preconception health is imperative.

In women with an intention to conceive, optimising health related behaviours and wellbeing in the time before pregnancy is favourable, with increased likelihood of heightened motivation and readiness to improve health behaviours that benefit conception, pregnancy health outcomes and the health of their baby (10). Previous research addressing preconception health in women predominately focuses on higher-risk populations (i.e. women with overweight or obesity, sub- or infertility, polycystic ovary syndrome, pre-existing chronic medical conditions) and/or higher-risk behaviours (i.e. reduction or cessation in tobacco smoking, alcohol consumption) and/or weight loss, in which intervention efficacy has been demonstrated (11-14). While this supports preconception as a significant window of opportunity to improve health outcomes, it does not ultimately address provision of effective preconception health and lifestyle care to general populations of women who are planning a pregnancy and are otherwise healthy. As such, wide reaching, accessible interventions that are applicable to broad populations of women during preconception remains a critical public health challenge.

OptimalMe is a co-designed, coaching based, digital health intervention that aims to meet the unique needs of women who intend to conceive, during preconception. OptimalMe aims to target an otherwise healthy population of women to initiate PCC holistically, addressing preventative clinical care and relevant lifestyle behaviours during preconception, pregnancy and postpartum. Here, we aim to explore the impact of OptimalMe on secondary outcome measures, including self-reported behaviour change during preconception, and compare the impact of different delivery modes (phone and video conferencing) on behaviour change outcomes.

Methods

Study Design

The OptimalMe project is a type III hybrid effectiveness-implementation study (15). The intervention is a parallel, two arm randomised trial at the level of the individual. Women receive the same

intervention, yet are randomised into two groups for remotely delivered health coaching (phone and video conferencing). Detailed study design and methodologies have been previously published (16).

Population, Eligibility Criteria and Recruitment

Detailed eligibility and recruitment methods have been previously published (16). In brief, the target population for OptimalMe were female members of one of Australia's largest private health insurance providers, Medibank Private, who joined or upgraded with pregnancy and birth cover within three months prior to recruitment, who were not pregnant but wished to conceive within 12 months, aged 18-44 years, that read and speak English and had access to a digital device (i.e. mobile phone and/or desktop computer) with internet access. A co-designed process with Medibank Private was developed to facilitate Australia-wide recruitment using an opt-in design with women randomly allocated to one of two coaching delivery modes, including phone or video conferencing (16).

Intervention Overview

OptimalMe is underpinned by our previous healthy lifestyle program, HeLP-her (17-23), a low-intensity behaviour change program grounded in social cognitive theory (24) which effectively optimises weight and lifestyle related behaviours. The intervention is designed to be non-prescriptive with simple messages on healthy eating and physical activity aligned with national guidelines (25-27). Behaviour change is iteratively practiced through identifying health priorities and needs, goal setting and action planning, problem solving and self-monitoring, facilitated by a health coach.

OptimalMe is a digital program, with preconception information and outcome measures informed by the Royal Australian College of General Practitioners (RACGP) guideline for 'preventive activities prior to pregnancy' (6). Preconception health information is complemented by evidence-based lifestyle information with digital resources to promote self-monitoring (i.e. a preconception health checklist, body mass index [BMI] calculator) and a goal setting tool to set and review action plans (16). The digital program is supported by two personalised coaching sessions of approximately 20 minutes at two to four and ten to twelve weeks post commencement.

Outcome Measures

Quantitative questionnaires were completed at baseline, and after completion of the preconception intervention (evaluation). Questionnaires include demographic (i.e. age, country of birth (COB), ethnicity [highest level of classification] (28), marital status, working status, household income etc); reproductive history (i.e. parity and previous pregnancy outcomes); genetic/family history; general physical assessment (i.e. weight, height, chronic disease history and cervical screening history);

screening for immunisation status; folate/folic acid and iodine supplementation; self-weighing frequency, macronutrient food group intake and physical activity and sedentary behaviours; and substance use (i.e. tobacco, alcohol and recreational drugs) (6, 29).

Self-reported weight and height were used to calculate BMI (weight/height (m^2)), which was classified according to the World Health Organization definitions: underweight ($\leq$18.50kg/m^2); normal-weight (18.50–24.99kg/m^2); overweight (25.00–29.99kg/m^2); and obese ($\geq$30.00kg/m^2) (30). Self-weighing behaviours were classified as frequent (i.e. daily, weekly or monthly weighing) or non-frequent (i.e. occasional or never weighing).

Current and/or recent behaviour relating to alcohol consumption, recreational drug use and tobacco smoking was collected. Tobacco use was recorded by asking 'do you currently smoke', (yes/no/no, I stopped for pregnancy) and alcohol consumption at baseline was recorded by asking 'do you currently drink alcohol', (yes/no/no, I stopped for pregnancy). Then at preconception evaluation women were asked 'since starting OptimalMe have you: smoked, consumed (any) alcohol, consumed four or more alcoholic drinks in a single occasion' (yes/no).

Analyses

Data analysis was performed using IBM SPSS Statistics version 25 (Armonk, New York, USA). All data are presented as mean ± standard deviation (SD) for continuous variables or frequencies and percentages for categorial variables. A $p<0.05$ was considered statistically significant. Where a significant p-value was identified in a multiple comparison, Bonferroni correction was used to examine if the significance remained after adjusting for multiple groups (31). All descriptive statistics were tested for skewness by using the Shapiro–Wilk test.

At baseline, the Kruskal–Wallis Test, Mann-Whitney U or the chi-squared test (χ^2 tests) were used to compare characteristics of participants stratified by health coaching delivery groups. Response rates varied for each question, and therefore numbers differ throughout the results. Broad Australian Standard Classification of Cultural and Ethnic Groups (ASCCEG) (28), were applied and amalgamated for analysis due to small representations within groups. Little's Missing Completely at Random (MCAR) (32) analysis for evaluation data was conducted based on key demographics (age, BMI, COB, ethnicity, education, income, work status and marital status).

Adherence to PCC guideline and self-monitoring behaviours (i.e. self-weighing) were evaluated by estimating the proportion of women at baseline eligible to optimise at least one of the following domains: weighing behaviour (i.e. non-frequent to frequent weighing), alcohol consumption (i.e. current alcohol consumption to no alcohol or reduction in excessive alcohol consumption),

preconception supplementation (i.e. no supplementation to current supplementation) and cervical screening (i.e. eligible for screening but no screening reported to screening completed). Other domains (i.e. genetic screening, immunisation, smoking and recreational drug use) were not evaluated due to the paucity of data or incomplete information at baseline. At evaluation, change in health behaviours were analysed between intervention groups (i.e. phone versus video conferencing), based on within participant behaviours using chi-square tests to evaluate differential outcomes according to intervention delivery, and at the level of the cohort, using a test of overall sample proportions (z-score calculation).

Ethics

The Monash Health Human Research and Ethics Committee has approved the study (reference: RES-19-0000291A) which has been registered on the Australian and New Zealand Clinical Trial Registry (ACTRN12620001053910).

Results

Participant Demographics

Overall 527 women expressed interest to participate. Of these, 33 did not meet the inclusion criteria and a further 186 failed to engage after expressing interest, leaving 308 overall who were enrolled in OptimalMe and randomised to coaching delivery groups (phone n=158 and video n=150). The mean age of the recruited cohort was 31.7 (4.3) years and the majority were born in Australia (71.2%) and of Oceanian or European ethnicity (41.4% and 26.8%, respectively). Most women were highly educated (80.1% held a bachelor degree or above), in fulltime employment (77.5%) and were married or in a de-facto relationship (92.7%). No significant baseline differences in demographic characteristics were found between the health coaching groups (Table 1).

Table 1. Baseline Demographic Characteristics

Characteristic	All	Health coaching group		P-value
		Phone	Video	
Age (years) mean (SD)	*n=308*	*n=158*	*n=150*	
	31.7 (4.3)	32.1 (4.4)	31.2 (4.1)	0.182
Country of birth	*n=302*	*n=155*	*n=147*	
Australia	215 (71.2)	104 (67.1)	111 (75.5)	0.107
Outside Australia	87 (28.8)	51 (32.9)	36 (24.5)	
Ethnicity (identify as)	*n=302*	*n=155*	*n=147*	
European	81 (26.8)	41 (26.5)	40 (27.2)	
Oceanian*	125 (41.4)	64 (41.3)	61 (41.5)	0.254
Asian**	54 (17.9)	33 (21.3)	21 (14.3)	
Other	42 (13.9)	17 (11.0)	25 (17)	
Education	*n=302*	*n=155*	*n=147*	
Bachelor degree & above	242 (80.1)	127 (81.9)	115 (78.2)	0.798

Certificate	19 (6.3)	10 (6.5)	9 (6.1)	
Diploma	24 (7.9)	10 (6.5)	14 (9.5)	
Year 10 or below	1 (0.3)	1 (0.6)	0 (0.0)	
Year 12 or equivalent	16 (5.3)	7 (4.5)	9 (6.1)	
Working status	**n=302**	**n=155**	**n=147**	
Casual/temporary work	13 (4.3)	7 (4.5)	6 (4.1)	
Full time paid work	234 (77.5)	116 (74.8)	118 (80.3)	0.631
No paid work	19 (6.3)	13 (8.4)	6 (4.1)	
Part time paid work	36 (11.9)	19 (12.3)	17 (11.6)	
Weekly gross household income (AUD)	**n=302**	**n=155**	**n=147**	
Less than $999 per week ($51,999 or less per year)	9 (3.0)	4 (2.6)	5 (3.4)	
$1,000-1,499 per week ($52,000-77,999 per year)	29 (9.6)	14 (9.0)	15 (10.2)	
$1,500-1,999 per week ($78,000-103,999 per year)	34 (11.3)	22 (14.2)	12 (8.2)	0.259
$2,000-2,999 per week ($104, 155,999 per year)	71 (23.5)	33 (21.3)	38 (25.9)	
$3,000 or more per week ($156,000 or more per year)	116 (38.4)	54 (34.8)	62 (42.2)	
I prefer not to answer	43 (14.2)	28 (18.1)	15 (10.2)	
Marital status	**n=302**	**n=155**	**n=147**	
Married or de facto	280 (92.7)	142 (91.6)	138 (138)	
Never married or single	19 (6.3)	11 (7.1)	8 (5.4)	0.883
Separated or divorced	3 (1.0)	2 (1.3)	1 (0.7)	
Number of children	**n=302**	**n=155**	**n=147**	
None (0)	261 (86.4)	130 (83.9)	131 (89.1)	
One (1)	32 (10.6)	18 (11.6)	14 (9.5)	0.343
Two (2)	5 (1.7)	3 (1.9)	2 (1.4)	
Three or more (≥3)	4 (1.3)	4 (2.6)	0 (0.0)	

*Australian Peoples, New Zealand Peoples, Polynesia, Micronesia, Melanesian and Papuan **North-East Asian, South-East Asian, Southern and Central Asian.

Compared with key demographic characteristics from the Australia Bureau of Statistics; 38.4% of our cohort reported a higher household income than the population median ($2,329 AUD/week) (33). The frequency of those reporting unemployment (6.3%) was comparable to Australian females aged 15 years and over in 2020 (6.4% unemployed) (34). A similar portion of women in this study were born overseas, compared with the overall Australian population (28.8% vs. 29.1%) (35).

Baseline Preconception Health and Behaviour

Overall, mean BMI at baseline was 25.7 (6.1) kg/m^2, with 55.8% (n=172) of women classified as a healthy BMI and 61.9% reporting regular self-monitoring of weight. The majority of women reported planning their first pregnancy (56.1%), with 32.2% reporting current contraception use. At baseline, 81.8% of women (n=252/308) had at least one preconception health behaviour eligible for change to improve weight related behaviours (i.e. self-monitoring) and adherence to PCC preventative health guidelines.

Approximately 40% were yet to initiate preconception supplementation and 14.0% did not have up-to-date screening for cervical cancer prevention in accordance with Australia's National Cervical Screening Program (36). Overall, ~60% of women reported recently consuming alcohol, while 15.9% had stopped consumption to prepare for pregnancy. The incidence of smoking and recreational drug use was low (2.0% and 0.3%, respectively). No significant differences were observed between the two intervention groups (Table 2).

Table 2. Baseline Preconception Health Conditions and Behaviours

Characteristic/factor or action	All	Health coaching group		P-value
		Phone	Video	
Weight (kg) mean (SD)	*n=308*	*n=158*	*n=150*	
	70.4 (17.7)	70.7 (18.6)	70.1 (16.8)	0.770
BMI (kg/m²) mean (SD)	*n=308*	*n=158*	*n=150*	
	25.7 (6.1)	25.9 (6.3)	25.5 (5.9)	0.493
BMI category	*n=308*	*n=158*	*n=150*	
Underweight	10 (3.2)	2 (1.3)	8 (5.3)	
Healthy	172 (55.8)	94 (59.5)	78 (52.0)	0.144
Overweight	65 (21.2)	30 (19.0)	35 (23.3)	
Obese	61 (19.8)	32 (20.3)	29 (19.3)	
Weighing behaviour	*n=302*	*n=155*	*n=147*	
Frequent	187 (61.9)	103 (66.5)	84 (57.1)	0.249
Infrequent	115 (38.1)	52 (33.5)	63 (42.9)	
Chronic conditions/medical history	*n=294*	*n=153*	*n=141*	
Asthma	40 (13.6)	19 (12.4)	21 (14.9)	0.405
Depression	39 (13.3)	18 (11.8)	21 (14.9)	0.359
Anxiety	68 (23.1)	33 (21.6)	35 (24.8)	0.394
Polycystic ovary syndrome (PCOS)	38 (12.9)	25 (16.3)	13 (9.2)	0.094
None	148 (50.3)	73 (47.7)	75 (53.2)	0.316
Reproductive history	*n=294*	*n=153*	*n=141*	
First pregnancy	165 (56.1)	81 (52.9	84 (59.6)	0.706
Diabetes in pregnancy (GDM)	5 (1.7)	3 (2.0)	2 1.4)	0.460
Pre-eclampsia	3 (1.0)	3 (2.0)	0 (0.0)	0.121
Miscarriage/stillbirth	30 (10.2)	14 (9.2)	16 (11.3)	0.858
Birth defect(s)	3 (1.0)	2 (1.3)	1 (0.7)	0.863
Pre-term birth	6 (2.0)	5 (3.3)	1 (0.7)	0.284
None of the above	89 (30.3)	47 (30.7)	42 (29.8)	0.943
Genetic conditions (personal or family history)	*n=301*	*n=155*	*n=146*	
No	164 (54.5)	87 (56.1)	77 (52.7)	
Unsure	86 (28.6)	43 (27.7)	43 (29.5)	0.904
Yes	51 (16.9)	25 (16.2)	26 (17.8)	
Diagnosed iron/vitamin D nutrient deficiency (current or previous)	*n=273*	*n=141*	*n=132*	
Iron	151 (87.3)	72 (51.1)	79 (59.8)	0.325
Vitamin D	113 (41.4)	58 (41.1)	55 (41.7)	0.939
Unsure	72 (26.4)	39 (27.7)	33 (25.0)	0.833
Vaccines (up-to-date)	*n=275*	*n=143*	*n=132*	
Measles, Mumps, Rubella (MMR)	243 (88.4)	126 (88.1)	117 (88.6)	0.770
Hepatitis B	234 (85.1)	126 (88.1)	108 (81.8)	0.266

Tetanus/Diphtheria/Pertussis (whooping cough)	225 (81.8)	122 (85.3)	103 (78.0)	0.229
Immunisation status (in most recent flu season)	**n=301**	**n=155**	**n=146**	
Influenza vaccine	186 (61.8)	96 (61.9)	90 (61.6)	0.902
Immunisation status (virus/vaccine)	**n=301**	**n=155**	**n=146**	
Chicken pox (Varicella)	280 (93.0)	143 (92.3)	137 (93.8)	0.782
Cervical screening	**n=301**	**n=155**	**n=146**	
Up-to-date	259 (86.0)	135 (87.1)	122 (84.9)	0.780
Smoking status	**n=301**	**n=155**	**n=146**	
No	285 (94.7)	145 (93.5)	140 (95.9)	
No, I have stopped to prepare for pregnancy	10 (3.3)	5 (3.2)	5 (3.4)	0.442
Yes	6 (2.0)	5 (3.2)	1 (0.7)	
Alcohol	**n=301**	**n=155**	**n=146**	
No	81 (26.9)	42 (27.1)	39 (26.7)	
No, I have stopped to prepare for pregnancy	48 (15.9)	20 (12.9)	28 (19.2)	0.472
Yes	172 (57.1)	93 (60.0)	79 (54.1)	
Recreational drug* use	**n=301**	**n=155**	**n=146**	
No	296 (98.3)	153 (98.7)	143 (97.9)	
No, I have stopped to prepare for pregnancy	4 (1.3)	1 (0.6)	3 (2.1)	0.517
Yes	1 (0.3)	1 (0.6)	0 (0.0)	
Taking preconception supplement	**n=301**	**n=155**	**n=146**	
Both folic acid and iodine	105 (34.9)	59 (38.1)	46 (31.5)	
Folic acid (folate)	78 (25.9)	38 (24.5)	40 (27.4)	0.463
Iodine	2 (0.7)	0 (0.0)	2 (1.4)	
None of the above	116 (38.5)	58 (37.4)	58 (39.7)	
Using contraception	**n=301**	**n=155**	**n=146**	
Yes	97 (32.2)	44 (28.4)	53 (36.3)	0.307

* (Cocaine, Marijuana, Methamphetamines, Methadone, Heroin, and Ecstasy)

Post Intervention Preconception Health and Lifestyle Behaviour Change

The OptimalMe evaluation was completed by 220 women, 71.2% of the study population, an average of 4.5 months after commencing the intervention. Using demographical information, evaluation data was found to be missing at random, therefore negating the need for imputation.

Following intervention, 73.2% of women reported that they had visited a general practitioner (GP) in preparation for pregnancy, 45.5% had consumed alcohol (any) and 12.3% had excessively consumed alcohol (four or more standard drinks in a single occasion). Eighty-six percent (85.5%) of women indicated that they had improved their diet (increased fruit or vegetable, or decreased discretionary food intake), physical activity (increased physical activity or decreased sedentary behaviour) and/or another personally defined goal area (e.g. including, but not limited to improving sleep habits, reducing stress, increasing water consumption or reducing alcohol consumption). Approximately half of women believed that completing the intervention had improved their knowledge relating to healthy food choices (49.5%), unhealthy food choices (40.5%) and ways to be physically active

(48.1%). Between intervention groups, those who received health coaching via phone were significantly more likely to have had genetic testing and taken a vitamin D supplement since starting OptimalMe, with no further differences found (Table 3).

Table 3. Post Intervention Preconception Health and Lifestyle Behaviours

Factor or action	All	Health coaching group		P-value
		Phone	Video	
Weight (kg) mean (SD)	*n=206*	*n=111*	*n=95*	
	69.6 (18.3)	70.3 (18.6)	68.7 (18.0)	0.524
BMI (kg/m²) mean (SD)	*n=206*	*n=111*	*n=95*	
	25.5 (6.2)	25.9 (6.2)	25.0 (6.3)	0.329
BMI category	*n=206*	*n=111*	*n=95*	
Underweight	9 (4.4)	1 (0.9)	8 (8.4)	
Healthy	119 (57.8)	68 (61.3)	51 (53.7)	0.039*
Overweight	40 (19.4)	19 (17.1)	21 (22.1)	
Obese	38 (18.4)	23 (20.7)	15 (15.8)	
Weighing behaviour	*n=217*	*n=114*	*n=103*	
Frequent	182 (83.9)	94 (82.5)	88 (85.4)	0.551
Infrequent	35 (16.1)	20 (17.5)	15 (14.6)	
Genetic testing	*n=220*	*n=116*	*n=104*	
	42 (19.1)	28 (24.1)	14 (13.5)	0.032
Smoking	*n=220*	*n=116*	*n=104*	
	4 (1.8)	3 (2.6)	1 (1.0)	0.340
Alcohol	*n=220*	*n=116*	*n=104*	
Any consumption	100 (45.5)	56 (48.3)	44 (42.3)	0.252
Four (4) or more drinks in one sitting	27 (12.3)	16 (13.8)	11 (10.6)	0.386
Taken recreational drugs	*n=220*	*n=116*	*n=104*	
	1 (0.5)	0 (0.0)	1 (1.0)	0.304
Had any vaccine# (excluding COVID)	*n=220*	*n=116*	*n=104*	
	73 (33.2)	35 (30.2)	38 (36.5)	0.512
Cervical screening	*n=220*	*n=116*	*n=104*	
	57 (25.9)	31 (26.7)	26 (25.0)	0.605
STI screening	*n=220*	*n=116*	*n=104*	
	49 (22.2)	27 (23.3)	22 (21.2)	0.561
Taken a preconception supplement	*n=220*	*n=116*	*n=104*	
	159 (72.3)	86 (74.1)	73 (70.2)	0.312
Taken a Vitamin D supplement	*n=220*	*n=116*	*n=104*	
	108 (49.1)	64 (55.2)	44 (42.3)	0.040
Visited GP for PCC	*n=220*	*n=116*	*n=104*	
	161 (73.2)	79 (68.1)	82 (78.8)	0.412
Improved lifestyle behaviours (any)	*n=220*	*n=116*	*n=104*	
I did not need to	11 (5.0)	7 (6.0)	4 (3.8)	
No	17 (7.7)	8 (6.9)	9 (8.7)	0.534
Unsure	4 (1.8)	3 (2.6)	1 (1.0)	
Yes	188 (85.5)	98 (84.5)	90 (86.5)	
Increased knowledge	*n=220*	*n=116*	*n=104*	
Healthy food choices	109 (49.5)	58 (50.0)	51 (49.0)	0.821
Unhealthy food choices	89 (40.5)	50 (43.1)	39 (37.5)	0.289
Methods for physical activity	106 (48.1)	59 (50.9)	47 (45.2)	0.479

* No statistical significance after post-hoc Bonferroni correction (adjusted p value=0.00625). # Vaccine [EXCLUDING COVID]: (Measles, Mumps, Rubella (MMR), Hepatitis B, Tetanus/Diphtheria/Pertussis (whooping cough), Chicken pox, Influenza (flu))

At follow-up, of those eligible (80.5%, n=177/220,) to optimise at least one preconception health behaviour to improve weight related behaviours (i.e. self-monitoring) and adherence to PCC preventative health guidelines, 67.8% reported at least one desired change (120/177). This proportion increased to 82.5% if alcohol cessation was replaced with a reduction in excessive consumption. Significantly improved outcomes include a change in the proportion reporting not consuming any alcohol (p=0.008), commencing preconception supplementation (p=0.010) and regularly self-monitoring weight (p<0.00001, Figure 1). A trend was observed in the proportion of women who reported up-to-date cervical screening at follow-up, however this did not reach statistical significance (p=0.078, Figure 1).

Figure 1. Test of proportions for desired behaviour

Test of proportions (overall sample)

Alcohol consumption (baseline)	129 / 172	
Alcohol consumption (follow-up)	120 / 100	z=-2.638, p=0.008
Cervical screening (baseline)	259 / 47	
Cervical screening (follow-up)	196 / 22	z=-1.758, p=0.078
Preconception supp (baseline)	185 / 116	
Preconception supp (follow-up)	159 / 61	z=-2.573, p=0.010
Weighing behaviour (baseline)	184 / 115	
Weighing behaviour (follow-up)	182 / 35	z=-5.515, p<0.00001

■ Desired behaviour (n)   ■ Undesired behaviour (n)

Discussion

The OptimalMe study is the first to our knowledge to examine the impact of a low-intensity digital health intervention with remotely delivered coaching to a general, otherwise healthy female population with the intention to conceive. Our findings demonstrate divergence from PCC objectives (6), as previously shown in Australian women planning a pregnancy (37). Our evaluation supports the provision of PCC education and remotely delivered health coaching as an effective strategy for optimising women's health, with improved adherence to preventative preconception health actions and lifestyle behaviours, and a considerable increase in the uptake of primary care consultations to prepare for pregnancy.

The OptimalMe cohort consisted of women with private health insurance who were otherwise healthy, with low incidence of chronic diseases or relevant medical history. Despite this, many preconception health and behaviours were suboptimal. Women with private health insurance signal

an intention to conceive by upgrading to, or joining with a policy that includes pregnancy care. These women are subject to a 12-month waiting period before a pregnancy related insurance claim can be made. This provides a unique insight into the individual perspective of preconception when a decision to conceive is made, and provides a window of opportunity for intervention in the months before pregnancy. This is opportune for PCC but particularly novel for women whom are otherwise healthy to understand how they are preparing for pregnancy and determine if there are opportunities for health promotion. Whilst we report higher socio-economic status (SES) and education attainment compared to the general population, our cohort aligns with a large portion of the female population as ~50% of Australian women of reproductive age have private health insurance, and 25% birth in private hospitals (38). Baseline reporting from the OptimalMe cohort emphasised a range of opportunities for change such as alcohol consumption, infrequent weighing, incomplete supplementation and cervical screening, and not engaging with PCC before ceasing contraception. The majority of women (n=252, 82%) presented with one or more opportunities for lifestyle or clinical improvement. This suggests that higher SES and education are not protective or predictive indicators of optimal preconception health. Our baseline results align with previous research showing that suboptimal PCC is common in the general population, and strengthens the need for interventions to improve awareness of PCC and preventative health prior to pregnancy to all women of reproductive age, irrespective of health status and demographic factors.

Previous research has identified barriers for engagement with clinical care to prepare for pregnancy. These include lack of health care engagement due to ambivalence in planning for pregnancy, uncertainty of timeline to conception, perceived absence of risks and lack of awareness of PCC (39). Preconception and digital health interventions targeting women with diabetes indicate that interventions can significantly improve attitudes toward seeking of, and reduce barriers for, PCC (14). Similarly, OptimalMe encouraged health care engagement by providing women with a checklist for preconception actions to address and promote self-directed partnership with their primary health care provider. Action items included discussing fertility optimisation and genetic risks, and reviewing supplements, medications and medical conditions and checking cervical screening requirements, immunisation status and contraception. Previous studies report 40% of women planning a pregnancy had sought health or medical advice for pregnancy preparation (37). Following the OptimalMe intervention, 73% of women in this cohort had visited a GP to prepare for pregnancy. Compliance with cervical screening improved by 40% in women whose screening was not in accordance with the National Cervical Screening Program (36) at baseline. OptimalMe shows significant improvement in rates of healthcare engagement which suggests coaching based digital

health interventions may decrease women's barriers for PCC and improve engagement in clinical settings.

The OptimalMe preconception intervention improved lifestyle related knowledge and behaviours, and decreased high risk behaviours, with significant proportional shift to desired behaviours reported after the intervention. A large proportion (62%) adopted frequent weighing behaviour from an infrequent weighing at baseline. Given the benefit of self-weighing for weight management during pregnancy (40) and its ability to enable immediate adjustment to weight-related behaviours (41), initiating and maintaining this behaviour during preconception may lead to prevention of weight gain as well as significant improvements in weight management once a pregnancy does occur. Approximately 35% of women who consumed alcohol at baseline reported ceasing consumption altogether at evaluation, and a large proportion (80%) abstained from excessive drinking, since starting the intervention. The prevalence of alcohol consumption and excessing drinking in women actively trying to conceive, without known participation in PCC or an intervention, has been reported at 85% and 56%, respectively (37). Women who excessively drink before pregnancy are at particular risk of drinking after becoming pregnant (42) and the preconception period is regarded a critical time to intervene, particularly for planned pregnancies (43). While our cohort reported lower alcohol consumption at baseline (57%) compared to previous literature (37), OptimalMe significantly decreased the number of women consuming alcohol as they approached pregnancy. Our findings align with other digital health interventions that have demonstrated effective preconception risk reduction (13). Given the improvement in modifiable behaviours, digital interventions with health coaching may be an effective method to communicate risks and achieve behaviour change for women with the intention to conceive. These findings may extend to other areas of health promotion through digital interventions, however due to the potential for pregnancy intentions to increase motivation, digital interventions need to be tested in different settings and populations.

OptimalMe provides a setting in which health coaches can inform and encourage behavioural and social change to optimise the health of women prior to pregnancy, with the online education modules designed to improve knowledge attainment and increase awareness of biomedical factors and encourage women into consultation with clinical care. It is promising that women demonstrate uptake of this low-intensity, non-prescriptive information provision. These results confirm that the provision of knowledge enhancing tools and general healthy lifestyle information, combined with skilled health coaching focusing on small, sustainable improvements to be an effective method for behaviour change and self-management. Encouragingly, no difference was observed between intervention delivery groups, suggesting that both phone and video conferencing are acceptable for

preconception behaviour change interventions. Reaching a general population via a digital platform has the potential to improve equity and access for broader populations of women. Ninety-one percent of the Australian population are active internet users and the internet is commonly used to obtain information (44). Digital interventions present an opportunity to reach, promote, and deliver PCC and lifestyle interventions to women thinking about, or planning a pregnancy, who may not be engaged with health care. The suboptimal preconception health and behaviour of this cohort support the need for enhanced efforts towards PCC on a population level. OptimalMe is fit-for-purpose to be used nationally as a whole of population approach to improving PCC. Further evaluation of engagement factors and scoping of how to reach women outside of the private healthcare sectors is needed, however OptimalMe demonstrates a feasible step in the right direction for PCC.

Strengths and Limitations

Our rigorously developed questionnaire assessed an extensive range of health and lifestyle behaviours in accordance with the majority of national PCC recommendations (6). Our stratification by health coaching delivery methods strengthens the understanding of the impact of remotely delivered health and lifestyle interventions. The self-reported nature of our data may be considered a limitation, however, OptimalMe is an adaptation of interventions with proven clinical outcomes (17). Therefore, in order to move towards implementation of efficacy-based programs to test effectiveness and scalability, controlled clinical outcomes adopted in randomised trial designs are secondary to testing feasibility for pragmatic scale up and broader uptake where self-reported outcome methodologies are more likely to be used to favour increased accessibility, reach and engagement.

Our cohort consisted of women who had private health insurance, which may limit the generalisability of our results to other populations owing to an overall higher socio-demographic profile. However, we studied a group of women from the general population who compare with Australian census data, and therefore our findings likely apply to most Australian women. Our evaluation had a response rate of 72%, which is potentially indicative of the remotely delivered design. This may have influenced our results but is unlikely to have led to bias (45). Further work is required to transition the OptimalMe platform to meet the needs of low literacy, Culturally and Linguistically Diverse (CALD) and Indigenous persons, same sex couples, gender diverse or non-gender specific individuals and singles.

Conclusion

OptimalMe demonstrates that a low-intensity, non-prescriptive preconception lifestyle and health intervention in otherwise healthy women improved knowledge, behaviour and engagement with primary care. These improvements in lifestyle and adherence to PCC recommendations will have beneficial effects on the health of women and their children in the short and longer term. The findings of this study have important implications for equitable access to an evidence-based intervention for women in the preconception life phase.

Acknowledgments

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Chapter 7. Thesis outcomes and conclusions

7.1   Impact and translation of thesis work

The outcomes of this thesis go beyond research publications, informing digital health interventions and PCC to broad and multiple stakeholders including women, their offspring, health professionals, the maternity and primary care sectors and the broader community. Importantly, this body of research has influenced health policy and has addressed critical health and information needs of women in the perinatal period to inform the design and delivery of an innovative and novel digital health platform that aligns with clinical practice to drive positive behaviour change.

A high impact outcome was influencing health policy in relation to alcohol consumption and prevention of pregnancy related harm. Our data was used as part of a multi-sector advocacy campaign urging heads of Government to adopt alcohol labelling laws which highlight the dangers of alcohol consumption during pregnancy in Australia and New Zealand. Our prospective prevalence data on high levels of drinking in pregnancy were disseminated to relevant Australian Ministers in May 2020 and influenced new requirements for mandatory pregnancy warning labels on packaged alcoholic beverages in the Australia New Zealand Food Standards Code (the Code) on 31 July 2020 (72). In the two years since this the cross-sectional study in chapter one was published, there has been significant progress in public health initiatives relating to preconception alcohol consumption. Current public health media campaigns inform of risks during early pregnancy and encourage women to cease consumption as soon as women start trying to conceive.

Additional findings from chapter one relating to overall health and lifestyle behaviours influenced the development of OptimalMe and strengthened the rationale for preconception interventions. Our results demonstrated disparity between Australia's preventative care objectives during preconception (28) and the health behaviours of Australian women planning a pregnancy. We have demonstrated that pregnancy planning is not predictive of optimal preconception health and behaviour, and opportunities exist to improve awareness and healthcare engagement. This is reinforced by the findings in chapter six pertaining to baseline preconception behaviours in women participating in OptimalMe. This finding has reinforced the need for targeted approaches to women

planning a pregnancy, in women without established fertility concerns or medical conditions, and irrespective of educational levels or SES. As less than half of women planning a pregnancy had sought health or medical advice to prepare for pregnancy, our findings support previous evidence suggesting a lack of engagement with clinical care during preconception (73, 74). Given the potential for evidence-based PCC to optimise fertility and reduce adverse maternal and child outcomes, efforts are required to strengthen partnerships between women and their healthcare providers in preparation for pregnancy. To improve preconception health, PCC objectives and information regarding modifiable behaviours, specifically relating to preconception-and-conception outcomes, were a central focus of OptimalMe, in addition to general healthy lifestyle information and weight gain prevention strategies. This includes educational material and a personalised checklist for PCC in the OptimalMe digital program. Our preliminary results in chapter six indicate a positive impact on healthcare engagement and lifestyle behaviour in women who participated in our feasibility trial, via self-reported behaviour change. Our protocol manuscript outlines our methodologies and will allow others to target these health outcomes and behaviours in future interventions and public health initiatives.

Chapter two and three are formative examples of qualitative data that is not impacted by research settings or researchers. Extensive qualitative evidence about experiences and outcomes is available from perinatal women. In a research setting these insights are susceptible to recall bias, especially during periods of rapid and significant change (75). Furthermore, during pregnancy many women do not discuss internet sourced information with their health providers (38), which may extend into research settings. Therefore, health providers and researchers may not be aware of potentially inaccurate information reported on the internet or perceptions and opinions women may perceive to be private. Digital forums enable insights into unmediated and uninhibited conversations to understand the needs and concerns of forum users. The novel methodologies provided new insights into the sentiment of women and the impact of the pandemic and postpartum period, enabling access to data during a period with critical limitations for researchers to reach women. Critically, this methodology provided a unique research avenue to explore women's needs within the context of COVID-19 and the limitations that physical distancing and public health measures in Victoria (i.e. lockdowns) had on the ability to conduct face to face research that directly influenced my PhD across 2020 and 2021.

The findings of our postnatal forum publication informed the final communication sent to women prior to birth in OptimalMe. As the findings demonstrated minimal focus on maternal and lifestyle health needs, OptimalMe informed women of the importance of their own health and wellbeing in the postpartum period and encouraged ongoing self-monitoring and healthy behaviours after birth. These findings have the potential to significantly influence the design and strategies of future projects in late pregnancy and postpartum. Beyond the perinatal period, the analysis of internet-based discussions demonstrates valuable insights regarding needs and behaviours that may be precluded in surveys and research settings, warranting ongoing use of these methodologies for other populations.

The findings of chapter four pertain to the poor quality and minimal behaviour change potential of digital gestation weight tracking tools which are applicable to a large number of women and significant for women's health initiatives. Our results demonstrate that digital tools targeted to women seeking ways to track their GWG have been installed millions of times, thereby potentially reaching millions of women. Tools were evaluated using validated scales and a list of criteria based on the standards of pregnancy care (76). Our findings show significant divergence between the content and information women from a general population are utilising, and the objectives of health-and-preventive-care during pregnancy. Pregnancy is a high-risk period for accelerated and excessive weight gain (16), which is a strong predictor for the development of future obesity and chronic diseases (77). Given the tendency of women to trust digital health information (48), it is problematic that poor quality information and weight tracking tools are reaching a significant population of women. These findings underscore a critical need for better linkage between health, research and commercial sectors; increased regulation of publicly available, consumer facing digital resources with health-related information; and warrant further research into the quality of other health-focused digital tools.

The theoretical underpinning of this thesis is the SCT, a psychological framework that focuses on how individuals acquire and use knowledge, behaviours, and beliefs through social interaction and observation (54). A central concept of the SCT is self-efficacy, which refers to an individual's belief in their ability to successfully perform specific tasks or achieve desired goals in different situations. Encompassed in the theory is goal setting, and practicing skills in self-management and self-care to enhance self-efficacy. As such, the SCT forms the foundation of the OptimalMe intervention, and

our outcome paper demonstrates that with practiced goal setting and skills in self-management, positive behaviour change is achievable. Forthcoming work will deepen our understanding of the impact and acceptability of goal setting within the program, and the adaptation of embedded goal setting into a digital platform.

Formative work in earlier chapters are also relevant to the SCT, where women exhibit knowledge, awareness and intention to optimise health and lifestyle related behaviours in preparation for pregnancy, yet suboptimal behaviours and increased support needs remain. This suggests that women require external support to facilitate behaviour change over and above intrinsic motivation. Taken together and integrating the principles of SCT, we can optimise our interventions and empower women to make positive changes in their health behaviours.

7.2   Outcome of aims

Position	Aims	Outcome
Overarching	[…] to explore health, lifestyle and information seeking-behaviours during preconception, pregnancy and postpartum to inform evidence-based implementation of digital healthy lifestyle interventions across these reproductive life-phases.	Achieved: cross sectional data examining women's health and lifestyle behaviours prior to pregnancy; synthesis of online conversations during pregnancy and postpartum; and an evaluation of digital tools for gestational weight tracking were consolidated to inform women's health, digital health interventions and the OptimalMe program.
Chapter 1	To examine the health behaviours of Australian women during preconception, in accordance with PCC recommendations, and to compare the health behaviours of women at different stages of family planning	Achieved: this seminal manuscript shows the divergence between the health and behaviour of women planning a pregnancy, and Australian preventative health objectives prior to pregnancy. Women actively trying to conceive did not have better outcomes than women with longer-term pregnancy plans (1-2 years). These findings demonstrate a strong need for improved awareness of PCC and

		behaviours. Chapter one provides insights from an under researched and hard to reach population group.
Chapter 2	To examine the public discourse of a perinatal cohort to understand unmet health information and support needs, and the impacts on mothering identity and social dynamics in the context of COVID-19.	Achieved: this publication was one of the first to highlight the concerns and anxiety of women planning a pregnancy, pregnant or raising young children during the COVID-19 pandemic.
Chapter 3	To explore the conversations of new mothers on a web-based parenting forum to investigate what topics or concerns are being discussed.	Achieved: chapter three presents a novel manuscript that identified findings beyond topical concerns and highlighted postpartum stress and significant support needs as women navigate the first year postpartum.
Chapter 4	To evaluate the quality and behaviour change potential of publicly available digital tools (websites and apps) that facilitate GWG tracking.	Achieved: the systematic search enabled identification and evaluation of consumer facing tools containing GWG tracking. We identified that such tools have significant reach, with millions of installations. Digital tools and the surrounding information were assessed for quality and functionality using numerous validated frameworks (66, 67) and criteria (68). Tools were visually appealing, engaging and easy to use, yet the quality of health information and GWG tracking was poor, not informed by relevant guidelines and did not promote behaviour change or health care engagement if weight gain was outside or recommendations.
Chapter 5	To generate key implementation learnings to inform the feasibility of future scale up and determine the effectiveness of intervention delivery	Achieved: the OptimalMe protocol provides an example of best practice implementation research; focused on system-level outcomes; and is underpinned by evidence from

		methods on engagement, experience, acceptability, knowledge, risk perception, health literacy, and modifiable weight-related health behaviours in women during preconception, pregnancy, and postpartum periods.	efficacy trials, systematic reviews, meta-analyses, and guidelines. This protocol underpins the OptimalMe program across preconception, pregnancy, postpartum, with my focus being on PCC.
Chapter 6		To capture new knowledge regarding implementation of evidence-based digital lifestyle interventions in preconception.	Achieved: chapter six provides baseline preconception insights from an under researched and hard to reach population group. The behaviour change analysis shows proportional shifts to positive behaviour within the whole cohort, and individual participant data demonstrates desired behaviour change. Outcomes of women in phone and video intervention groups were compared which show similar outcomes for self-reported behavioural impact.

7.3   Conclusions and future directions

This thesis is built on the clear and compelling case for preconception interventions in women planning a pregnancy. It focuses on adapting and implementing lifestyle interventions into PCC, generating new knowledge about women's health and lifestyle behaviour during preconception. I have addressed the gap in prospective preconception research from women approaching pregnancy, contributing to established retrospective research from pregnant women, and general reproductive aged populations. My findings align with previous research, supporting the need for improved preconception health and preventative care, and extend this to inform implementation. In an otherwise healthy population, with high education and SES, we have demonstrated suboptimal alignment with preventative care objectives prior to pregnancy (28). These findings establish a critical need for improvement in women's health and lifestyle behaviours, and for preconception interventions such as OptimalMe. Further research is needed to understand the preconception health and behaviours of other populations, such as women birthing in public hospitals and those from lower SES and more diverse populations. This is especially important as the social gradient of health would suggest that the women in our research, who demonstrated

suboptimal baseline behaviours during preconception, would have better overall health and lower risks compared to those of lower socioeconomic positions (78). Exploration of barriers and enablers for digital health engagement and health promotion interventions among women of lower SES is critical to extend the reach of OptimalMe to more diverse population groups. The interconception period is an opportunity of interest.

OptimalMe is the first intervention known to the authors that is broad reaching, engaging otherwise healthy women prior to pregnancy who have the intention to conceive, to examine the impact of a remotely delivered coaching and digital health intervention. Results show positive impacts on self-reported behaviour change, with future analyses planned to further evaluate OptimalMe. In my forthcoming research, I intend to investigate engagement and acceptability factors within OptimalMe, via mixed-method analyses. This research will enable delineation of the impact of health coaching compared with other intervention components, such as digital resources and behaviour change tools, both alone and in conjunction. Preliminary analyses suggest that women require health coaching support to engage with digital interventions, and they value the contributions of a coach and the associated accountability they provide. These findings align with the results of a network meta-analysis of behavioural lifestyle interventions to optimise GWG, which demonstrated that the most effective interventions contain numerous behavioural components; such as goal setting, feedback, monitoring and shaping knowledge (79). My forthcoming research will aid in the development of future digital health intervention design and validate the core components of our weight gain prevention intervention in a digital setting with women during preconception and pregnancy.

Women's engagement with the internet for peer support and health information presents a case for digital health intervention during the perinatal period. The culmination of findings from internet-based communities and tools that women are engaged with during the perinatal period has been used to inform our digital health intervention. I explored digital forums, which are frequently used sources of digital support and information, and synthesised conversations to identify novel insights into women's needs. Those seeking health information and self-management tools on the internet should have access to evidence-based, accurate information. I have demonstrated unmet needs in women's support-and-information seeking, emphasising the need for improved health promotion during these critical periods. Overall, these insights informed our program design, enabling

development of a program shown to have a positive impact on lifestyle behaviours and uptake of healthcare to prepare for pregnancy. I have contributed to new knowledge in the field of implementation research that will inform future large-scale antenatal digital health interventions.

Skills and future direction

During this PhD I have gained skills in designing, implementing and evaluating digital health interventions; an exciting field which I hope to continue to learn from and impact. I have performed dynamic and interesting analyses, utilising new methodologies and developed a broad understanding of women's engagement with digital tools and forums. These learnings have been pragmatically utilised to develop and implement strategies to improve women's health. Post-doctorally, I will continue the evaluation of OptimalMe, including an in-depth understanding into digital health engagement via a mixed-method analyses, expanding our insights regarding the impact of remote intervention delivery modes. OptimalMe will be scaled for delivery in Monash Health Antenatal Care, Victoria's largest public health maternity care setting, to increase the reach and application into culturally and linguistically diverse (CALD) populations. Owing to the diverse catchment of Monash Health, a co-design process is currently underway to refine OptimalMe for delivery in this setting. This research involves experts in digital and interaction design, to enhance engagement and usability, and a consumer and community involvement (CCI) group that encompasses women from CALD communities with lived pregnancy experiences.

The established adverse health outcomes experienced by women during their reproductive years underscore the critical importance of interventions like OptimalMe. These interventions offer a unique opportunity to reach a wide range of women from diverse population groups at a low cost, thus improving their health outcomes and positively influencing future generations. Scaled delivery of evidence-based digital interventions that possess comparable visual appeal, functionality, and engagement to publicly available digital tools offer potential to counteract the prolific use of commercially developed tools that lack credibility, safety, and efficacy in lifestyle modification and self-management of GWG. Implementation learnings will provide vital understanding of population penetration, health system feasibility, uptake and sustainability, cost-effectiveness, return on investment and associated health outcomes to inform practice and policy and ultimately, transformative change. Finally, I will extend this work into other populations, including

interconception, understanding and evaluating ways to engage women for lifestyle modifications and improved health and lifestyle awareness during this formative life stage.

Appendices

Appendix 1. Supplementary material for Chapter 1

1.1 Improving Health in Australia, Monash Pre-Pregnancy Questionnaire

Supplementary Material S1 (Preconception Health and Lifestyle Behaviours of Women Planning a Pregnancy: A Cross Sectional Study)

Improving Health in Australia, Monash Pre-Pregnancy Questionnaire

1. **I agree to participate in this research study. I understand the purpose and nature of this study and I am participating voluntarily. I understand that I can withdraw from the study at any time, without any penalty or consequences.**
   - ☐ Yes
   - ☐ No <end survey>
2. **I grant permission for the data generated from this questionnaire to be used by Monash University to inform educational material and intervention design to improve the future health of mothers and their children.**
   - ☐ Yes
   - ☐ No <end survey>

Before you begin the questionnaire, it is important for us to know whether or not you are <u>currently pregnant</u>. The questions we ask will differ slightly depending on your circumstances.

3. *Are you currently pregnant? (Please select <u>one</u> option only)*
   - ☐ Yes <redirect to complete our Pre-pregnancy Questionnaire_Version 5 (ii)_CURRENTLY pregnant>
   - ☐ No

1. Planning Around Future Pregnancy

The questions in this section ask for detail about reproductive and contraception information.

1. **Are you planning a pregnancy in future?** *(Please select <u>one</u> option only)*

   - ☐ Yes, I am currently trying to conceive
   - ☐ Yes within 1 year
   - ☐ Yes within 5 years
   - ☐ Yes within 10 years *(Please proceed to question 3)*
   - ☐ No I have completed my family *(Please proceed to question 3)*
   - ☐ No I do not wish to have a future pregnancy *(Please proceed to question 3)*
   - ☐ I prefer not to answer *(Please proceed to question 3)*
   - ☐ I am unsure *(Please proceed to question 3)*

The question below asks about any actions you are currently taking to actively plan for a pregnancy.

2. **From the items below, what are you currently doing to improve your health in preparation for pregnancy?** *(Please select <u>all</u> that you are currently doing)*

☐ taking folic acid

☐ taking iodine

☐ taking vitamin D

☐ trying to stop or cut down smoking

☐ trying to stop or cut down drinking alcohol

☐ Improving diet

☐ increasing exercise levels

☐ improving sleeping patterns

☐ seeking medical/health advice

☐ taking some other action, please describe _____

☐ I am not doing any of the above <u>currently</u>

3. **Please tick to show if you have used <u>any</u> of the following methods of contraception <u>in the 6 months when engaging in sexual intercourse.</u>**

    (Even if you stopped using contraception, you can still tick option b. *'Nothing now – I am trying to conceive'* and tick other methods you had previously used within the past 6 months) *(Please select <u>one</u> response for each of the options a to n)*

Type	How often in the past 6 months have you used the following contraception method when engaging in sexual intercourse?			
	Never *0 in 10*	**Occasionally** *1-4 in 10*	**Some of the time** *5-9 in 10*	**Every time** *10 in 10*
a. Nothing	☐	☐	☐	☐
b. Nothing now – I am trying to conceive	☐	☐	☐	☐
c. Withdrawal	☐	☐	☐	☐
d. Condoms	☐	☐	☐	☐
e. Birth control pills (Oral contraceptives)	☐	☐	☐	☐
f. Cap/diaphragm	☐	☐	☐	☐
g. Contraceptive Injection (Depo-Provera)	☐	☐	☐	☐
h. Contraceptive Implant (Implanon)	☐	☐	☐	☐
i. Intrauterine device (IUD or coil)	☐	☐	☐	☐
j. Intrauterine system (IUS e.g. Mirena)	☐	☐	☐	☐
k. NuvaRing vaginal contraceptive ring	☐	☐	☐	☐
l. Abstinence (I am not having sex)	☐	☐	☐	☐
m. Emergency contraception (Morning-After	☐	☐	☐	☐
n. Other (please give details)	☐	☐	☐	☐

4. **Have you or your partner been treated or currently undergoing treatment for infertility?**

    ☐ Yes

    ☐ No

5. **Have you heard of a reproductive life plan? A reproductive life plan is a plan to have children (or not), the number, spacing and timing of intended children)?**

    ☐ Yes

    ☐ No

2. Lifestyle Information

The following section asks about your lifestyle, behaviours and experiences.

1. **In regards to your weight, are you currently:**

   ☐ A healthy weight (BMI: ≥18.5 - <25)
   ☐ Overweight (BMI: ≥25)
   ☐ Underweight (BMI: <18.5)
   ☐ Unsure

2. **Are you currently attempting to maintain a healthy weight or lose weight?**

   ☐ Yes, maintain a healthy weight
   ☐ Yes, lose weight
   ☐ No

3. **Are you currently experiencing any problems with your teeth or gums (e.g. tooth decay or holes in your teeth, bleeding gums, periodontal or gum disease)?**

   ☐ Yes
   ☐ No

4. **Have you visited the dentist in the past 12 months?**

   ☐ Yes
   ☐ No (If no, please specify why_____)

5. **Have you ever smoked?**

   ☐ Yes
   ☐ No
   ☐ Prefer not to answer

6. **If *yes*, are you currently smoking?**

   ☐ Yes, I am smoking _ _ _ cigarettes a day and I am currently <u>not</u> trying to quit.
   ☐ Yes, I am smoking _ _ _ cigarettes a day, but I am currently trying to quit in case I become pregnant.
   ☐ Yes, I am smoking _ _ _ cigarettes a day, but I am currently trying to quit for other reasons.
   ☐ No, I am not currently smoking in case I become pregnant.
   ☐ No, I am not currently smoking for other reasons.

Image: Examples of a standard drink of alcohol Adapted from Australian Government National Health and Medical Research Council (NHMRC) 2009, Australian guidelines to reduce health risks from drinking alcohol https://www.nhmrc.gov.au/guidelines-publications/ds10

7. **On average, how many standard drinks of alcohol did you have <u>per week</u> in the past <u>3 months</u>?** *(Please refer to the image above for examples of a standard drink of alcohol. If you are not drinking alcohol please put 0)*

	Monday - Thursday	**Weekends (Friday to Sunday)**
Average drinks consumed in the past 3 months	_ _ _	_ _ _

8. **In the past 3 months, how many times did you consume <u>four standard drinks or more on a single occasion</u>?** *(Please refer to the image above for examples of a standard drink of alcohol. If you are not drinking alcohol please put 0)*

    ☐ Number of times (please enter number of times) _____
    ☐ I don't remember/I don't know
    ☐ I had stopped drinking alcohol because I was trying to get pregnant

9. **Have you ever taken recreational drugs (e.g. Cocaine/crack, Marijuana, Methamphetamines, Methadone, Heroin, Ecstasy)?**

    ☐ Yes
    ☐ No *(**Please go to** section 3: Pre-pregnancy health information received)*
    ☐ Prefer not to answer *(**Please go to** section 3: Pre-pregnancy healthy information received)*

10. **If <u>*yes*</u>, when was the last time you took recreational drugs?** *(Please select <u>all</u> that apply)*

    ☐ Today
    ☐ Last week
    ☐ Last month
    ☐ Last year
    ☐ 5+ years ago

☐ I have stopped taking recreational drugs in case I became pregnant

☐ I have stopped taking recreational drugs for other reasons

☐ Prefer not to answer

3. Medical History and Previous Pregnancies

1. **Do you have a personal or family history of any genetic conditions?**

☐ Yes

☐ No

☐ Unsure

2. **If _yes_, were you _tested_ for any of these genetic conditions?**

☐ Yes

☐ No

☐ Unsure

3. **Please tick any vitamins or supplements you are _currently_ taking. *(Please select _all_ that apply)***

Vitamin or supplement name	Currently taking (please tick)
Multivitamin for pre-pregnancy (e.g. Blackmores Conceive Well Gold)	☐
Blackmores I-Folic	☐
Folate	☐
Iron	☐
Iodine	☐
Vitamin D	☐
Other (please specify) _____	☐
None	☐

4. **Are you up to date with any of the following immunisations? *(Please select _all_ that apply)***

☐ Measles, Mumps, Rubella (MMR)

☐ Hepatitis B

☐ Chickenpox (Varicella)

☐ Tetanus/Diphtheria/Pertussis (whooping cough booster)

☐ Influenza

☐ Others *(Please specify)* _____

☐ None of the above

5. **Have you undertaken a screening for cervical cancer prevention (e.g. Pap smear)?**

    ☐ Yes
    ☐ No

6. **Have you been tested for any sexually transmitted infections (e.g. Gonorrhoea, chlamydia) in the last 6 months?**

    ☐ Yes
    ☐ No

7. **Have you been pregnant before?**

    ☐ Yes
    ☐ No

4. Information About You

The following questions relate to your individual details and characteristics

1. **What is your date of birth?**

    _ _ / _ _ / _ _ _ _

2. **What country where you born in?**

    ☐ Australia
    ☐ United Kingdom
    ☐ India
    ☐ Sri Lanka
    ☐ New Zealand
    ☐ Afghanistan
    ☐ Philippines
    ☐ Mauritius
    ☐ China
    ☐ South Africa
    ☐ Other (please specify) _____

3. **What is your postcode?**

    _ _ _ _

4. **Do you identify as being Aboriginal and/or Torres Strait Islander?** *(Please select one option only)*

☐ Yes, Aboriginal
☐ Yes, Torres Strait Islander
☐ Yes, Aboriginal and Torres Strait Islander
☐ No, neither

5. **What is the highest level of schooling you have completed?** *(Please select one option only)*

☐ Year 9 or below (Junior High)
☐ Year 10 or equivalent (Middle High)
☐ Year 11 or equivalent
☐ Year 12 or equivalent (senior high)

6. **What is the highest post-school qualification you have completed? (please select one option only)**

☐ No post-school qualification/s
☐ Certificate
☐ Diploma
☐ Bachelor degree and above
☐ Apprenticeship

7. **Which of the following best describes your <u>main current</u> employment status?**

☐ In full time paid work
☐ In part time or casual paid work
☐ Work without pay (e.g. in a family business)
☐ Home duties only – no paid work
☐ Studying
☐ Unemployed – looking for work
☐ Unpaid voluntary work
☐ Unable to work due to sickness or injury
☐ Other *(Please specify)* _

8. **What is the average gross income (before tax) that your household receives each year, including pensions, allowances, and financial support?** *Please note that 'household' refers to the total of all major income earners.*

☐ $40,000 or less
☐ $41,000 – 64,999
☐ $65,000 – 80,000
☐ More than $81,000
☐ I prefer not to answer

9. **What is your current marital status?**

☐ Married
☐ Defacto
☐ Separated
☐ Divorced
☐ Widowed
☐ Never married

10. **What is your height without shoes? This is important,** *please measure your height or provide the closest estimate in centimeters or meters or feet.*

_____

11. **What is your weight without shoes? This is important,** *please measure your current weight or provide the closest estimate in kg.*

_____ kg

12. **How often do you weigh yourself?**

☐ Daily
☐ Weekly
☐ Monthly
☐ Occasionally
☐ Never

13. **Have you gained weight in the past year?**

☐ Yes
☐ No
☐ Unsure

14. **If yes, how much weight have you gained?**

☐ 1 – 2 kg
☐ 3 – 4 kg
☐ 5 kg
☐ 6 – 10 kg
☐ Greater than 10 kg

Ministerial letter: Deputy Chief Health Officer

Department of Health and Human Services

50 Lonsdale Street
Melbourne Victoria 3000
Telephone: 1300 650 172
GPO Box 4057
Melbourne Victoria 3001
www.dhhs.vic.gov.au
DX 210081

BAC-CO-2953

Rhonda Garad
Monash Centre for Health Research and Implementation
43-51 Kanooka Grove,
CLAYTON VIC 3145
Rhonda.Garad@monash.edu

Dear Dr Garad

Thank you for your email addressed to Jenny Mikakos MP, Minister for Health, Minister for Ambulance Services regarding pregnancy warning labels. The Minister has asked me to reply on her behalf. I apologise for the delay in responding.

Fetal Alcohol Spectrum disorders are a life-long disability that is an easily preventable disorder if alcohol is not consumed during pregnancy. However, many Australian surveys and evidence shows many women continue to report having consumed alcohol while pregnant and for many this is because there is confusion around if alcohol is safe to drink while pregnant. Pregnancy warning labels on alcohol are therefore important preventative public health measures.

At the Australia and New Zealand Ministerial Forum on Food Regulation (the Forum) meeting held on 17 July 2020, the Forum confirmed its ongoing commitment to mandatory pregnancy warning labels on alcohol. This decision was made in recognition of the imperative to prevent these disorders and reduce the significant effects of these conditions on families and the communities that support them.

The proposed draft standard for pregnancy warning labels recommended by Food Standards Australia New Zealand was accepted by the Forum, with the only change from the earlier proposal being a change in the signal words from 'HEALTH WARNING' to 'PREGNANCY WARNING'. Given the ongoing effects of a severe bushfire season and the coronavirus pandemic an extended transition period for implementation to three years was proposed and agreed.

The standard for pregnancy warning labels will now be gazetted and included in the Australia New Zealand Food Standards Code. The implementation period of three years will apply from the date of gazettal.

VICTORIA
State
Government
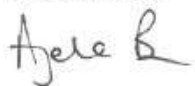
OFFICIAL

The Minister is satisfied that the label is the minimum required to alert consumers of the dangers of drinking while pregnant in order to reduce the incidence of these disorders and protect children.

I thank you for taking the time to write about this matter.

Yours sincerely

Dr Angie Bone
Deputy Chief Health Officer (Environment)
Health Protection Branch

27 / 08 / 2020

Deputy Premier
Minister for Education and Training
Minister for Mental Health and Wellbeing
Minister for Disability Services and Community Development
Minister for Trade
Minister for Advanced Manufacturing and Defence Industries

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Tasmanian Government

28 AUG 2020

Dr Rhonda Garad
Senior Lecturer and Research Fellow in Knowledge Translation
Monash Centre for Health Research and Implementation (MCHRI)
Email: Rhonda.Garad@monash.edu

Dear Dr Garad

Thank you for your letter on 21 July 2020, expressing your appreciation for the Tasmanian Government on its decision to support a more visible red, black and white pregnancy warning label on alcoholic beverages.

Leading up to the decision, I very much appreciated the information received from many individuals, Health and other organisations which helped establish a compelling social, scientific and economic case to support reform.

As the Minister for Mental Health and Wellbeing, Education and Disability Services and Community Development, this was an important outcome and one that will not only benefit future Tasmanian children but all Australians.

I feel well informed on the impact of Fetal Alcohol Specturm Disorder (FASD) on the wellbeing of children and their educational outcomes. However, I do recognise that more needs to be done in this area and I would be interested to receive feedback or policy ideas you may have, to support an ongoing decline in FASD.

Thank you once again for your positive feedback following the meeting of the Australia and New Zealand Ministerial Forum on Food Regulation.

I am very proud of the outcome we all achieved together.

Yours sincerely

Jeremy Rockliff MP
Deputy Premier
Minister for Mental Health and Wellbeing

The Hon Roger Cook MLA
Deputy Premier
Minister for Health; Mental Health

Our Ref: 60-29239

Dr Rhonda Garad
Senior Lecturer and Research Fellow in Knowledge Translation
Monash Centre for Health Research and Implementation
Rhonda.Garad@monash.edu

Dear Dr Garad

Thank you for your emails of 16 and 21 July 2020 regarding your support for pregnancy warning labels on alcoholic beverages and information on the Monash Centre for Health Research and Implementation (MCHRI) Preconception Health and Lifestyle Behaviours research study. I note, with interest, the MCHRI study findings that most women trying to conceive reported alcohol consumption during the previous 3-month period; and three out of five (59 percent) of these women reported drinking alcohol at concerning levels.

I appreciate your message of thanks for the McGowan Government support of the pregnancy warning labels on alcoholic beverages initiative. As you are likely aware, the State Government welcomes this final decision for an effective and evidence-based pregnancy warning label to be mandated in food law.

This labelling initiative is a significant and necessary step in increasing awareness of the dangers of consuming alcohol during pregnancy, and as you mentioned, can help to highlight the importance of abstaining from alcohol while trying to get pregnant. Increased awareness at individual and community levels will assist in reducing the harmful effects of drinking alcohol during pregnancy.

Thank you again for your support on this key public health measure and for sharing MCHRI's important research outputs.

Yours sincerely

HON ROGER COOK MLA
DEPUTY PREMIER
MINISTER FOR HEALTH; MENTAL HEALTH
-7 AUG 2020

13th Floor, Dumas House, 2 Havelock Street, WEST PERTH WA 6005
Telephone: +61 8 6552 6500 Facsimile: +61 8 6552 6501 Email: Minister.Cook@dpc.wa.gov.au

1.3 Supporting Media Interest
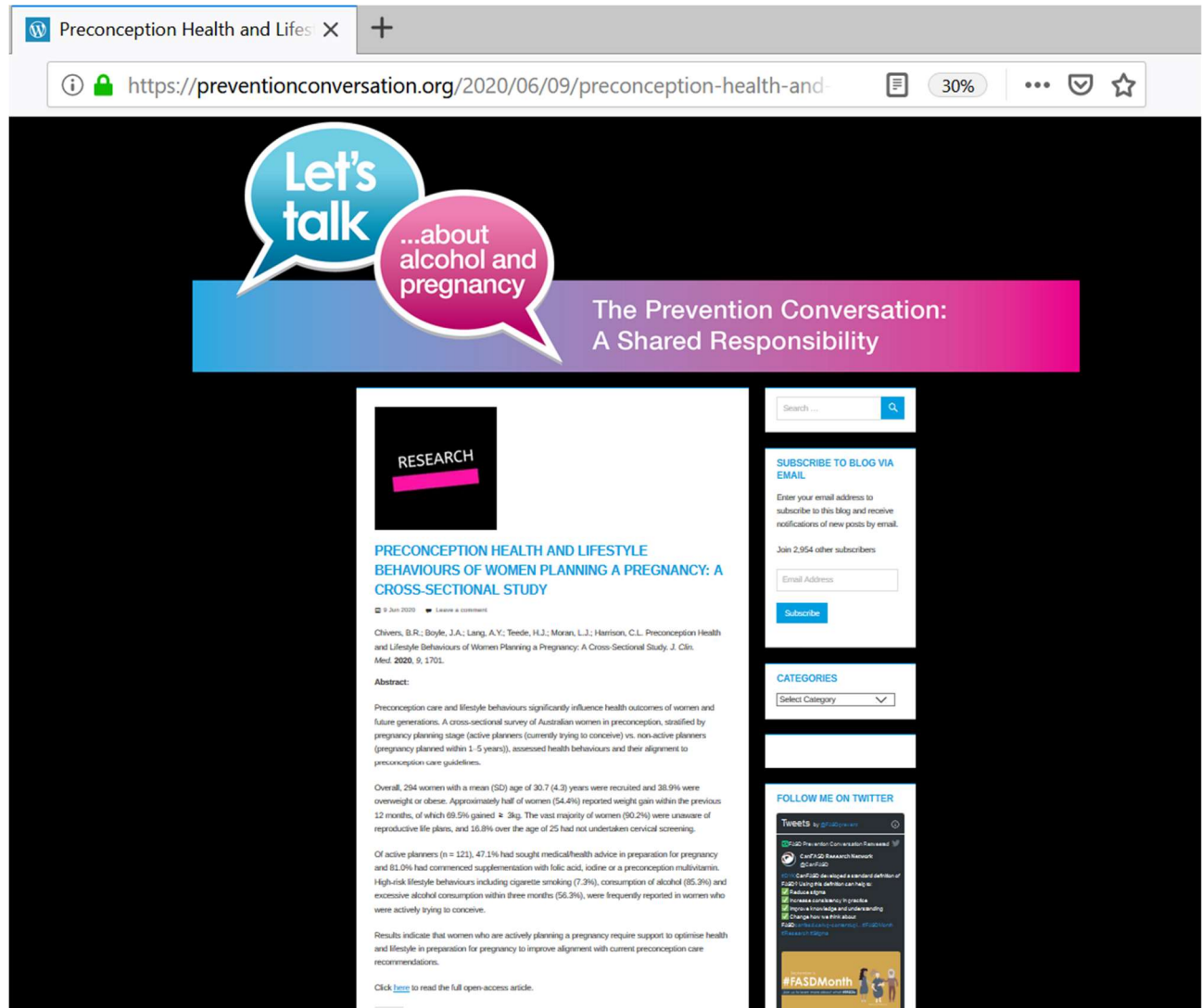
Supplementary material for Chapter 1 not included:

11 additional ministerial letters;

Media article published online in Chinese.

Appendix 2. Supplementary material for Chapter 2

2.1 Monash News: Media Article 4

Women close to giving birth also indicated they were considering a home birth. One woman stated that although she did not want to be 'alarmist', the lack of information on hospital safety made her feel 'vulnerable'.

The perinatal period involves a major life transition requiring increased levels of social, emotional and health professional support.

"Health professionals need to understand that women have unique information needs particularly around risk and safety related to pregnancy and newborn health," Dr Harrison said.

"Support needs of this population remain high and therefore in the presence of significant impacts to support networks we need to look at ways to meet those needs in a COVID-safe way."

"Our results demonstrate pregnant women and new mothers are uniquely impacted by the COVID-19 pandemic. The lack of nuanced and timely information appears to have exacerbated the risk of psychological and psychosocial distress in this vulnerable group who demonstrate heightened distress, reduced social and emotional support, anticipatory grief, increasing inter-family conflicts and direct impacts on family planning behaviours," Dr Harrison said.

Read the full paper in Journal of Medical Internet Research titled: _Perinatal distress during COVID-19: a thematic analysis of an online parenting forum._ DOI: 10.2196/22002

MEDIA ENQUIRIES
Wendy Smith
Media Monash University
T: +61 425 725 836 E: wendy.smith1@monash.edu
For more Monash media stories, visit our news and events site

Categories

Public Health and Preventive Medicine | Research | COVID-19

Tags

perinatal | COVID-19 | Cheryce Harrison | Rhonda Garad | Bonnie Chivers

2.2 Infographic to Support Research Translation via Social Media to Public and Government

PERINATAL DISTRESS COMPOUNDED BY UNMET NEEDS DURING COVID-19

UNDERSTANDING PERINATAL EMOTIONAL WELL-BEING AND SUPPORT NEEDS DURING COVID-19.

Thematic analysis of COVID-19 related posts from a leading Australian online forum for new and expecting mothers.

"All I am thinking and dreaming about is COVID-19! I'm super paranoid, I feel like even getting groceries, I have anxiety."

SENTIMENT ANALYSIS

38.1% Positive

Negative 61.9%

Analysis of 831 forum posts.

COMMON TERMS

RISKS WORRYING CONCERNING STRUGGLE CONCERN STRESS RISK SCARED WORRY ANXIETY STRUGGLING STRESSFUL SCARING STRESSING ANXIOUS WORRIED RISKING

FIVE KEY THEMES
IN COVID-19 FORUM POSTS

1. Heightened distress due to a high-risk external environment;

2. Grief and despair due to deprivation of social and family support/rituals;

3. Altered family and support relationships;

4. Feeling guilty for being happy;

5. Postponing family planning.

"I am due to attend my pregnancy scan ... I am getting nervous about having to travel. I'm considering not going at all."

Women in the perinatal period have been uniquely impacted by COVID-19 which has be compounded by a lack of direct communication and support. This group need targeted, accessible, consistent, relevant, timely and reassuring health information.

MONASH University **M**CHRI
Monash Centre for Health Research and Implementation

Study authors: Chivers BR*, Garad RM*, Boyle JA, Skouteris H, Teede HJ, Harrison CL.
Infographic: Chivers BR.
*Joint first authors.

Appendix 3. Supplementary material for Chapter 3

3.1 Multimedia Appendix 1: Frequently Used Words in Forum User-generated Content (word cloud)

Appendix 4. Supplementary material for Chapter 4

4.1 Multimedia Appendix 1. Gestational weight gain criteria

Question	Definition	Further information/example	Answer options.
1. Is GWG tracking a major feature of the app/website?	Weight logging/tracking is prominent.		-Yes -No
2. Is supportive information about GWG a major feature of the app?	Information/feedback relating to the weight tracker is easy to access and seamlessly links to the tracker.		-Yes -No
3. Is the inclusion of a weight tracker in the app/website likely to highlight the importance of GWG to the user?	The inclusion of weight tracking in the app clearly demonstrates and communicates the importance of healthy GWG.		-Yes -No
4. Does the app/website clearly chart the user's weight against the GWG recommendations?	Clearly shows the recommended range of GWG based on the user's preconception BMI and map the user's weight entries against this.		-Yes -No
5. Does the app/website alert that weight gain is outside recommendations?	i.e. a pop-up with an alert/information or a red dot, which would otherwise not be red if weight logs are within a healthy range.		-Yes -No
6. Does the app direct the user into consultation with a health professional if weight gain is above or below the recommendations?	The app flags unhealthy weight gain and suggests that the user should seek support for a doctor or health practitioner.	May suggest booking an appointment with their GP or discussing weight gain with their OB.	-Yes -No
6b. If yes, to above in what case does the app recommend the user seek medical advice? *			-only if GWG is above recommendations -only if GWG is below recommendations

			-if GWG is either above or below recommendations -NA
7. Does the app reference guidelines for GWG? (if a guideline other than the IOM is referenced please note in free text)			-Yes, IOM guideline is referenced -No -Other (free text)
8. Does the app/website reference total GWG recommendations? (i.e. 11.5-16kg if Normal BMI at conception)			-Yes -No
9. Does the app/website reference rates for GWG recommendations? (i.e. weight gain recommendations per week)			-Yes -No
10. Are BMI modifications for Asian ethnicity available?			-Yes -No
11. Are there GWG modifications for twins/triplets etc.?			-Yes -No
12. Does the app encourage a healthy diet for optimal GWG?			-Yes -No
13. Does the app encourage regular moderate physical activity for optimal GWG?			-Yes -No
14. Was the app developed in consultation with O&G?			-Yes -No
16. Was the app developed in consultation with midwifery?			-Yes -No
17. Was the app developed in consultation with allied health (EP, dietitian, physio etc.)?			-Yes -No
18. Was the app developed in consultation with academics?			-Yes -No
19. Was the app developed in consultation with consumers?			-Yes -No
20. Was the app developed in consultation with 'other'?			-Yes (please specify) -No

*results for 6b were not included in the manuscript as zero (n=0, 0.0%) tools met criteria 6.

4.2 Multimedia Appendix 2. Mobile App Rating Scale

App Classification

The Classification section is used to collect descriptive and technical information about the app. Please review the app description in iTunes / Google Play to access this information.

App name:_____

Rating this version:_____**Rating all versions:** _____

Developer: _____

N ratings this version:_____**N ratings all versions:** _____

Version:_____**Last update:** _____

Cost - basic version:_____**Cost - upgrade version:** _____

Platform: □ iPhone   □ iPad   □ Android

Brief description: _____

_____

Focus: what the app targets
(select all that apply)

□ Increase Happiness/Well-being

□ Mindfulness/Meditation/Relaxation

□ Reduce negative emotions

□ Depression

□ Anxiety/Stress

□ Anger

□ Behaviour Change

□ Alcohol /Substance Use

□ Goal Setting

□ Entertainment

□ Relationships

☒ Physical health

☒ Other: *Gestational weight gain*

Theoretical background/Strategies (all that apply)

□ Assessment

□ Feedback

□ Information/Education

□ Monitoring/Tracking

□ Goal setting

□ Advice /Tips /Strategies /Skills training

□ CBT - Behavioural (positive events)

□ CBT – Cognitive (thought challenging)

□ ACT - Acceptance commitment therapy

□ Mindfulness/Meditation

□ Relaxation

□ Gratitude

□ Strengths based

□ Other

Affiliations:

□ Unknown   □ Commercial   □ Government   □ NGO   □ University

Age group (all that apply)

□ Children (under 12)

□ Adolescents (13-17)

□ Young Adults (18-25)

☒ Adults

□ General

Technical aspects of app (all that apply)

□ Allows sharing (Facebook, Twitter, etc.)

□ Has an app community

□ Allows password-protection

□ Requires login

□ Sends reminders

□ Needs web access to function

App Quality Ratings

The Rating scale assesses app quality on four dimensions. All items are rated on a 5-point scale from "1. Inadequate" to "5. Excellent". Circle the number that most accurately represents the quality of the app component you are rating. Please use the descriptors provided for each response category.

SECTION A

Engagement – fun, interesting, customisable, interactive (e.g. sends alerts, messages, reminders, feedback, enables sharing), well-targeted to audience

1. **Entertainment: Is the app fun/entertaining to use? Does it use any strategies to increase engagement through entertainment (e.g. through gamification)?**
   1   Dull, not fun or entertaining at all
   2   Mostly boring
   3   OK, fun enough to entertain user for a brief time (< 5 minutes)
   4   Moderately fun and entertaining, would entertain user for some time (5-10 minutes total)
   5   Highly entertaining and fun, would stimulate repeat use

2. **Interest: Is the app interesting to use? Does it use any strategies to increase engagement by presenting its content in an interesting way?**
   1   Not interesting at all
   2   Mostly uninteresting
   3   OK, neither interesting nor uninteresting; would engage user for a brief time (< 5 minutes)
   4   Moderately interesting; would engage user for some time (5-10 minutes total)
   5   Very interesting, would engage user in repeat use

3. **Customisation: Does it provide/retain all necessary settings/preferences for apps features (e.g. sound, content, notifications, etc.)?**
   1   Does not allow any customisation or requires setting to be input every time
   2   Allows insufficient customisation limiting functions
   3   Allows basic customisation to function adequately
   4   Allows numerous options for customisation
   5   Allows complete tailoring to the individual's characteristics/preferences, retains all settings

4. **Interactivity: Does it allow user input, provide feedback, contain prompts (reminders, sharing options, notifications, etc.)? Note: these functions need to be customisable and not overwhelming in order to be perfect.**
   1   No interactive features and/or no response to user interaction
   2   Insufficient interactivity, or feedback, or user input options, limiting functions
   3   Basic interactive features to function adequately
   4   Offers a variety of interactive features/feedback/user input options
   5   Very high level of responsiveness through interactive features/feedback/user input options

5. **Target group: Is the app content (visual information, language, design) appropriate for your target audience?**
   1. Completely inappropriate/unclear/confusing
   2. Mostly inappropriate/unclear/confusing
   3. Acceptable but not targeted. May be inappropriate/unclear/confusing
   4. Well-targeted, with negligible issues
   5. Perfectly targeted, no issues found

A. Engagement mean score = _____

SECTION B

Functionality – app functioning, easy to learn, navigation, flow logic, and gestural design of app

6. **Performance: How accurately/fast do the app features (functions) and components (buttons/menus) work?**
   1. App is broken; no/insufficient/inaccurate response (e.g. crashes/bugs/broken features, etc.)
   2. Some functions work, but lagging or contains major technical problems
   3. App works overall. Some technical problems need fixing/Slow at times
   4. Mostly functional with minor/negligible problems
   5. Perfect/timely response; no technical bugs found/contains a 'loading time left' indicator

7. **Ease of use: How easy is it to learn how to use the app; how clear are the menu labels/icons and instructions?**
   1. No/limited instructions; menu labels/icons are confusing; complicated
   2. Useable after a lot of time/effort
   3. Useable after some time/effort
   4. Easy to learn how to use the app (or has clear instructions)
   5. Able to use app immediately; intuitive; simple

8. **Navigation: Is moving between screens logical/accurate/appropriate/ uninterrupted; are all necessary screen links present?**
   1. Different sections within the app seem logically disconnected and random/confusing/navigation is difficult
   2. Usable after a lot of time/effort
   3. Usable after some time/effort
   4. Easy to use or missing a negligible link
   5. Perfectly logical, easy, clear and intuitive screen flow throughout, or offers shortcuts

9. **Gestural design: Are interactions (taps/swipes/pinches/scrolls) consistent and intuitive across all components/screens?**
   1. Completely inconsistent/confusing
   2. Often inconsistent/confusing
   3. OK with some inconsistencies/confusing elements

    4   Mostly consistent/intuitive with negligible problems

    5   Perfectly consistent and intuitive

B. Functionality mean score = _____

SECTION C

Aesthetics – graphic design, overall visual appeal, colour scheme, and stylistic consistency

10. **Layout: Is arrangement and size of buttons/icons/menus/content on the screen appropriate or zoomable if needed?**

    1   Very bad design, cluttered, some options impossible to select/locate/see/read device display not optimised

    2   Bad design, random, unclear, some options difficult to select/locate/see/read

    3   Satisfactory, few problems with selecting/locating/seeing/reading items or with minor screen- size problems

    4   Mostly clear, able to select/locate/see/read items

    5   Professional, simple, clear, orderly, logically organised, device display optimised. Every design component has a purpose

11. **Graphics: How high is the quality/resolution of graphics used for buttons/icons/menus/content?**

    1   Graphics appear amateur, very poor visual design - disproportionate, completely stylistically inconsistent

    2   Low quality/low resolution graphics; low quality visual design – disproportionate, stylistically inconsistent

    3   Moderate quality graphics and visual design (generally consistent in style)

    4   High quality/resolution graphics and visual design – mostly proportionate, stylistically consistent

    5   Very high quality/resolution graphics and visual design - proportionate, stylistically consistent throughout

12. **Visual appeal: How good does the app look?**

    1   No visual appeal, unpleasant to look at, poorly designed, clashing/mismatched colours

    2   Little visual appeal – poorly designed, bad use of colour, visually boring

    3   Some visual appeal – average, neither pleasant, nor unpleasant

    4   High level of visual appeal – seamless graphics – consistent and professionally designed

    5   As above + very attractive, memorable, stands out; use of colour enhances app features/menus

C. Aesthetics mean score = _____

SECTION D

Information – Contains high quality information (e.g. text, feedback, measures, references) from a credible source. Select N/A if the app component is irrelevant.

13. **Accuracy of app description (in app store): Does app contain what is described?**

   1   Misleading. App does not contain the described components/functions. Or has no description
   2   Inaccurate. App contains very few of the described components/functions
   3   OK. App contains some of the described components/functions
   4   Accurate. App contains most of the described components/functions
   5   Highly accurate description of the app components/functions

14. **Goals: Does app have specific, measurable and achievable goals (specified in app store description or within the app itself)?**

   N/A Description does not list goals, or app goals are irrelevant to research goal (e.g. using a game for educational purposes)
   1   App has no chance of achieving its stated goals
   2   Description lists some goals, but app has very little chance of achieving them
   3   OK. App has clear goals, which may be achievable.
   4   App has clearly specified goals, which are measurable and achievable
   5   App has specific and measurable goals, which are highly likely to be achieved

15. **Quality of information: Is app content correct, well written, and relevant to the goal/topic of the app?**

   N/A There is no information within the app
   1   Irrelevant/inappropriate/incoherent/incorrect
   2   Poor. Barely relevant/appropriate/coherent/may be incorrect
   3   Moderately relevant/appropriate/coherent/and appears correct
   4   Relevant/appropriate/coherent/correct
   5   Highly relevant, appropriate, coherent, and correct

16. **Quantity of information: Is the extent coverage within the scope of the app; and comprehensive but concise?**

   N/A There is no information within the app
   1   Minimal or overwhelming
   2   Insufficient or possibly overwhelming
   3   OK but not comprehensive or concise
   4   Offers a broad range of information, has some gaps or unnecessary detail; or has no links to more information and resources
   5   Comprehensive and concise; contains links to more information and resources

17. **Visual information: Is visual explanation of concepts – through charts/graphs/images/videos, etc.** – clear, logical, correct?

   N/A There is no visual information within the app (e.g. it only contains audio, or text)
   1   Completely unclear/confusing/wrong or necessary but missing
   2   Mostly unclear/confusing/wrong
   3   OK but often unclear/confusing/wrong
   4   Mostly clear/logical/correct with negligible issues

5   Perfectly clear/logical/correct

18. **Credibility: Does the app come from a legitimate source (specified in app store description or within the app itself)?**
   1   Source identified but legitimacy/trustworthiness of source is questionable (e.g. commercial business with vested interest)
   2   Appears to come from a legitimate source, but it cannot be verified (e.g. has no webpage)
   3   Developed by small NGO/institution (hospital/centre, etc.) /specialised commercial business, funding body
   4   Developed by government, university or as above but larger in scale
   5   Developed using nationally competitive government or research funding (e.g. Australian Research Council, NHMRC)

19. **Evidence base: Has the app been trialled/tested; must be verified by evidence (in published scientific literature)?**
   N/A The app has not been trialled/tested
   1   The evidence suggests the app does not work
   2   App has been trialled (e.g., acceptability, usability, satisfaction ratings) and has partially positive outcomes in studies that are not randomised controlled trials (RCTs), or there is little or no contradictory evidence.
   3   App has been trialled (e.g., acceptability, usability, satisfaction ratings) and has positive outcomes in studies that are not RCTs, and there is no contradictory evidence.
   4   App has been trialled and outcome tested in 1-2 RCTs indicating positive results
   5   App has been trialled and outcome tested in $\geq$ 3 high quality RCTs indicating positive results

*D. Information mean score =*_____*

* Exclude questions rated as "N/A" from the mean score calculation.

APP SUBJECTIVE QUALITY | SECTION E

20. **Would you recommend this app to people who might benefit from it?**

   1   **Not at all**   I would not recommend this app to anyone
   2   There are very few people I would recommend this app to
   3   **Maybe**   There are several people whom I would recommend it to
   4   There are many people I would recommend this app to
   5   **Definitely**   I would recommend this app to everyone

21. **How many times do you think you would use this app in the next 12 months if it was relevant to you?**
   1   **None**
   2   1-2
   3   3-10
   4   10-50

5   >50

22. Would you pay for this app?

    1   No
    3   Maybe
    5   Yes

23. What is your overall star rating of the app?

    1   One of the worst apps I've used
    2
    3   Average
    4
    5   One of the best apps I've used

Scoring
App quality scores for
SECTION
  A: Engagement Mean Score = _____
  B: Functionality Mean Score = _____
  C: Aesthetics   Mean Score = _____
  D: Information Mean Score = _____
App quality mean Score   **= __**
App subjective quality Score = _____
App-specific

These added items can be adjusted and used to assess the perceived impact of the app on the user's knowledge, attitudes, intentions to change as well as the likelihood of actual change in the target health behaviour.

SECTION F

_____

    1.   Awareness: This app is likely to increase awareness of the importance of addressing [insert target health behaviour] (Gestational weight gain)

1 = Strongly Diagree, 2 = Somewhat Disagree, 3 = Neutrals, 4 = Somewhat Agree, 5 = Strongly Agree

    2.   **Knowledge: This app is likely to increase knowledge/understanding of [insert target health**
        behaviour] (Gestational weight gain)

1 = Strongly Diagree, 2 = Somewhat Disagree, 3 = Neutrals, 4 = Somewhat Agree, 5 = Strongly Agree

    3.   **Attitudes: This app is likely to change attitudes toward improving [insert target health**
        behaviour] (Gestational weight gain)

1 = Strongly Diagree, 2 = Somewhat Disagree, 3 = Neutrals, 4 = Somewhat Agree, 5 = Strongly Agree

    4.   **Intention to change: This app is likely to increase intentions/motivation to address [insert**
        target health behaviour] (Gestational weight gain)

1 = Strongly Diagree, 2 = Somewhat Disagree, 3 = Neutrals, 4 = Somewhat Agree, 5 = Strongly Agree

5. **Help seeking: Use of this app is likely to encourage further help seeking for [insert target health behaviour] (if it's required) (Gestational weight gain)**

1 = Strongly Diagree, 2 = Somewhat Disagree, 3 = Neutrals, 4 = Somewhat Agree, 5 = Strongly Agree

4.3 Multimedia Appendix 3. App Behavior Change Scale

Item	Question	Definition	Example or further information	Response: Present (yes/no)
1.1	Does the app have the ability to customize and personalize some features?	Elements of the app can be personalized through specific tools or functions that are specific to the individual using the app.	To select a disease type from among several available and then to follow a specific path or set of tools or systems. To select to receive emails or texts of a specific nature. To choose "yes" or "no" to a specific capability of the app would be considered personalization. To create a personalized exercise plan.	
1.2	Was the app created with expertise and/or Does the app provide information that is consistent with national guidelines? (Are the most recent IOM guidelines referenced?)	This would be found in the about section or generally in the app.	• Does the app suggest 30 min of exercise each day? • Does it recommend 5 veg and 3 fruit? • Does it seek to build resilience and promote help seeking? • Is there any evidence that the app was created by an expert? (doctor/professional body/university)	
1.3	Does the app ask for baseline information?	This includes BMI[a], weight, smoking rate, exercise, or drinking behaviours	• This might be at the set-up phase or in a profile setting.	
1.4	Does the app provide instruction on how to perform the behaviour?	The app is clear in telling the person how to perform a behaviour or preparatory behaviours, either verbally, through video, or in written form. NB: the behaviour that is seeking to be changed (weight gain above or below recommendation), not information on how to use the app	• This could include recipes, meals planes or structured advice such as showing person how to use gym equipment, sharing sample plans for action.	
1.5	Does the app provide information about the consequences of continuing and/or discontinuing behaviour?	The app gives the user information about the consequences of behaviour in general, this includes information about the relationship between the behaviour and its possible or likely consequences in the general case. This information can be general or personalized.	• Consequences may include health risks to mother and baby and/or informing on decreased risks of complications (LGA, SGA, CS, GDM) if GWG is within recommendations	
2.1	Does the app ask for willingness for behaviour change?	Is there a feature during setup where you describe how ready you are for behaviour change?	• This may be in the form of a scale of readiness or in a question that asks the user to describe how ready you are.	
2.2	Does the app allow for the setting of goals?	The person is encouraged to make a behavioural resolution. The person is encouraged to set a	• This is the explicit noting of a goal or choosing a goal from one provided within the app.	

		general goal that can be achieved by behavioural means. This includes sub goals or preparatory behaviours and/or specific contexts in which the behaviour will be performed. The behaviour in this technique will be directly related to or be a necessary condition for the target behaviour.		
2.3	Does the app have the ability to review goals, update, and change when necessary?	Involves a review or analysis of the extent to which previously set behavioural goals (regardless of short or long) were achieved.	● This is where a goal can be changed. This allows people to act on previously set goals and then revise or adjust where needed.	
3.1	Does the app give the user the ability to quickly and easily understand the difference between current action and future goals?	Allows user to see how they are tracking against a goal and to see the difference between what they want to do and what they are currently doing. This will give some feedback on where they are at and what they need to change to get to where they want to be.	● This could be in the form of a graph or some other visual describing how close the user is to meeting their goals.	
3.2	Does the app have the ability to allow the user to easily self-monitor behaviour?	The app allows for a regular monitoring of the activity.	● Allows for tracking of weight gain. ● Connects with watch that records daily steps that can be reviewed. ● Allows for easy logging of exercise or meditation. ● Allows tracking of food intake.	
3.3	Does the app have the ability to share behaviours with others (including social media or forums) and/or allow for social comparison?	The app allows the person to share his or her behaviours on social media or in forums. This could also include a *buddy* system or a leader board.	● Share with Facebook or other socials ● Tell the user that they are doing x and at this time, other people like them are doing y (comparative behaviour)	
3.4	Does the app have the ability to give the user feedback—either from a person or automatically?	The app is able to provide the person with feedback, comments, or data about their own recorded behaviour. This might be automatic or could be personal.	● Does the app have a *coach* function?	
3.5	Does the app have the ability to export data from app?	The app allows for the export of information and progress to an external user.	● Export to a computer or to another user such as a doctor or fitness expert. ● Sharing to Facebook does not count.	
3.6	Does the app provide a material or social reward or incentive?	App provides rewards for attempts at achieving a behavioural goal. This might include efforts made toward achieving the behaviour or progress made in preparatory	● Financial, either in returning money that was not spent on, for example, cigarettes or in paying someone to engage in a specific activity.	

		steps toward the behaviour or in achieving a goal.	● Social or public, for example, congratulating the person for each day that he or she meets his or her exercise target.	
3.7	Does the app provide general encouragement?	The app provides general encouragement and positive reinforcement on actions leading to the goal.	● This could include achievement badges or telling the user that they are a certain percentage closer to their goal.	
4.1	Does the app have reminders and/or prompts or cues for activity?	The app prompts the user to engage in the activity. The app has the ability to give notifications or reminders to cue the behaviour.	● This could be like the apple watch reminding you to exercise or to log your weight.	
4.2	Does the app encourage positive habit formation?	The app prompts explicit rehearsal and repetition of the behaviour–not just tracking or logging.	● An example of this are the couch to 5 km apps that provide a training schedule.	
4.3	Does the app allow or encourage for practice or rehearsal, in addition to daily activities?	App does not have a lock on activities or a number that you cannot exceed daily.	● This would include allowing the user to undertake extra activities in a single day.	
4.4	Does the app provide opportunity to plan for barriers?	The app encourages the person to think about potential barriers and identify ways of overcoming them.	● Might give strategies for cravings or night time food indulgences.	
4.5	Does the app assist with or suggest restructuring the physical or social environment?	The app prompts the person to alter the environment in ways so that it is more supportive of the target behaviour.	● Might suggest locking up or throw away or their high-calorie snacks or take their running shoes to work.	
4.6	Does the app assist with distraction or avoidance?	The app gives suggestions and advice on how the person can avoid situations or distract themselves when trying to reach their goal.	● For example, may suggest that the user not eat chocolate if it is associated with overeating or cravings.	

4.4 Multimedia Appendix 4. Quality evaluation criteria

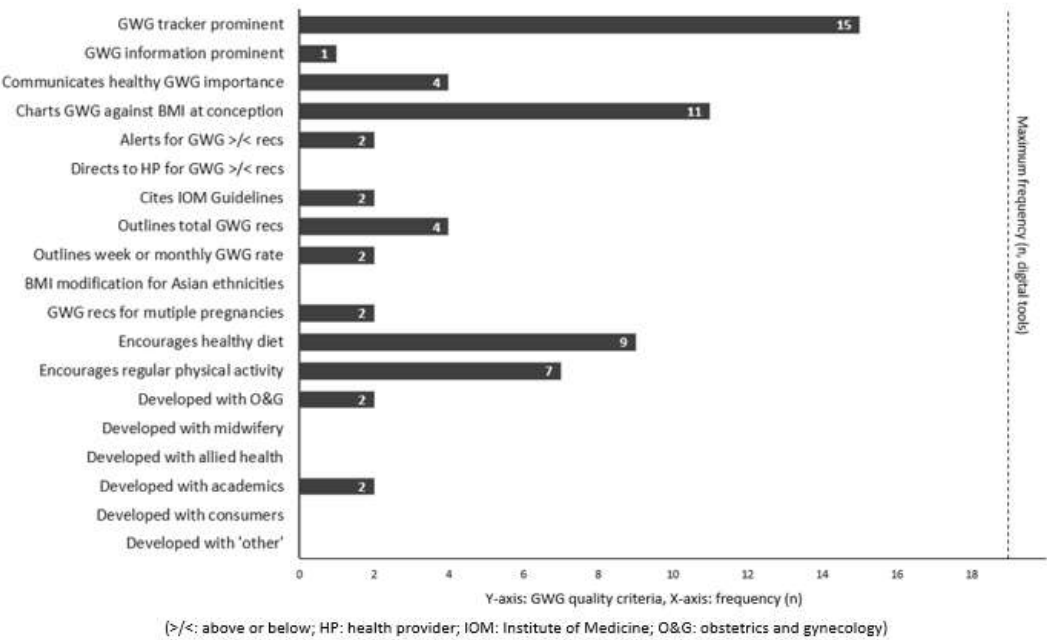Does the app/website or app store description/developer website state and/or clearly display the following:

	Present (yes/no)
Statement of purpose of the app/website	
Contact details provided (email or phone/fax)	
Ownership disclosure (who owns the app/website)	
Copyright	
Advertisement disclosures	
Sponsorship disclosures	
Author/developer disclosures	
Author/developer credentials (credentials and affiliations)	
Independence of sponsors/funders	
References provided	

Type of references provided
    - Meta-analysis
    - Systematic review
    - Narrative review
    - Scoping review
    - RCT
    - Cohort or cross-sectional study
    - Opinion piece
    - Grey literature (i.e. media)
    - Government Guidelines
    - Position statement
    - Medical Textbook	

4.5 Multimedia Appendix 5. Description of Digital Tools for GWG Management (results table)

Manuscript Reference	App name/ website	Platform	Developer	User rating	Installations	Cost (AUD)	Affiliation
App01	Pregnancy Tracker, Week by Week, Day by Day	Android	Timskiy	4.9	500,000+	$0.00 - $16.99/ in-app item	Commercial
App02	Pregnancy + | tracker app, week by week in 3D	iOS/Android	Health & Parenting Ltd	4.8	10,000,000+	$0.00 - $5.99	Commercial
App03	Pregnancy app (iOS), Pregnancy Week by Week (Android)	iOS/Android	Amila	4.8	5,000,000+	$0.00	Commercial
App04	280days: Pregnancy Diary	iOS/Android	Amane Factory Inc.	4.8	1,000,000+	$0.00 - $2.99	Commercial
App05	Nurture: Pregnancy + Baby App (iOS), GLOW. Pregnancy & Baby Tracker + Baby Registry App (Android)	iOS/Android	Glow Inc	4.8	1,000,000+	$0.00 - $79.99/ subscription	Commercial
App06	Ovia Pregnancy Tracker: Baby Due Date Countdown	iOS/Android	Ovia Health	4.8	1,000,000+	$0.00	Commercial
App07	MomDiary: Week by week Pregnancy Tracker	Android	High-tech solution	4.8	100,000+	$0.00	Commercial
App08	AMMA Pregnancy Tracker & Baby Due Date Calculator	Android	Period Tracker & Pregnancy and Baby Calendar	4.7	5,000,000+	$0.00 - $11.99/ subscription	Commercial
App09	I'm Pregnant - Pregnancy Week by Week	Android	BabyJoyApp	4.7	1,000,000+	$0.00 - $1.99	Commercial
App10	My Pregnancy (iOS), My Pregnancy - Pregnancy Tracker App 🤰 (Android)	iOS	Neiman / Aleksei Nieman	4.7	500,000+	$0.00	Commercial
App11	Embarazo Semana a Semana	iOS/Android	Marilia SAS	4.7	500,000+	$0.00	Commercial
App12	Belly - Your pregnancy app	iOS/Android	Life of Svea AB	4.7	10,000+	$0.00	University
App13	Pregnancy Care - Pregnancy Tracker & Tips	Android	KudoMetrics Technologies Private Limited	4.7	500+	$0.00	Commercial
App14	My Pregnancy Tracker (iOS), My Pregnancy Tracker Week by Week + Due Date (Android)	iOS/Android	My Pregnancy and Baby Tracker	4.6	100,000+	$0.00 - $23.00	Commercial
App15	Pregnancy Companion - Week by Week Tracking	Android	Healthcare Apps	4.4	50,000+	$0.00 - $4.09	Commercial
App16	Pregnancy Week by Week	Android	Promotube AAC	4.4	10,000+	$0.00	Commercial
App17	PregiCare - Pregnancy Toolkits, Weekly, Daily info	Android	Flipflapp	4.2	10,000+	$0.00 - $7.99/ in-app item	Commercial
App18	Pregnancy Calendar	Android	Ruthie apps	4.1	10,000+	$0.00	Commercial
Web01	Get Healthy NSW	Website	Get Healthy NSW	Not applicable	Not applicable	Not applicable	Government

4.6 Multimedia Appendix 6. Performance on gestational weight gain (GWG) quality questions (inclusion of GWG-specific tools or features) (results figure)

Y-axis: GWG quality criteria, X-axis: frequency (n)

(>/<: above or below; HP: health provider; IOM: Institute of Medicine; O&G: obstetrics and gynecology)

4.7 Multimedia Appendix 7. Performance on quality evaluation (results table)

Criteria	Frequency, n (%)
Statement of purpose	16 (84.2)
Contact details provided (email or phone/fax)	18 (94.7)
Ownership disclosure (owner of the app/website disclosed)	14 (73.7)
Copyright statement	14 (73.7)
Advertisement disclosure	13 (68.4)
Sponsorship disclosure	1 (5.3)
Author/developer disclosure	12 (63.2)
Author/developer credentials	2 (10.5)
Independence of sponsors/funders	0 (0.0)
References provided	4 (21.2)
Meta-analysis	1 (5.3)
Systematic review	1 (5.3)
Narrative review	0 (0.0)
Scoping review	0 (0.0)
Randomised control trial (RCT)	1 (5.3)
Cohort or cross-sectional study	1 (5.3)
Opinion piece	0 (0.0)
Media	1 (5.3)
Government guidelines	2 (10.5)
Position statement	0 (0.0)
Medical textbook	2 (10.5)
Quality evaluation, mean (SD) / total	**5.4 (2.9) / 21**

4.8 CRE HiPP Bite – Published on the CRE HiPP Knowledge Synthesis Hub

| Preconception | Pregnancy | Workforce Capacity | Early-Mid Career Researchers |

CRE HiPP BITE

Brokering Innovation Through Evidence

A bite-sized summary of a piece of research in pregnancy health, presented by Early Career Researcher Bonnie (Chivers) Brammall

A study to identify publicly available digital tools (websites and apps) that facilitate GWG tracking and evaluate their quality, behaviour change capacity and ability to highlight the importance of optimising GWG.

Assessing the content and quality of digital tools for managing gestational weight gain: A systematic search and evaluation (publication pending)

BACKGROUND

- Gestational weight gain (GWG) outside of recommended ranges, according to body mass index, increases the risk of pregnancy and neonatal complications, and commonly occurs in 70% of pregnancies globally (23% below and 47% above recommended ranges, respectively).

- Digital health is a popular and widely used source of health information for pregnant women.

- Evidence-based online resources have the potential to assist women in achieving healthy GWG.

Digital tools were assessed using two validated scales (MARS and ABACUS) and two sets of questions relevant to evidence-based health information and GWG management

FINDINGS

Overall, 18 mobile apps and one website were eligible for this study. On evaluation the digital GWG tracking tools assessed had:

- High consumer engagement: downloaded >25 million times cumulatively
- High consumer rating: 4.1-4.9 / 5.0
- Easy to use, aesthetically appealing and engaging design with over 90% commercially developed
- Poor quality of information relating to GWG
- Tools and information generally not linked to primary care or relevant guidelines
- Non-personalised recommendations for gestational weight gain
- Limited-to-no behaviour change capacity (ABACUS) for gestational weight management i.e. lifestyle change, goal setting, willingness to change or barrier identification
- Very few alert features when weight gain was outside of recommended ranges
- **No** direction to engage with health care provider when a weight was logged outside of recommended range, increasing safety concerns.

This study was completed by:
Mrs B R Brammall, Dr R M Garad, Assoc Prof J A Boyle, Dr M J Hayman, Assoc Prof S J de Jersey, Prof H J Teede, Mr Q V Hong, Ms A Carrandi & Dr C L Harrison

RECOMMENDATIONS FOR PRACTICE

The digital tools assessed represent a **missed opportunity** to inform and guide women to manage weight gain during pregnancy. There is a **critical need to improve the quality and regulation** of publicly accessible online resources. These **should be informed by** healthcare, policy, guidelines and consumer needs during pregnancy.

What is CRE HiPP

The Centre of Research Excellence in Health in Preconception and Pregnancy (CRE HiPP) is an innovative, passionate, multi-disciplinary team of researchers, clinicians, students and consumers.

We aim to refine and implement health promotion, lifestyle improvement and obesity prevention, strategically targeting women preconception and during pregnancy, to improve the health of women and the next generation.

Find out more about CRE HiPP at our website: hipp.org.au.

This BITE was published on 28 July 2022.

Methods

Search terms:
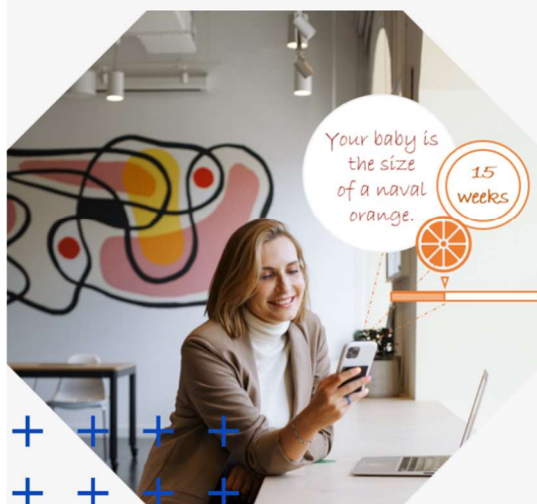pregnancy, gestational, weight, gain, tracker, calculator, graph.

Search engines:
Google, BING and Yahoo
Apple AppStore, IOS and GooglePlay, Android.

+ Mobile Application Rating Scale (MARS) (16)

+ App Behaviour Change Scale (ABACUS) (17)

+ Gestational Weight Gain (GWG) Criteria

+ Quality Evaluation (18)

Results

n=1,085 screened for inclusion
(n=162 websites vs n=923 apps)

n=18   n=1

User-rating: 4.10 to 4.90
>25 million installations (via GooglePlay only).
Affiliated with:
Commercial enterprises (n=17, 89.5%)
Government services (n=1, 5.3%)
Universities (n=1, 5.3%)

MARS
**Overall quality score 2.26 to 4.39, out of 5,
mean (SD): 3.17 (0.75)**
Functionality, Aesthetics, Engagement, Information

App (GWG) specific: 1.00 to 4.50
(n=15, 78.9%) scored 2.50 or less.

ABACUS
Mean (SD) score 6 (3.6), out of 21
Four behaviour change techniques were
most prominent, included in >50%.
Personalisation, baseline info collected,
self-monitor with ease, providing instructions

GWG Criteria

n=11, 58% weight chart based on preconception BMI

n=2, 10.5% alerted weight gain >/< recommended range

n=0, 0.0% directed to consult a health professional if weight entry was >/< recommendations

Of 19 criteria, (n=11, 57.9%) contained three or less.

Quality Evaluation

Statement of purpose (n=16, 84.2%)

Developer/author contact details (n=18, 94.7%)

Ownership disclosure/copyright statement (n=14 73.7%)

Independence of sponsors/funders (n=0, 0.0%)

Author/developer credentials (academics & O&G) (n=2, 10.5%)

References (n=4. 21.2%)
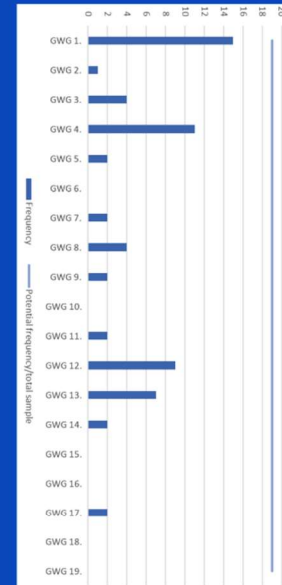
Summary

- Information quality poor (relating to GWG).
- Limited ability to guide behaviour change for optimised GWG.
- Advice for achieving healthy GWG was present in less than 50% (overall, advice was unspecific; unlikely to be associated with evidence-based info).
- Minimal likelihood to alert, or direct women to health care provider if GWG >/< thresholds.
- Missed opportunity.
- Critical need to improve the quality and regulation of publicly accessible online resources.
- Informed by healthcare, policy and consumer needs during pregnancy.

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ICO 2022

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18 - 22 October 2022 in Melbourne, Australia

Assessing the Content and Quality of Digital Tools for Managing Gestational Weight Gain: A Systematic Search and Evaluation

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INTRODUCTION

Gestational weight gain (GWG) outside of recommended ranges, according to body mass index, increases the risk of pregnancy and neonatal complications (1) and commonly occurs in 70% of pregnancies globally (23% below and 47% above recommendations, respectively) (2).

Digital health is a popular and widely used source of health information for pregnant women (3).

In conjunction with promotion of healthy lifestyle behaviours, Evidence-based online resources have the potential to assist women in achieving healthy GWG (4).

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AIM

A study to identify publicly available digital tools (websites and apps) that facilitate GWG tracking and evaluate the quality, behaviour change capacity and ability to highlight the importance of optimising GWG.
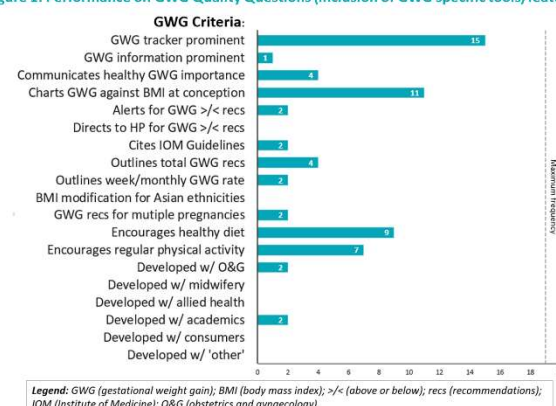
RESULTS

Overall, 18 mobile apps and one website were eligible for this study. On evaluation digital GWG tracking tools:

- had high consumer engagement: >25 million downloads
- had high consumer rating: 4.1-4.9 / 5.0
- were mostly (90%) **commercially** developed
- were easy to use, aesthetically appealing and engaging
- had poor quality information relating to GWG
- were generally **not linked to primary care or relevant guidelines**
- did not always capture preconception BMI, therefore **recommended weight gain was not personalised**
- had **limited-to-no behaviour change** capacity (ABACUS) for gestational weight management i.e. lifestyle change, goal setting, willingness to change or barrier identification

Most (n=17) did not alerted the user when weight was outside of recommended range, and **none** directed user to health care when a weight was logged outside of recommended range.

Figure 1: Gestational weight tracking was a major feature of most of the digital tools, displayed prominently to users (n=15, 79%), in line with our inclusion criteria. Eleven (n=11, 58%) of the digital tools charted weight recommendations based on preconception weight and height. All other criteria were present in less than half of the digital tools.

Figure 1: Performance on GWG Quality Questions (inclusion of GWG specific tools/features)

GWG Criteria:

Criterion	Value
GWG tracker prominent	15
GWG information prominent	1
Communicates healthy GWG importance	4
Charts GWG against BMI at conception	11
Alerts for GWG >/< recs	2
Directs to HP for GWG >/< recs	
Cites IOM Guidelines	2
Outlines total GWG recs	4
Outlines week/monthly GWG rate	2
BMI modification for Asian ethnicities	
GWG recs for mutiple pregnancies	2
Encourages healthy diet	9
Encourages regular physical activity	7
Developed w/ O&G	2
Developed w/ midwifery	
Developed w/ allied health	
Developed w/ academics	2
Developed w/ consumers	
Developed w/ 'other'	

Legend: GWG (gestational weight gain); BMI (body mass index); >/< (above or below); recs (recommendations); IOM (Institute of Medicine); O&G (obstetrics and gynaecology).

METHOD

Searches were conducted in an Australian web browser, using website search engines (Google, BING and Yahoo) and mobile app stores (Apple AppStore/iPhone Operative Systems (iOS) and GooglePlay, Android).

Search terms emulating terms likely used by end-users: *pregnancy weight, pregnancy weight tracker, pregnancy weight gain calculator, pregnancy weight graph* and *gestational weight tracker.*

Evaluated using the Mobile App Rating Scale (**MARS**) (5-6), the App Behaviour Change Scale (**ABACUS**) (7-8) as well as criteria to evaluate **the rigor and safety of GWG information.**

CONCLUSIONS

The majority of tools were of **low quality** overall, had **minimal ability to support behaviour change** and had **minimal linkage to evidence-based information or partnership with healthcare**.

Minimal likelihood to positively influence GWG.

Due to the extensive use of publicly available digital tools these findings underscore the **critical need for better linkage between health, research and commercial sectors, to design applications for GWG management**.

ACKNOWLEDGEMENT

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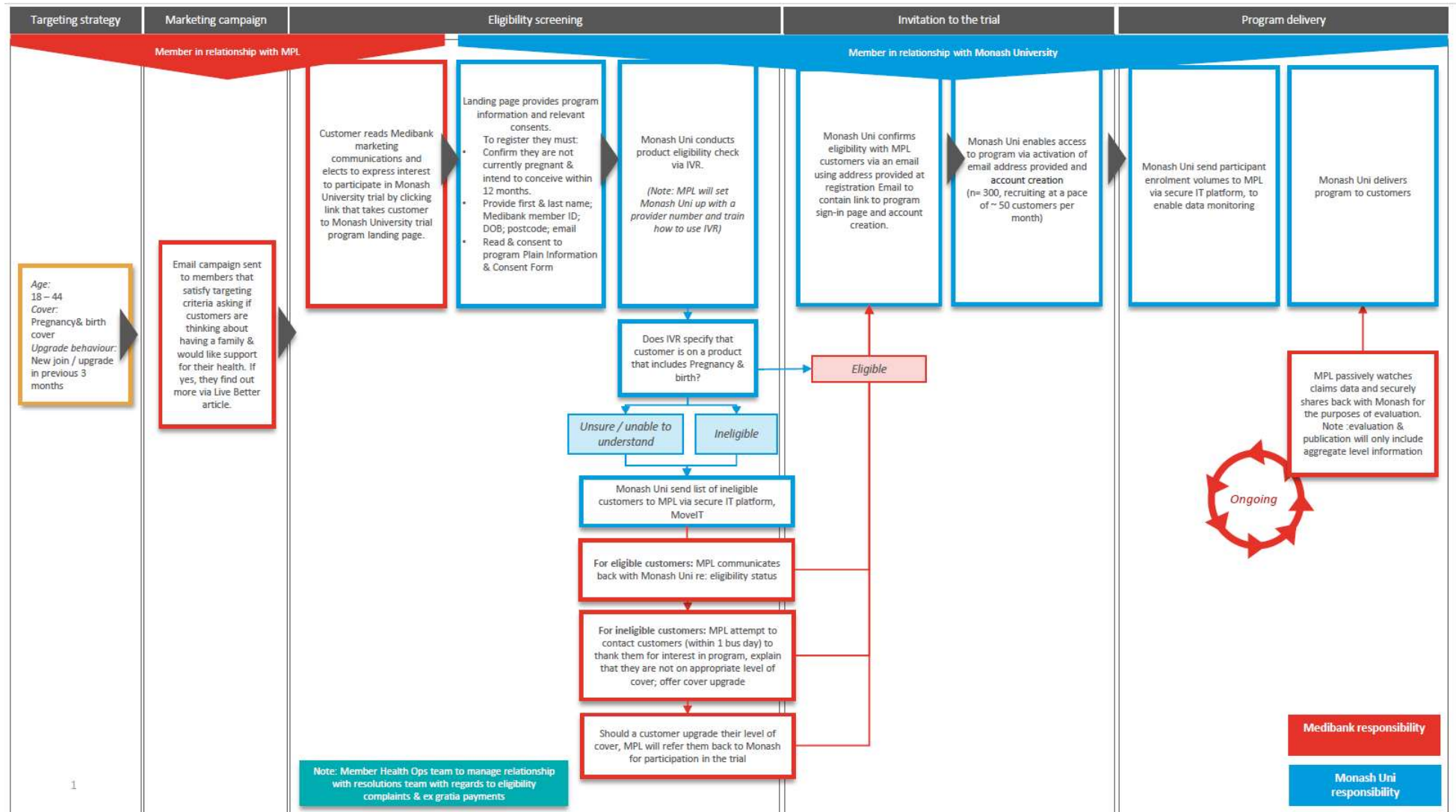First author: Bonnie (Chivers) Brammall
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Appendix 5. Supplementary material for Chapter 5

5.1 Multimedia Appendix 1. Co-designed recruitment strategy

5.2 Multimedia Appendix 2. OptimalMe Health-Related Content (fact sheets) within Preconception, Pregnancy, and Postpartum Modules

Multimedia Appendix 2

MA2 Table. Health related content (factsheets) within preconception, pregnancy and postpartum modules

OVERARCHING TOPIC	MODULE		
	Preconception	**Pregnancy**	**Postpartum**
PSYCHOSOCIAL WELLBEING AND SOCIAL SUPPORT	Healthy relationships	Relationships and pregnancy	Healthy relationships
	Emotional wellbeing	Anxiety during pregnancy	Postpartum anxiety and depression
			Baby blues
			Social support networks
HEALTHY LIFESTYLE BEHAVIOURS	Healthy eating preconception	Healthy eating pregnancy	Healthy eating postpartum
	Physical activity guidelines	Physical activity guidelines and exercise safety	Physical activity guidelines and exercise safety
	Weight gain prevention	Gestational weight gain recommendations	Your body post-birth and postpartum weight retention
	Smoking, alcohol and other drug use	Preparing and choosing food safely	Sleep derivation
		Seafood consumption during pregnancy	
MEDICAL INFORMATION/ SCREENING	Cervical screening	Gestational diabetes	
	Genetic testing	Hypertension (pre-eclampsia)	
	Recommended vaccinations		
	Recommended supplementation		
PRE-EXISTING HEALTH	Your fertility		
	Polycystic Ovary Syndrome		
	Reproductive history		
	Medication and conception planning		
	Chronic conditions and conception planning		
PREGNANCY SPECIFIC HEALTH INFORMATION		Listeria, Salmonella and Toxoplasmosis in pregnancy	
		Non-invasive prenatal testing	
		The pelvic floor during pregnancy	
		The development of your baby during pregnancy	
		Sex during pregnancy	
		Morning sickness	
		Maternity leave entitlements	
		Labour and birth	
		Umbilical cord blood banking	
		Things to discuss with your doctor	
INFANT HEALTH			First hours after birth
			Sleep routines and safe sleeping
			Feeding your baby

Appendix 6. Supplementary material for Chapter 6

6.1 Supplementary Table 1. Within participant pre-and-post behaviour (results table)

| Factor or action | Overall | Health coaching group | | P-value |
		Phone	Video	
Alcohol consumption *				
Baseline, alcohol consumer *Eligible for behaviour change at baseline*	119	66	53	0.268
Behaviour change, post intervention (no alcohol since intervention)	44 (37.0%)	25 (37.9%)	19 (35.8%)	0.489
Eliminated high risk behaviour, post intervention (no excessive drinking since intervention)	*94 (79.0%)*	*52 (78.8%)*	*42 (79.2%)*	*0.500*
Cervical screening				
Baseline, screening not up-to-date *Eligible for behaviour change at baseline*	38	19	19	0.560
Behaviour change, post intervention (cervical cancer screen complete)	15 (39.5%)	6 (31.6%)	9 (47.4%)	0.590
Preconception supplementation				
Baseline, not taking preconception supplement *Eligible for behaviour change at baseline*	79	38	41	0.450
Behaviour change, post intervention (supplementation initiated)	44 (55.7%)	21 (55.3%)	23 (56.1%)	0.542
Weighing behaviour				
Baseline, infrequent weighing *Eligible for behaviour change at baseline*	81	36	45	0.240
Behaviour change, post intervention (changed to frequent weighing)	52 (64.2%)	20 (55.6%)	32 (71.1%)	0.082
Opportunities for change				
Points of eligible behaviour change	317	159	158	
Change achieved **	155 (48.9%)	72 (45.3%)	83 (52.5%)	

* (n=25) non-drinkers at baseline reported (any) consumption since intervention, (n=2) of which had excessively drunk. No statistically significant difference between intervention groups. ** Excludes high risk alcohol consumption as baseline results pertain to "any" consumption only, no data available regarding excessive drinking at baseline.

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Improving preconception health and lifestyle behaviours through digital health intervention: The OptimalMe Program

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INTRODUCTION

The increasing prevalence of obesity and suboptimal lifestyle behaviours in reproductive aged women are major public health concerns (1), in the context of preconception these factors have significant impacts (2)

The preconception period presents an opportune moment for lifestyle modification, with increase motivation for behaviour change (3)

OptimalMe is a co-designed, digital health intervention that aims to meet the unique needs of women during preconception.

OptimalMe is the first study known to the authors, to target a healthy population of women and initiate preconception care (PCC) and optimise lifestyle behaviour relevant to preconception.

AIM

Here, we report the impact of OptimalMe on self-reported behaviour change, after completion of the preconception phase of the intervention, and the impact of different delivery modes (phone vs video coaching) on behaviour change outcomes in women who provided baseline and follow-up data.

RESULTS

Follow-up evaluation was completed by n=220 women, 71.2% of the study population, ~4.5 months after beginning the program.

Self-reported improvement was made to lifestyle behaviours, health behaviours and clinical actions.

73.2% had visited a general practitioner (GP) in preparation for pregnancy, since starting the program.

Adherence to Australia's National Cervical Screening Program (NCSP) improved, **39.5% of those who needed to update screening did so by the time of follow-up** (Fig 1).

85.5% reported positive behaviour change relating to diet, physical activity or a lifestyle behaviour of their choice i.e. sleep or stress levels.

Women believed that OptimalMe had **improved their knowledge** relating to **healthy food choices (49.5%), unhealthy food choices (40.5%)** and ways to be **physically active (48.1%)**.

Alcohol consumption decreased (Fig 2) and **regular weighing increased** (Fig 3).

Of the n=119 women who drank alcohol at baseline, 79.0% not binge drunk since starting OptimalMe, **eliminating high-risk behaviours**.

Women who received phone coaching were significantly more likely to have had genetic testing and be taking vitamin D, compared to video coaching. No other significant differences were observed. **Demonstrating that both video and phone coaching had similar impacts on behaviour change.**

Fig 1: Cervical cancer screening
Baseline: n=180 / n=38
Post-intervention: n=196 / n=22
■ Up-to-date cervical screening ■ Not up-to-date

Fig 2: Alcohol consumption (any)
Baseline: n=99 / n=119
Post-intervention: n=120 / n=100
■ Non-drinker ■ Alcohol consumer

Fig 3: Weighing behaviour
Baseline: n=135 / n=83
Post-intervention: n=182 / n=36
■ Regular weighing ■ Non-regular weighing

METHOD

Reproductive aged, Medibank Private Members who had recently upgraded their policy to include pregnancy and birth cover were invited to participate in OptimalMe.
The study population received:
Online modules with educational information about **preconception care (4)**, **preparing for pregnancy** and **healthy diet and physical activity** (fact sheets).
Online **self-management** and **behaviour change tools** (goal setting and preconception care checklist)
Coaching intervention (x2) with a health professional via video or phone.

CONCLUSIONS

The OptimalMe study is the first to examine the impact of a remotely delivered personal coaching and electronic health (eHealth) intervention to a general female population with the intention to conceive.
Our findings support the provision of preconception care education as an effective strategy for optimising maternal and child health, with women demonstrating improved adherence to the PCC and an uptake of primary care consultations to prepare for pregnancy. OptimalMe is an effective method to engage women prior to pregnancy in a manner that is adjunct to traditional PCC by health care professionals (HCPs) within clinical settings and shows promising results for behaviour change.

ACKNOWLEDGEMENT

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