

Characterizing the Factors Associated with Women's Adherence to Institute of Medicine
Gestational Weight Gain Guidelines and Assessing a Possible Role for Mobile Health through
the Evaluation of a Pregnancy-Specific Application *SmartMoms Canada*

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ABSTRACT

Fetal exposure to an intrauterine environment affected by maternal obesity and excessive gestational weight gain (GWG) pose several adverse short- and long-term health risks to infants. Excessive GWG and maternal obesity are of high priority to public health across many nations. Improving maternal and child health can be achieved by encouraging women to meet Institute of Medicine (IOM) weight gain recommendations, sound clinical guidance, and other forms of support. Another means of helping women adhere to weight gain guidelines is by making use of the near ubiquitous nature of mobile technology and promoting healthy pregnancies through reliable mobile health (mHealth) applications (apps). The objective of the first study of this thesis was to examine the associations between psychosocial factors and achieving IOM-recommended weight gain during pregnancy. Cross-sectional data were collected from pregnant and postpartum women who responded to a validated questionnaire, the Electronic Maternal health survey. Multiple logistic regression analyses were used to determine predictors associated with meeting IOM guidelines. The objective of the second study was to conduct a preliminary exploration of women's attitudes towards an evidence-based, mHealth app, *SmartMoms Canada*, as a valid source of pregnancy-related information and its ability to offer physical activity, nutrition, and lifestyle support. Focus groups were organized to assess women's attitudes towards the app and inductive thematic content analysis was utilized to interpret focus group data. It was found that self-efficacy and perceived controllability of behaviours are important factors contributing to whether women meet IOM weight gain recommendations. Further, pregnant women are quite receptive to mHealth technology and positively viewed the future prospective of *SmartMoms Canada* as a means of promoting overall maternal health. Combined, these findings will contribute to our understanding of how to best improve maternal-fetal health outcomes in the near future.

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ABBREVIATIONS

ACOG	The American College of Obstetricians and Gynecologists
BMI	Body Mass Index
CI	Confidence Interval
eHealth	Electronic Health
EMat	Electronic Maternal health survey
GWG	Gestational Weight Gain
HCP (s)	Health Care Provider (s)
IOM	Institute of Medicine
LGA	Large for Gestational Age
mHealth	Mobile Health
OR	Odds Ratio
PPWR	Post-partum Weight Retention
SCT	Social Cognitive Theory
SES	Socioeconomic Status
SGA	Small for Gestational Age
SOGC	The Society of Obstetricians and Gynaecologists of Canada
TPB	Theory of Planned Behaviour
WHO	World Health Organization

CHAPTER 1 – INTRODUCTION AND THEORETICAL BACKGROUND

1.1 INTRODUCTION

The World Health Organization (WHO) defines overweight and obesity as the accumulation of abnormal or excessive fat, resulting in several health risks.¹ Although thought to be an unrefined measure, a person's body mass index (BMI; weight (kg) divided by height (m) squared) can be best used as a population measure of obesity. A BMI equal to or greater than 25 kg/m² is considered to be overweight, and a BMI equal to or greater than 30 kg/m² is considered to be obese.¹ Nearly two thirds of Canadian adults and one third of children are overweight or obese and the associated economic burden of obesity is between 4.6 to 7.1 billion dollars.² Worldwide, women of reproductive age are disproportionately affected by obesity.³⁻⁵ Notably, among Canadian women aged 18 years and older, the rate of obesity has increased from 14.5% in 2003 to 18.7% in 2014.⁶ The prevalence of weight gain above recommendations also known as excessive gestational weight gain (GWG), has steadily risen among obstetric populations and poses considerable risks for both mother and infant.^{3,7} Fetal exposure to an intrauterine environment affected by maternal obesity and excessive GWG increases the likelihood of babies born with downstream chronic diseases, large-for-gestational-age (LGA), and obesity later in life.

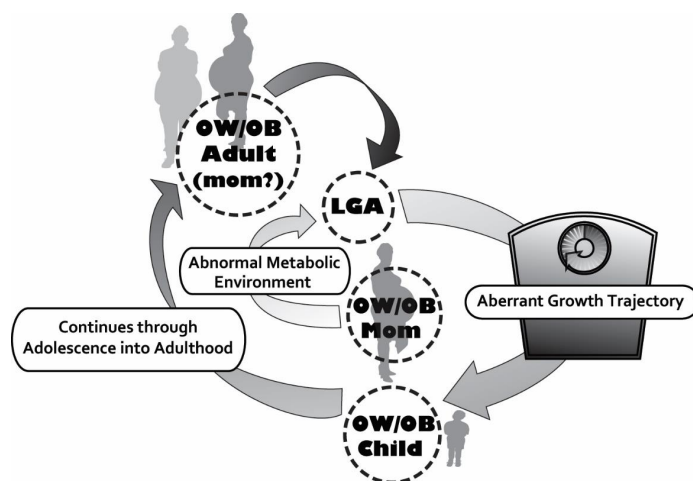


Figure 1. Adapted from Adamo et al. *Int. J. Environ. Res. Public Health* 2012, 9(4), 1263-1307.

Excessive GWG has also been linked to the intergenerational cycle of obesity or when women with overweight or obesity give birth to LGA offspring, who subsequently have a greater likelihood of becoming obese themselves and if female, perpetuating this cycle by delivering larger neonates (see Figure 1).^{5,8} Therefore, overweight and obesity are major public health concerns across many nations that require immediate action towards ensuring a healthier population.

1.2 THESIS OBJECTIVES

Knowing the risks, and recognizing the downstream sequelae associated with entering pregnancy at a high BMI or exceeding the evidence-based GWG guidelines, this thesis aimed to:

- 1) Characterize women's perceptions of weight gain, physical activity, and diet during pregnancy along with assess the barriers and facilitators associated with the perceived success of meeting IOM weight gain recommendations using a previously validated questionnaire called the Electronic Maternal Health Survey (EMat).
- 2) Qualitatively evaluate how receptive pregnant women and new mothers are towards utilizing a novel mHealth tool, *SmartMoms Canada*, throughout their pregnancies as a feasible and reliable source of information and possible future aid in achieving guideline-concordant weight gain.

1.3 THE ELECTRONIC MATERNAL HEALTH SURVEY

The Electronic Maternal (EMat) health survey is a validated questionnaire designed to assess women's perceptions, attitudes, and behaviours, towards the recent Institute of Medicine (IOM) weight gain recommendations (detailed below), physical activity, and nutritional practices, as well as other pregnancy-related behaviours.⁹ The survey was developed by an expert panel of seven individuals and was constructed using branching logic in eight comprehensive steps, so as to avoid redundancies.⁹ Survey respondent data has been collected on an ongoing basis since 2014 through a secure data capture tool, REDCap™.

There are two key theoretical frameworks to consider as they relate to the development and analysis of the EMat health survey. The development of the EMat health survey was grounded in Social Cognitive Theory (SCT) so as to encompass key constructs related to perceived behavioural control of GWG and associated health behaviours. The SCT, developed by Canadian psychologist, Albert Bandura, outlines predictive and modifiable factors associated with behaviour change.¹⁰ The theory embodies a model of *reciprocal determinism*, whereby behaviour, cognition, personal factors, and environmental influences operate in tandem.¹⁰ The theory posits that behaviour change is a product of a personal sense of control – if one believes that they can take action to remedy a problem, than one will be increasingly willing and committed in doing so. The first important construct of SCT is *self-efficacy*, or the belief in one's capacity to exercise control over taxing demands and one's own functioning.¹⁰ Low self-efficacy is associated with helplessness and susceptibility to terminating efforts early and failing to meet challenging demands; in contrast, individuals with high self-efficacy exhibit a strong sense of competence, leading to successful outcomes.¹¹ The second important construct of SCT is *outcome expectancies*, or beliefs regarding the consequences of one's actions.¹⁰ Combined, self-efficacy and outcome expectancies influence one's behaviours, and one's setting of and pursuit of goals. Since its conceptualisation, SCT has been applied to several areas including mental and physical health, sociopolitical change, health, and personality psychology.¹² Of particular importance, is the application of SCT in health, which is outlined in Bandura's work, "Health Promotion by Social Cognitive Means."¹³ According to Bandura, social cognitive approaches focus on promoting effective self-management of personal health habits. Of relevance to the EMat survey, SCT presents central determinants that include 1) knowledge of health risks and advantages of certain health practices, 2) the self-efficacy that one can exercise control over personal health habits, 3) outcome expectancies regarding the consequences of one's health habits, 4) one's personal health goals and plans to attain those goals,

5), perceived facilitators in achieving the goals, and lastly, 6) the social and structural impediments and perceived barriers in attaining one's health goals.^{12,13}

Perceived self-efficacy and perceived controllability of one's actions are often linked, however, there are key distinctions to be aware of. Perceived controllability or locus of control was first developed by Julian Rotter and relates to the extent by which people believe they can control the outcome of their actions.¹⁴ Individuals with an *internal locus of control* believe that the consequences of their actions are due to their own abilities, whereas individuals with an *external locus of control* believe that the consequences of their actions are outside of their control and attribute outcomes of their actions to external factors.¹⁴

The second theoretical framework in relation to the analysis of the EMat health survey is the Theory of Planned Behaviour (TPB). The TPB posits that behavioural intentions are precursors of behaviour, whereby intentions are influenced by the attitude towards the behaviour, subjective norm, and perceived behavioural control.^{15–17} Therefore, an individual's intention towards adopting a certain behaviour will depend on if they perceive that behaviour positively (i.e. attitude), consider that others believe it is essential they exhibit this behaviour (i.e. subjective norm) and that the individual believes this behaviour to be under their control (i.e. perceived behavioural control). The TPB has been previously used as a framework in predicting behavioural intention and behaviour during pregnancy. Pregnant women's perceptions of weight gain, physical activity, and nutrition have been evaluated using the TPB by Whitaker and colleagues.¹⁸ As an example, a woman's attitude towards physical activity may result in behavioural change due to her personal beliefs regarding the risks or advantages of exercise during pregnancy. This study found that the TPB was a useful framework in assessing women's weight-related intentions during pregnancy. Thus, the TPB was discussed as a potential framework in assessing women's attitudes,

subjective norm, and perceived behavioural control over adhering to IOM weight gain recommendations in the analysis of the EMat health survey.

1.4 SMARTMOMS CANADA

The *SmartMoms Canada* project was developed by an interdisciplinary team of researchers and led by Dr. Kristi B. Adamo. The primary objective of the *SmartMoms Canada* project is to evaluate a mobile-technology based program designed to help women adhere to GWG guidelines, improve maternal-fetal health, and ultimately halt the intergenerational cycle of obesity by promoting a reduction in excessive GWG, leading to fewer LGA babies, less post-partum weight retention (PPWR), thereby preventing subsequent obesity in mom and future offspring. The *SmartMoms Canada* mobile health (mHealth) application (app) is modelled after the US SmartMoms app, developed by Dr. Adamo's colleagues at Pennington Biomedical Research Center in Baton Rouge, Louisiana.¹⁹ The *SmartMoms Canada* mHealth tool allows pregnant women to monitor their weight gain, daily physical activity, and food intake habits as well as receive individualized feedback and support. This novel, research-based pregnancy app, with the help of Wi-Fi™ enabled accessories (Fitbit fitness tracker and BodyTrace scale), offers women sleep and several other lifestyle recommendations, as well as regular delivery of health information regarding GWG, physical activity, and nutrition.

A preliminary evaluation of an alpha version of the *SmartMoms Canada* mHealth app was conducted using qualitative methods. Two focus groups with both pregnant and recently postpartum women were organized to assess women's receptiveness towards the app, along with their viewpoints on the design, content, functionality, and future prospective of the app. In order to achieve our results from focus group data, thematic content analysis was conducted. Thematic analysis is a widely used form of analysis for qualitative research. It is a method of identifying, analyzing, and outlining patterns or themes within data that provides a nuanced account of groups

of themes within data.²⁰ In conducting thematic analysis, themes can be recognized using either an inductive (i.e. bottom-up) or a deductive (i.e. top-down) approach.²⁰ An inductive approach to thematic analysis is primarily *data-driven*, whereby the coding of the data is performed without an *a priori* coding frame and free of the researchers' preconceptions.²¹ In contrast, a deductive or theoretical approach to thematic analysis is *analyst-driven*, whereby the researcher performs the analysis based on their own theoretical and analytic interests.²⁰

1.5 RATIONALE AND RELEVANCE OF STUDY

Of significant concern to public health is the fact that women of childbearing age are disproportionately faced with the burden of overweight and obesity. Maternal pre-pregnancy BMI and GWG are two independent and modifiable factors that may be addressed through adequate education and intervention. Exceeding GWG guidelines has detrimental short- and long-term health effects on both mothers and infants, contributing to an intergenerational cycle of obesity.⁸ Few studies have examined the combination of women's knowledge, perceptions, and barriers to achieving IOM weight gain recommendations, particularly within a Canadian context. When developing interventions to help reduce excessive GWG, there is also little consideration for the psychosocial aspects surrounding pregnancy and how these factors impact behaviour and lifestyle. Consideration for women's social environment during pregnancy, awareness, and perceptions along with barriers and facilitators to healthy GWG is imperative in mediating future research and interventions. Importantly, given the recent and rapid emergence of mHealth technology in daily life, studies on how pregnant women and new mothers interact with these new information technologies are scant. Evaluating how women perceive mHealth, and particularly a new mHealth tool, *SmartMoms Canada*, as a means of evidence- and research-based information, will contribute to a growing field aimed at understanding human-internet interaction. New insights informed through the qualitative assessment of the *SmartMoms Canada* mHealth pregnancy app, presented

here, may also guide our understanding of how mHealth interventions can provide advantageous prenatal guidance, notably, adhering to IOM weight gain recommendations.

CHAPTER 2 – REVIEW OF THE LITERATURE

2.1 DEVELOPMENTAL ORIGINS AND THE INTRAUTERINE ENVIRONMENT

The concept of fetal programming or developmental plasticity, first emerged from seminal epidemiological studies on infant and adult mortality conducted by David Barker and colleagues.^{22–24} This work triggered extensive interest in understanding how favourable or unfavourable environmental factors operating *in utero* may program or alter one's susceptibility to downstream disease.²⁵ In turn, this led to the *Fetal Origins of Adult Disease* or *Barker's Hypothesis*, later becoming a field of study termed the *Developmental Origins of Health and Disease* (DOHaD), currently a prolific paradigm of modern pediatrics.²⁶ The precise mechanisms through which downstream health is altered *in utero* are not yet well understood. However, the DOHaD hypothesis centres around the premise that environmental influences on gene expression, that is, epigenetic modifications, initiated via environmental perturbations during intrauterine growth, have been shown to play a significant role in fetal predisposition to downstream chronic diseases such as coronary heart disease, hypertension, and type 2 diabetes mellitus.^{25,27}

In line with fetal programming, maternal obesity and excessive GWG during pregnancy are two key influencers of the intrauterine environment.^{25,28} It is widely accepted that the strongest risk factor for both childhood obesity and metabolic imbalance is maternal pre-gravid (or, pre-pregnancy) obesity.²⁹ However, irrespective of pre-pregnancy weight, previous work has found a strong relationship between GWG and weight status during childhood and adulthood.³⁰ Similarly, independent of maternal BMI, excessive weight gain during pregnancy is a predictor of delivering a LGA neonate, thereby increasing the likelihood of overweight and obesity in future generations.³¹ The frequency and severity of adverse outcomes associated with maternal obesity, including downstream obesity in offspring, is increased when pregnant women with obesity

experience weight gain above recommended guidelines.³⁰ Therefore, optimizing guideline-concordant weight gain during pregnancy is crucial in improving maternal-fetal health outcomes.

2.2 BIOLOGY AND ENVIRONMENT

In discussing maternal obesity, it is important to note that there is no simple explanation as to what causes obesity. Obesity is a chronic disease that is thought to develop from complex interactions, of both genotype and environmental factors.³² Thus, human biology and environmental circumstances are involved. The attempt to attribute biological or environmental factors to behaviour, has been conducted with classic genetic studies of twins, and is known as the nature *v.* nurture debate, however ongoing and inconclusive.³³ Biological and environmental factors associated with behaviour may intersect at epigenetics, in which adverse or nurturing environmental factors result in changes at the molecular level, thereby impacting gene expression.^{34–36} The premise of the DOHaD hypothesis introduced above, is epigenetic modifications through environmental influences (i.e. maternal overweight, obesity, and excessive GWG) that occur *in utero*, thereby impacting the downstream health of both mother and infant. Recently, the field of behavioural epigenetics, although growing in complexity, attempts to answer how nurture can shape nature.³⁷ As such, the consideration of both biology and environment are essential to our understanding of maternal-fetal health. Maternal genetic predisposition to obesity and maternal lifestyle conditions are equally important factors governing downstream health and behaviours that should be accounted for when developing interventions to reduce excessive GWG among pregnant women who present with overweight and obesity.

2.3 INSTITUTE OF MEDICINE GESTATIONAL WEIGHT GAIN GUIDELINES

In 1990, the United States Institute of Medicine (IOM) released weight gain recommendations that were based on pre-pregnancy BMI.³ These guidelines did not consider all three classes of obesity in determining the weight gain limits for women categorized as obese prior to pregnancy. Moreover,

an upper weight gain limit did not exist for women within this category.³⁸ Since then, an increase in overweight and obesity among women of childbearing age, along with a failure of many women to adhere to the 1990 IOM guidelines, prompted a necessary re-examination.³⁸

The recent 2009 IOM guidelines, presented in Table 1, sought to reflect the rapid demographic changes observed in obstetric populations. The new guidelines differ from the 1990 guidelines in two distinct ways: Firstly, the BMI categories are currently based on the WHO categories and secondly, a narrow range (including both lower and upper limits) of weight gain for women with obesity has been incorporated.³ Many organizations and societies have adopted the re-examined guidelines and are used by clinicians as a basis for practice. According to these guidelines, women who are underweight before pregnancy are recommended to gain between 12.5 and 18.0 kg. Those who are normal weight are to gain between 11.5 to 16.0 kg, and those who are overweight and obese before pregnancy are to gain between 7.0 to 11.5 and 5.0 to 9.0 kg, respectively. Weight gain within the guidelines is strongly recommended and has been shown to result in healthful pregnancies.³⁸

Table 1**2009 Institute of Medicine Weight Gain Guidelines using Pre-Pregnancy BMI.**

		Total Weight Gain	Rates of Weight Gain ^a 2 nd and 3 rd Trimester
Pre-Pregnancy Weight Category	Pre-Pregnancy BMI (kg/m ²)	Range (kg)	Mean and Range (kg/week)
Underweight	< 18.5	12.5 to 18.0	0.51 (0.44 to 0.58)
Normal Weight	18.5 to 24.9	11.5 to 16.0	0.42 (0.35 to 0.50)
Overweight	25.0 to 29.9	7.0 to 11.5	0.28 (0.23 to 0.33)
Obese (all classes)	≥ 30.0	5.0 to 9.0	0.22 (0.17 to 0.27)

^a Calculations assume a 0.5 to 2.0 kg weight gain in 1st trimester.³

2.4 EXCESSIVE GESTATIONAL WEIGHT GAIN

The prenatal period has often been considered a “teachable moment” in a woman’s lifespan.³⁹ Pregnant women are in close contact with their healthcare providers (HCPs) and are increasingly concerned about their baby’s health, making this an optimal time to adopt healthier behaviours.³⁹ Weight gain during pregnancy or GWG is a normal and expected component of a healthy pregnancy.⁴⁰ A systematic review and meta-synthesis of qualitative research on pregnant women’s perceptions of GWG found that women were motivated to make lifestyle changes for the concern of their baby’s health. Interestingly, when asked explicitly, many women did not associate or recognize the risks of excessive GWG to both the short- and long-term maternal and fetal health implications.⁴¹ Thus, it is important to consider that environmental, structural, intra- and inter-personal factors all contribute to a complex social environment surrounding weight gain in pregnancy that may generate various disadvantages and barriers to certain women.⁴¹

As previously discussed, weight gain above IOM guidelines is associated with several, well-documented, adverse maternal and infant health outcomes.⁴² For pregnant women, these may include increased risk of high blood pressure and pre-eclampsia,^{40,43} caesarean delivery,⁴⁴ postpartum weight retention,⁴⁵ diabetes,⁴⁶ and obesity.⁵ In turn, infants are at greater risk of pre-term delivery,⁴⁷ being born LGA,⁴⁸ and downstream metabolic disorder along with overweight and obesity later in life.⁴⁹ When examining the associations between GWG above or below the IOM recommendations, a 2017 systematic review by Goldstein and colleagues, assessing over 1 million pregnant women, found that 47% of women exceeded the 2009 IOM recommendations.⁴² Women with a pre-pregnancy BMI categorized as underweight or normal weight, also develop the same maternal and infant complications as women who are overweight prior to pregnancy if they experience excessive GWG.³⁰ Thus, exceeding weight gain recommendations is an independent and modifiable risk factor. Fortunately, negative health outcomes of excessive GWG can be

prevented through prenatal interventions, education, health promotion strategies, and knowledge of the importance of healthy pregnancy weight gain.

2.5 FACTORS ASSOCIATED WITH ADHERENCE TO WEIGHT GAIN RECOMMENDATIONS

In a survey conducted by McDonald and colleagues, only 12% of women reported being appropriately counselled on the 2009 IOM pregnancy weight gain guidelines.⁵⁰ Previous work has shown that women have poor knowledge of detailed pregnancy recommendations, specifically the IOM guidelines.^{51,52} In contrast to patient reports, many HCPs document counseling on GWG along with physical activity and nutrition.⁵³ It is important to note, however, that reports of women's knowledge of IOM recommendations have been inconsistent and may lack generalizability. Among general practitioners, obstetricians, midwives, nurse practitioners, and registered nurses in Canada, information on GWG was discussed early in pregnancy but no longer addressed unless there were concerns.⁵⁴ Interestingly, very few HCPs report discussing individualized GWG goals, the rate of GWG necessary based on pre-pregnancy BMI, or the risks associated with excessive GWG to both the mother and baby.⁵⁴ A qualitative study on GWG goal setting found that pregnant women highly value discussions with their HCPs that focus on setting specific goals for weight gain during pregnancy.⁵⁵ Furthermore, women report clinicians as the most reliable source of information and would like to have open and frequent conversations, as opposed to reactive ones based on concern.⁵⁵ It is clear that there are gaps in knowledge acquisition from pregnant patients and dissemination from their HCPs. Having limited counseling on recommendations is a taxing barrier to achieving guideline-concordant weight gain during pregnancy that needs to be addressed, especially in developing adequate prenatal interventions.

2.6 WEIGHT STIGMA AND SENSITIVITY ASSOCIATED WITH WEIGHT GAIN RECOMMENDATIONS

Although adhering to IOM weight gain recommendations and minimizing excessive GWG are essential for short- and long-term maternal and fetal health, it is important to recognize that certain

women in society, those considered to be members of vulnerable groups, are faced with stigma related to weight gain and experience several social, structural, and cultural disadvantages concerning access to resources and overall quality of life.

Stigma can be defined as a negative stereotype, whereas discrimination is a behaviour that results from negative stereotypes; individuals can be commonly faced with both stigma and discrimination.⁵⁶ Disadvantaged and vulnerable groups in society are particularly subject to societal neglect and stigmatization. In Canada, vulnerable groups include children and pregnant women, Indigenous peoples, and seniors.⁵⁷ Vulnerable groups also include members of a minority population, persons with disabilities, refugees, members of the LGBTQI+ community, and individuals of low socioeconomic status.⁵⁸ Due to several factors, these individuals face many obstacles in their daily lives. In like manner, weight stigma can be defined as prejudice and discriminatory actions towards an individual solely based on that individuals' weight and body size.⁵⁹ Disadvantaged and vulnerable groups in society may also be subject to weight stigma. Of relevance to this thesis, weight stigma is pervasive in healthcare settings in Western society, especially in maternity care, ultimately impacting women's psychological and physical health.⁶⁰ Moreover, weight bias, or negative attitudes towards obesity and individuals with obesity, is also important to consider as both weight bias and weight stigma may be critical causes of health inequalities of vulnerable groups and may impact one's quality of care.⁶¹

In light of the recent focus on the management of overweight and obesity during and after pregnancy, it is essential to consider the experiences during maternity care of pregnant women who present with overweight and obesity, as well as maternity care providers' attitudes towards these patients. A two-tiered study involving Australian pregnant women and maternity care providers found that, compared to lower weight women, those who presented with a higher BMI were significantly more likely to report negative encounters and experiences, throughout

pregnancy and postpartum.⁶⁰ Additionally, maternity care providers presented views of pregnant women who were overweight or obese as displaying poor self-management behaviours and interestingly, those care providers who reported possessing few stigmatising attitudes, portrayed less positive viewpoints towards pregnant women who were overweight and obese.⁶⁰ Of relevance to a Canadian population, Canadian Indigenous women face several barriers in accessing maternal health services and by great proportion, receive inadequate prenatal care relative to other pregnant women in Canada.⁶² A systematic review of Canadian Indigenous women's perspectives of maternal health care services found that the availability of healthcare resources, healthcare services' consideration of socio-economic barriers, and the impact of colonization on the interactions with HCPs, were the key factors that influenced Indigenous women's maternal health experiences.⁶² The review stresses the importance of incorporating community-driven, woman-centered, and culturally sound maternal health services so as to reduce health disparities among Indigenous women in Canada, and arguably, among vulnerable groups in society. Thus, as previous work has found, it is critical to engage the experiences and perspectives of pregnant women who are overweight and obese, when informing the development of maternal overweight and obesity initiatives, so as to best consider both the social experiences and clinical health needs of this often stigmatized group of women.⁶³

The understanding of the stigmatization of large female bodies and the association of women's physical appearance with the behaviours of an unfit mother or mother-to-be, is also of great importance to overall maternal-fetal health. The degree of weight stigma in maternity care has not been well documented or studied and given that women are at increased risk of poor mental health during and after pregnancy, the impact of weight stigma and bias warrants further study.⁶⁰ Discomfort, intolerance, and feeling of repulsion when caring for pregnant women with obesity and the assumption that these women are unmotivated, lazy, and lack skills and awareness

to manage their weight, are some pertinent and problematic stigmatizing attitudes portrayed by maternity care providers.^{64,65} In opposition to the aforementioned viewpoints, in a study examining young women's discursive constructions of health, it was found that women's construction of health during pregnancy places great emphasis on fetal health and the responsibility of pregnant women to control their health.⁶⁶

The understanding of how gender identity interconnects with several systems of power and how this affects the most marginalized groups in society is known as *intersectional feminism*. By viewing reproductive justice through an intersectional lens, Parker concludes that the understanding of the relationship between women's body weight and reproductive health outcomes, need to consider the social and political context of health, body weight and mothering, social and economic justice, one's environment, immigrants' and disability rights, and discrimination based on race, gender, and sexual orientation.⁶⁷ Parker also informs that the 'responsibilizing' of obesity and population health to women's reproductive bodies and behaviours can maintain a system of social and health inequalities, whereby women who are most marginalized in society (i.e. Indigenous women, women living in poverty, women of colour, single mothers) and who have the least access to resources to sustain a healthy pregnancy weight, are subject to considerable pressures of self-regulation.⁶⁷ These women, in particular, are most vulnerable to being blamed for unexpected or poor reproductive health outcomes, and concern over maternal weight may portray pregnant women with overweight or obesity as unfit mothers. It is thus important to consider sociological perspectives with respect to pregnant embodiment.

In addition to weight stigma and bias, as well as the sociological perspectives of pregnant embodiment, pregnancy is in fact a vulnerable time for women and weight sensitivity must also be considered. Vanstone and colleagues, using qualitative analysis, found that weight gain during pregnancy occurs within a complex social environment and is a sensitive and anxiety-producing

topic, wherein women who are socially disadvantaged may succumb to further obstacles such as limited resources, in achieving appropriate weight gain.⁴¹ Healthcare providers have also reported that weight is a sensitive topic to discuss with their pregnant patients.⁶⁸ Importantly, however, women are motivated and seek advice on pregnancy weight gain and diet, thus, it is critical that HCPs are guided and receive adequate training on how to discuss the sensitive and complex topic that is, weight gain during pregnancy,⁶⁹ particularly among women of vulnerable groups of society.

2.7 PHYSICAL ACTIVITY AND DIET DURING PREGNANCY

Pregnancy is an optimal time for women to pursue healthful behaviours such as increased physical activity. Women who are pregnant, along with their developing fetus, may benefit from adopting or continuing an active lifestyle.⁷⁰ According to the American College of Obstetricians and Gynecologists (ACOG), despite long-held beliefs, physical activity during pregnancy has minimal risks.⁷¹ In fact, pregnancy outcomes are improved from regular activity, such as weight management, reduced risk of gestational diabetes, and improved psychological health.⁷¹ Healthcare providers in particular, should encourage women to engage in physical activity as there is no evidence to support that habitual, moderate activity will harm the developing fetus. Inherently, women who present with contraindications face restrictions to physical activity and are unlikely to exercise during pregnancy.⁷² Nevertheless, for most women, engaging in regular activity is safe, beneficial in managing GWG, and recommended as a core component of a healthy pregnancy.^{70,73} The Society of Obstetricians and Gynecologists of Canada (SOGC) in tandem with the Canadian Society of Exercise Physiology (CSEP), recommend that pregnant women take part in 30 minutes of moderate to vigorous exercise, four times per week.⁷² However, many pregnant women are not meeting physical activity guidelines⁷⁴ and specifically, in Ontario, only 23% of women meet SOGC recommendations.⁷⁵ A systematic review examining women's engagement in physical activity before, during, and after the postnatal period of pregnancy found a significant decrease in

moderate to vigorous physical activity postnatally compared to pre-pregnancy, and this decline in activity often did not increase postpartum.⁷⁶

Unfortunately, most pregnant women report not receiving any, or very little guidance, on pregnancy-specific counselling of how to engage in physical activity.⁷⁷ This is problematic as studies indicate that with adequate and sufficient knowledge, women are more likely to gain within recommendations throughout pregnancy.^{78,79} Intrapersonal factors such as lack of time, discomfort during pregnancy, and fatigue are other pertinent barriers to physical activity whereas social support plays an enabling role.⁸⁰ However, minimal research has been conducted thus far examining key barriers and enablers to physical activity during pregnancy, which is essential for introducing relevant clinical practices that may help reduce excessive GWG. In particular, the assessment of barriers or enablers to physical activity in relation to women's knowledge of the perceived pragmatism of meeting recommendations will further elucidate our understanding.

In addition to remaining active throughout pregnancy, the consumption of a varied and healthful diet is another behaviour that should be encouraged among pregnant women. Proper nutrition with a balanced diet, including both micro- and macro-nutrients, is paramount for the development of the fetus.⁸¹ In line with the DOHaD hypothesis, malnutrition, encompassed by both undernutrition and overnutrition, has been shown to impact fetal metabolic pathways and increase the risk of childhood and adult diseases well beyond the neonatal period.^{81,82} Poor maternal dietary habits throughout pregnancy have also been linked to a greater likelihood of postpartum weight retention⁸³ and excessive GWG.⁸⁴ Given the intergenerational nature of the aforementioned outcomes,⁸ an adequate and solution-driven understanding of barriers and enablers to the consumption of a healthy maternal diet is of utmost importance.

The “eating for two” adage, once a societal norm, passed down for generations as advice for pregnancy, has been debunked as an inappropriate and inaccurate recommendation.⁸⁵ During

the first trimester of pregnancy, women do not require an increase in their daily caloric intake to support fetal growth.⁸⁶ Although caloric intake should be individualized, accounting for the woman's activity level, age, and BMI, it is generally accepted that women require an increase of approximately 340 and 450 kcal per day during the second and third trimesters, respectively.⁸⁶ Both the IOM and Health Canada are in accord with these dietary recommendations for pregnant women.⁸⁷ Today, women continue to hold inaccurate beliefs regarding appropriate weight management during pregnancy,⁸⁸ have limited knowledge of nutritional requirements, and report minimal nutritional counseling from their care providers.⁸⁹ This is especially true of women from lower income groups who face a myriad of additional barriers such as lack of social support and resources, education and counseling, and financial hardships.⁹⁰ A Cochrane review of 65 Randomised Controlled Trials (RCT) involving over 11,000 women who contributed data for quantitative analysis found that diet, or exercise, or both, can significantly diminish the risk of excessive GWG.⁹¹ In contrast, systematic reviews examining dietary interventions in pregnant women with overweight or obesity have been inconsistent and have not reached similar conclusions.^{92,93} Barriers that may diminish maternal diet quality include early pregnancy symptoms such as nausea and vomiting, socio-economic status, maternal depression, and accessibility of healthy foods.⁹⁴ Among Canadian women, there is only partial understanding of the barriers that pregnant women, in particular those with overweight and obesity, face in achieving a healthful diet. A thorough understanding of women's awareness of healthy nutrition and their perceptions of the realism in adopting healthy dietary behaviours during pregnancy can guide future interventions that may facilitate behavioural change.

2.8 MOBILE HEALTH TECHNOLOGY AND PRENATAL CARE

According to the International Telecommunication Union, in 2015 there were over 7 billion mobile cellular subscriptions worldwide; thus, mobile technology is ubiquitous.⁹⁵ Such technology has

immense potential to provide avenues for dissemination of health promotion programs and interventions aimed at informing personal health parameters.⁹⁶ A meta-analysis of 44 RCTs promoting healthy GWG, found significant reductions in GWG in the intervention compared to the control group when all physical activity, diet, and mixed approach interventions were analyzed together.⁹⁷ However, these interventions may be costly, intensive, and time-consuming for both provider and recipient. Mobile health (mHealth) technology offers a cost-effective alternative to overcoming limitations of standard prenatal care that can extend to an oft-neglected subgroup of women living in remote geographical locations.^{98,99}

Currently, pregnant women have turned to both mHealth and electronic health (eHealth) information technologies. It is important to consider, however, as previously discussed, that weight gain may be a sensitive topic for many women and sufficient counselling with a clinician, although time-consuming, remains a strong facilitator to healthy pregnancy weight gain.⁴¹ Naturally, there may be criticism over the use of these technologies as a replacement for information that would normally be delivered by HCPs. Therefore, critical perspectives of mHealth and regular self-tracking should be considered when a potential shift in power dynamics from clinician to one's self arises. The widespread nature of mobile technology has elicited personal data commodification (or, the process of exchanging, placing economic value and marketing), along with personal surveillance that has called attention to the consequences of digitalization as a social norm. Some scholars of the social sciences have provided detailed analysis of self-tracking cultures.¹⁰⁰ Prominently, Deborah Lupton's "The Quantified Self" explores various themes that provide theoretical insight on the control and power underlying self-tracking. Pivotal questions are probed that examine social dynamics of digitalization such as how knowledge of personal digital data impacts one's perception of one's self, how self-tracking may impact power relations, and how commodification of personal data produces methods of strict regulation and control.

A qualitative study examining women's and health professionals' views of mHealth interventions found that health professionals expressed potential risks and limitations of using mHealth as trusted sources of information.¹⁰¹ Willcox and colleagues suggest that HCPs are more critical of the potential of technology to veer control of information from trusted sources (i.e. health professionals and health organizations), to nontrusted sources (i.e. mHealth and eHealth), yielding privacy concerns and potential for misinformation. However, the researchers found positive perceptions surrounding mHealth as a means of promoting physical activity, healthy diet and GWG. Similarly, Lupton and colleagues conducted focus group discussions with pregnant women and new mothers and discovered that high value was placed on the support and information received from online sources such as Google, Facebook, and YouTube, as well as various pregnancy applications (apps) featuring self-tracking options.¹⁰²

Although medical literature has expressed variability in the quality of information offered by health and medical apps, pregnant women continue to see value and benefit from using digital media to support their various information needs.¹⁰² While women may value multi-faceted and interactive digital platforms, when faced with professional information needs, women seek more trustworthy apps or online sources supported by health professionals or well-established organisations.¹⁰² Lupton's work has also demonstrated that although pregnant women express the anxiety-provoking nature of pregnancy and early parenting, they view the access of information from apps and online media as a means of regaining control and providing peace of mind.^{102,103} Some work has also indicated that HCPs display support for mHealth and would refer a patient to health-focused apps as they see the potential of improving health outcomes of their patients.¹⁰⁴

The practice of self-weighing may be fraught with negative connotations, implying a coerced cycle of pushed and imposed self-tracking, strict regulation and control, and privacy concerns over shared personal data metrics. However, there are documented advantages to self-

weighing in general and during pregnancy that stem beyond the cultural phenomenon of self-tracking. Self-weighing for consideration of patient health has been shown to be beneficial. A systematic review of 22 research articles found that 75% of self-weighing only interventions and 67% of combined interventions (i.e. other self-monitoring strategies such as self-weighing and tracking of food intake and physical activity) improved weight outcomes and no negative psychological effects were associated with self-weighing at a frequency of daily or weekly.¹⁰⁵ Women's opinions of being weighed at routine antenatal visits have also been examined. A study by Brownfoot and colleagues, assessing 782 healthy pregnant women enrolled in an RCT, found that the majority of women were generally satisfied with being weighed at antenatal visits and this did not provoke anxiety.¹⁰⁶ The authors concluded that regular weighing throughout pregnancy does not contribute to psychological harm and self-weighing could be incorporated into successful interventions to reduce excessive GWG. Moreover, mHealth and eHealth information technologies have shown significant promise in developing countries and low to middle-income countries¹⁰⁷, reaching women of vulnerable groups in society, and have been promoted by the WHO as an encouraging means of improving maternal and child health.^{96,108}

The consideration of self-weighing and frequent weight management is of particular importance in the context of pregnancies classified as overweight and obese. Given that excessive GWG and postpartum weight retention are two key contributors of the intergenerational cycle of obesity⁸ and that exceeding GWG recommendations places both infant and mother at increased risk of future health complications,^{29–31} understanding the role of self-weighing among pregnant women categorized as overweight and obese is paramount. A RCT assessing self-weighing and simple dietary advice for pregnant women identified as overweight and obese found that quality of life (indicated by the WHO Quality of Life assessment) was not impaired by the intervention.¹⁰⁹ Additionally, since pregnancy is considered a “teachable moment” for weight control and obesity

prevention, the act of daily self-weighing and monitoring has been found to be a key component to successful weight loss maintenance.³⁹ Therefore, lifestyle interventions that include self-monitoring may aid pregnant women with overweight and obesity in adhering to GWG recommendations, thereby preventing excessive GWG and future maternal-fetal health risks.

CHAPTER 3

PREAMBLE TO ARTICLE 1

The following article titled, “Women’s Self-Efficacy is Associated with Meeting Institute of Medicine Gestational Weight Gain Recommendations: Findings from the Canadian Electronic Maternal Health Survey” was submitted to *BMC Pregnancy and Childbirth* on July 20th, 2018. The manuscript ID provided by the journal upon submission was PRCH-D-18-00806. The format of the manuscript presented below is in accordance with the journal guidelines.

As of September 2018, the manuscript is currently under *peer-review*.

Women's self-efficacy is associated with meeting Institute of Medicine gestational weight gain recommendations: findings from the Canadian Electronic Maternal health survey

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Running head: Self-efficacy and gestational weight gain recommendations

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ABSTRACT

Background: Fetal exposure to an intrauterine environment affected by maternal obesity and excessive gestational weight gain increases the likelihood of infants born large for gestational age and obesity in childhood. This study sought to examine women's perceived attainability of the 2009 Institute of Medicine (IOM) weight gain guidelines and factors associated with adherence.

Methods: Cross-sectional data were collected from pregnant ($n = 320$) and postpartum ($n = 1179$) women who responded to a validated questionnaire, the Electronic Maternal (EMat) health survey. Consenting women completed the survey through REDCap™, a secure online forum. Multiple logistic regression analyses were used to evaluate several correlates associated with meeting or not meeting recommendations.

Results: Odds ratios (ORs) were adjusted for relevant behavioural and sociodemographic covariates. There were no significant differences between adjusted and unadjusted ORs with respect to self-efficacy, barriers, and facilitators to weight gain during pregnancy. Women who *worried* about gaining too much weight were significantly less likely to meet IOM guidelines (OR = 0.48, 95% CI = 0.33 – 0.69). An internal locus of control for weight gain was associated with a greater likelihood of meeting guidelines when women perceived to be firstly, in control of their weight gain (OR = 1.75, 95% CI = 1.29 – 2.37), secondly, healthy and exercised (OR = 1.91, 95% CI = 1.34 – 2.71), and thirdly, when no barriers to healthy weight gain were indicated (OR = 1.43, 95% CI = 1.04 – 1.95). An external locus of control depicted by women perceiving weight gain as *beyond control* of the mother was associated with a significantly reduced likelihood of achieving weight gain guidelines (OR = 0.58, 95% CI = 0.39 – 0.88).

Conclusions: Self-efficacy and perceived controllability of behaviours are important factors to consider when developing interventions that can help women achieve guideline-concordant weight gain during pregnancy and ensure downstream health of both mother and baby.

Keywords: Self-efficacy, locus of control, excessive gestational weight gain, obesity, Institute of Medicine, and pregnancy.

BACKGROUND

In recent years, there has been a rapid transition to overweight or obesity among women of reproductive age [1, 2]. In Canada, women of childbearing age are increasingly heavier [3, 4] and approximately one third of women enter pregnancy at a body mass index (BMI) categorized as either overweight or obese [5, 6]. Similarly, in the United States, nearly two-thirds of women of reproductive age are either overweight or obese [7, 8]. In 2009, the American Institute of Medicine (IOM) established re-examined guidelines for weight gain during pregnancy so as to reflect the dramatic changes observed among obstetric populations [9]. These guidelines, along with those from the Society of Obstetricians and Gynaecologists of Canada (SOGC) sought to mitigate the various adverse health consequences to both mother and child associated with excessive weight gain [10, 11].

Entering pregnancy overweight or obese, or experiencing excessive gestational weight gain (GWG), can contribute to the intergenerational cycle of obesity, whereby women give birth to a large-for-gestational age (LGA) neonate, who might subsequently follow a rapid growth trajectory and, if female, perpetuate this cycle by delivering larger neonates who in turn exhibit a greater likelihood of downstream obesity [12–14]. Excessive GWG is an independent and modifiable risk factor, in which women characterized as having a pregravid BMI of underweight or normal weight and who experience weight gain above recommendations, can develop identical maternal and fetal health complications as women who are overweight or obese prior to pregnancy [15, 16]. Gestational weight gain above IOM guidelines is associated with an increased risk of high blood pressure and pre-eclampsia [17, 18], caesarean delivery [19], gestational diabetes [20], postpartum weight retention [21] and obesity [13]. For infants, health risks include being born LGA [22], preterm delivery [23], downstream metabolic disorder and overweight and obesity later in life [24].

Improving maternal and child health outcomes can be achieved by encouraging women to meet weight gain recommendations in combination with offering sound clinical guidance and support. Since their inception in 2009, a large proportion of women, approximately 50%, continue to exceed IOM weight gain recommendations [25]. Additionally, our research team has performed a comprehensive review of current literature and has found that GWG counselling between patient and healthcare provider (HCP) is infrequent and often inaccurate [26]. Patient knowledge of specific and targeted GWG recommendations are strongly associated with appropriate weight gain [27]. Thus, insufficient use of guidelines in clinical practice is a barrier towards prenatal health.

Awareness of IOM guidelines is an essential contributor to healthy weight gain, however, this may not be sufficient to change prenatal behaviours [27, 28]. Psychological factors associated with GWG such as self-perception, which have been found to play a role in excessive GWG [29] must also be considered. In addition, studies have shown that regular engagement in physical activity and exercise during pregnancy serve a protective effect against excessive GWG [29–31] [Ruchat et al., 2018, *British Journal of Sports Medicine*, in press] however, the psychosocial barriers and facilitators of physical activity during pregnancy have yet to be examined in detail.

To date, several studies have attempted to decipher the reasons as to why women gain weight outside of IOM recommendations during pregnancy [29, 32]. Recent systematic reviews of current literature and reviews of interventions [33–35] have consistently highlighted the importance of considering antecedent psychosocial risk factors of excessive GWG and encourage the integration of these theory-based interventions in prenatal care so as to improve maternal health-outcomes [36]. To our knowledge, this is the first study of its kind to assess the findings from a comprehensive and validated questionnaire, a Canadian Electronic Maternal (EMat) health survey, and to quantitatively evaluate various psychosocial factors (self-efficacy, locus of control, self-confidence, knowledge, attitudes, perceptions, barriers, facilitators) associated with meeting

IOM weight gain guidelines. The primary purpose of this study was to examine the association between perceived factors and achieving guideline-concordant weight gain during pregnancy. A secondary purpose was to examine the association between physical activity practices, barriers, and facilitators to exercise, and achieving IOM-recommended weight gain during pregnancy. Thus, these findings will contribute to the current literature by further examining the psychosocial factors associated with meeting IOM weight gain recommendations.

METHODS

Ethical Approval

The current study was performed in accordance with the regulations set forth by the Declaration of Helsinki. The University of Ottawa, Research Ethics Board (file number: A06-15-02) and the Children's Hospital of Eastern Ontario Research Institute, Research Ethics Board (file number: CHEOREB# 14/183X) approved the ethical components of the present study. Participants provided consent to publish; electronic and informed consent was obtained from all survey respondents before commencing the survey.

Study Design

Women's perceived success in meeting IOM weight gain guidelines along with factors associated with adherence were assessed. Cross-sectional data was gathered from both currently pregnant women and women who gave birth in the year following the adoption of the 2009 IOM guidelines. The EMat health survey, a validated questionnaire designed to assess women's knowledge and perceptions of current IOM gestational weight gain guidelines, physical activity, and nutritional practices, as well as pregnancy-related health behaviours, is hosted online through a secure data capture tool, REDCap™ (Vanderbilt University, Nashville, TN, USA). Consenting participants securely and confidentially took part in the online survey.

Survey Development

The survey, grounded in Social Cognitive Theory, was constructed using branching logic to prevent redundancies and was developed in eight comprehensive steps, which are described in detail in the published validation manuscript by Ockenden and colleagues [37]. An expert panel of seven individuals – a clinical psychologist specializing in health behaviour, a qualitative researcher in women’s health with expertise in socio-cultural factors of behaviour, a physiologist with expertise in nutrition and physical activity during pregnancy, an internal medicine and obstetrics specialist, two maternal health experts, and a pregnant woman who was also a recent mother, were congregated to ensure content validity of survey constructs and items. Preliminary validation of the survey concluded strong test-retest reliability and was found to be a unique online tool that can help better understand the factors associated with guideline-discordant weight gain during pregnancy and inform interventions that can support women’s reproductive health.

Survey Respondents and Administration

Pregnant and postpartum women who gave birth after May 2009 were invited to participate in the study. Survey responses were collected over four years from 2014 to 2018. Women were recruited through social media websites (Facebook and Twitter postings) and the corresponding author’s laboratory website. In addition, a snowball recruitment method was used in which participants who completed the study promoted the survey to their friends, families, and colleagues and provided them with the information to access the survey. Women who agreed to participate were directed to a secure link where they could access the survey. Once the link was selected, women were taken to the electronic consent form and could only proceed to the questions after providing informed consent. The survey was limited to English-speaking pregnant and postpartum women only who were at least 18 years of age.

Variables of Interest

Outcome variable. The dependent variable of the study was whether pregnant and postpartum women met the 2009 IOM gestational weight gain recommendations.

Independent variables. Independent variables included in the analysis were composed of questions associated with self-efficacy (addressing both internal and external locus of control), self-confidence, barriers/facilitators to meeting a target weight during pregnancy and adopting healthful lifestyle behaviours.

Exploratory variables. Participants were asked about physical activity practices and healthy eating during pregnancy. Exploratory variables included in the analysis were comprised of questions associated with barriers and facilitators to adopting these healthful lifestyle behaviours.

Behavioural and Sociodemographic Covariates

Behavioural covariates included in the analysis were smoking frequency and alcohol consumption throughout pregnancy using the following selection options: Every day, 2-3 times a week, once a week, once every 2-3 weeks, once a month, on special occasions only, never, and prefer not to answer. Sociodemographic covariates such as age, ethnicity, education, employment status, income, marital status, and geographical living environment were also included in the analysis as potential confounders.

Statistical Analysis

Among completed responses from pregnant women, self-reported pregravid weight (6 months prior) and height were used to calculate pregravid BMI. Pregnant women's ($n = 320$) current gestational age (weeks) and weight (kg) were used to compute whether respondents were on track to meeting IOM guidelines. Perceived pregravid BMI category (1-year prior) from postpartum women ($n = 1179$) along with self-reported weight gained during the most recent past pregnancy was used to determine whether women met GWG recommendations. Data from both pregnant and

postpartum women were combined in the analyses of questions related to self-efficacy, barriers and facilitators to weight gain (Table 3) as these questions were programmed to be asked to all women who took part in the survey. Multiple logistic regression analysis was performed using IBM SPSS ver. 24 (IBM Inc., Armonk, NY, USA). To determine whether women met IOM guidelines, pregravid BMI and weight gained during pregnancy were coded and computed using SAS ver. 9.4 (SAS Institute, Cary, NC, USA). Women were categorized as having met guidelines or not met guidelines. This served as the dichotomous outcome (dependent) variable described above. For all data analyses, statistical significance was defined at $p \leq 0.05$.

RESULTS

Overall, 1488 women completed the survey. Missing and incomplete data constituted a total of 357 participants. 1130 participant responses were included in the analysis. Characteristics of survey respondents are found in Table 1. Most women were between the ages of 30 to 39 years (pregnant $n = 222$, 69.4%; postpartum $n = 874$, 74.1%), married (pregnant $n = 256$, 80.0%; postpartum $n = 992$, 84.3%), and had graduate degrees (pregnant $n = 122$, 38.1%; postpartum $n = 512$, 43.5%). Pregnancy-related characteristics of respondents are presented in Table 2. The proportion of pregnant and postpartum women who met IOM guidelines (pregnant $n = 158$, 49.4%; postpartum $n = 534$, 45.3%) was lower than those who did not meet guidelines (pregnant $n = 162$, 50.6%; postpartum $n = 645$, 54.7%).

Several correlates were significantly associated with meeting or not meeting recommendations. Combined analyses of pregnant and postpartum women (Table 3; $n = 1131$) found that women who reported they *worried* about gaining too much weight while pregnant were 52% less likely to meet IOM weight gain guidelines relative to those who reported they did not worry (OR = 0.48, 95% CI = 0.33 – 0.69). Women who agreed with the statement, “*Do you think women should be careful about gaining too much weight during pregnancy*”, were approximately

twice as likely to meet weight gain guidelines than those who disagreed with the statement (OR = 1.75, 95% CI = 1.07 – 2.85). Those who presented with an internal locus of control in which they agreed to the following three statements, “*I can control the amount of weight I gain while pregnant*” (OR = 1.75, 95% CI = 1.29 – 2.37), “*If I am healthy and exercise, I can control my weight while pregnant*” (OR = 1.91, 95% CI = 1.34 – 2.71) and, “*I don’t believe there are any barriers to gaining a healthy amount of weight,*” (OR = 1.43, 95% CI = 1.04 – 1.95) were all also approximately twice as likely to meet IOM guidelines whereas those who presented with an external locus of control and perceived that “*Weight gain during pregnancy is beyond control of the mother*” were 42% less likely to meet weight gain recommendations (OR = 0.58, 95% CI = 0.39 – 0.88). There were no statistically significant associations among perceived facilitators towards gaining a targeted weight while pregnant and meeting IOM guidelines.

Presented in Table 4 are physical activity practices, barriers, and facilitators to exercise. Overall, most pregnant ($n = 263$, 84.0%) and postpartum ($n = 918$, 80.2%) women reported planning to exercise during pregnancy, however, when asked whether they engaged in exercise as much as they would have liked during pregnancy, the majority of pregnant ($n = 248$, 77.5%) and postpartum ($n = 788$, 66.8%) women stated “No”. Pregnant women who selected “too tired” as a barrier to not exercising as much as they would like were approximately 50% less likely to meet IOM guidelines (OR = 0.53, 95% CI = 0.27 – 0.95). Additionally, pregnant women who selected “too much pain/discomfort” (OR = 0.17, 95% CI = 0.08 – 0.35) and “too self-conscious” (OR = 0.07, 95% CI = 0.01 – 0.63) were approximately 90% less likely to meet weight gain recommendations. Among postpartum women, social support was a perceived barrier to meeting IOM guidelines whereby those who indicated that they had “no one to go with” (OR = 0.39, 95% CI = 0.19 – 0.80) were significantly less likely to meet weight gain recommendations.

Table 1
Characteristics of survey respondents

Characteristic	Currently Pregnant (n, %)	Postpartum (n, %)
Total	320 (21%)	1179 (79%)
<i>Age Group</i>		
18 to 29	88 (27.5%)	185 (15.7%)
30 to 39	222 (69.4%)	874 (74.1%)
40 to 50+	10 (3.1%)	120 (10.2%)
<i>Marital Status</i>		
Married/In a relationship	310 (96.9%)	1132 (96.0%)
Not married	9 (2.81%)	45 (3.82 %)
<i>Highest Level of Education</i>		
Less than High School	0 (0%)	2 (0.17%)
High School/GED	13 (4.06%)	31 (2.63%)
Some Post-Secondary Education	12 (3.75%)	59 (5.01%)
Trade Certification or Diploma	7 (2.19%)	27 (2.29%)
Non-University Certificate or Diploma	53 (16.6%)	152 (12.9%)
Bachelor's Degree	113 (35.3%)	394 (33.5%)
Graduate Degree	122 (38.1%)	512 (43.5%)
<i>Employment Status</i>		
Employed	285 (89.1%)	1010 (85.7%)
Currently unemployed	35 (10.9%)	168 (14.2%)
<i>Approximate Household Income</i>		
Less than \$30,000 – \$60,000	33 (10.3%)	134 (11.4%)
\$60,000 – \$120,000	133 (41.6%)	400 (34.0%)
\$120,000 – \$150,000	137 (42.8%)	587 (49.9%)
Prefer not to answer	17 (5.31%)	55 (4.68%)
<i>Living Environment</i>		
Urban area	107 (33.4%)	386 (32.7%)
Suburban	152 (47.5%)	587 (49.8%)
Rural area	61 (19.1%)	206 (17.5%)

Note. GED refers to General Equivalency Diploma. An urban area is defined as a large city (population greater than 1 million); a suburban area is defined as a smaller city or region outside an urban area (population greater than 10,000 to less than 1 million); and a rural area is defined as a small town (population less than 10,000).

Table 2
Pregnancy-related characteristics of survey respondents

Characteristic	Currently Pregnant (n, %)	Postpartum (n, %)
Total	n = 320 (21%)	n = 1179 (79%)
<i>IOM GWG Guidelines</i>		
Met guidelines	158 (49.4%)	534 (45.3%)
Did not meet guidelines	162 (50.6%)	645 (54.7%)
<i>Country of Prenatal Care</i>		
Canada	310 (96.9%)	1112 (95.0%)
USA	4 (1.25%)	24 (2.05%)
Other	6 (1.88%)	35 (2.99%)
<i>Number of Biological Children under 6 years old at home</i>		
None	4 (1.79%)	34 (2.89%)
1	160 (71.4%)	680 (57.7%)
2 or more	60 (26.8%)	464 (39.4%)
<i>Pregnancy planned</i>		
Yes, pregnancy occurred naturally	267 (83.4%)	954 (81.3%)
Yes, pregnancy occurred due to fertility treatment	22 (6.88%)	80 (6.81%)
No, pregnancy was not planned	29 (9.06%)	137 (11.7%)
<i>Perceived Weight Category</i>		
Underweight	5 (1.57%)	33 (2.82%)
Normal weight	213 (67.0%)	807 (68.9%)
Overweight	79 (24.8%)	275 (23.5%)
Obese	20 (6.29%)	57 (4.86%)
I don't know	1 (0.31%)	0 (0%)
Prefer not to answer	0 (0%)	0 (0%)
<i>Do you know your personal calorie requirements?</i>		
Yes	163 (53.1%)	673 (62.1%)
No	144 (46.9%)	411 (37.9%)
<i>Have/did your eating habits change during pregnancy?</i>		
My eating habits are healthier	46 (15.0%)	286 (25.9%)
My eating habits have stayed the same	185 (60.3%)	531 (48.1%)
My eating habits are less healthy	68 (22.2%)	269 (24.4%)
I don't know	8 (2.61%)	17 (1.54%)
<i>Do you consider feelings of weight dissatisfaction after pregnancy normal within your social network?</i>		
Yes	52 (16.3%)	846 (72.3%)
No	65 (20.3%)	192 (16.4%)
Don't know	23 (7.19%)	130 (11.1%)
Prefer not to answer	2 (0.63%)	3 (0.26%)

Table 3
Self-efficacy, barriers, and facilitators to weight gain among pregnant and postpartum women

Correlates	Adjusted OR (95% CI)
<i>Do/Did you worry that you may gain too much weight while pregnant?</i>	
No	1.00
Sometimes	0.77 (0.55 – 1.07)
Yes	0.48 (0.33 – 0.69)
<i>Do/Did you feel it acceptable to gain as much weight as you want while pregnant?</i>	
Disagree	1.00
Not sure	0.64 (0.40 – 1.03)
Agree	0.94 (0.63 – 1.40)
<i>If you are eating a well-balanced, healthy diet, do you feel it shouldn't matter how much weight you gain while you're pregnant?</i>	
Disagree	1.00
Not sure	0.81 (0.55 – 1.19)
Agree	0.83 (0.63 – 1.09)
<i>Do you think women should be careful about gaining too much weight during pregnancy?</i>	
Disagree	1.00
Not sure	1.87 (1.04 – 3.35)
Agree	1.75 (1.07 – 2.85)
<i>I can control the amount of weight I gain while pregnant.</i>	
Disagree	1.00
Not sure	1.27 (0.89 – 1.81)
Agree	1.75 (1.29 – 2.37)
<i>If I am healthy and exercise, I can control my weight while pregnant.</i>	
Disagree	1.00
Not sure	1.69 (1.12 – 2.53)
Agree	1.91 (1.34 – 2.71)
<i>Although you may have many obligations, do you feel that you can still be physically active?</i>	
No (n = 198)	0.93 (0.57 – 1.53)
Yes (n = 930)	1.00 (0.67 – 1.50)
<i>When you are pregnant, do you feel that you can eat healthy foods and avoid foods that aren't good for you?</i>	
No (n = 169)	0.63 (0.38 – 1.05)
Yes (n = 953)	0.96 (0.65 – 1.44)
<i>What do you believe are the barriers to gaining within a targeted weight during pregnancy?</i>	
Lack of support from family or friends	1.32 (0.96 – 1.82)
Lack of guidance from HCP	1.33 (1.00 – 1.78)
Weight gain during pregnancy is beyond control of the mother	0.58 (0.39 – 0.88)
It is difficult to exercise during pregnancy	0.88 (0.68 – 1.14)
It is difficult to eat healthy during pregnancy	0.87 (0.63 – 1.22)
I don't believe there are any barriers to gaining a healthy amount of weight	1.43 (1.04 – 1.95)
<i>What do you believe contributes to women being able to gain within a targeted weight during pregnancy?</i>	
Support from family or friends	1.00 (0.78 – 1.28)
Guidance from HCP	1.08 (0.85 – 1.37)
Weight gain management during pregnancy is a priority for me	1.04 (0.79 – 1.37)
I get regular exercise during pregnancy	0.94 (0.74 – 1.20)
I eat healthy during pregnancy	1.02 (0.80 – 1.31)

Note. Total Pregnant and Postpartum (n = 1488); Missing and Incomplete (n = 357); Included in analysis (n = 1131); did not meet guidelines (n = 611); met guidelines (n = 520). ORs were adjusted for relevant behavioural and sociodemographic covariates. There were no significant differences between adjusted and unadjusted ORs. Statistically significant associations are **bolded** (p < 0.05). Associations approaching significance are *italicized*.

Table 4
Physical activity practices, barriers, and facilitators to exercise

Variables	Pregnant Adjusted OR (95% CI)	Postpartum Adjusted OR (95% CI)
Physical activity practices, barriers and facilitators to exercise		
<i>Do/did you plan to exercise during pregnancy</i>	<i>n</i> = 320	<i>n</i> = 1179
No	50 (16.0%)	226 (19.8%)
Yes	263 (84.0%)	918 (80.2%)
<i>Did you exercise as much as you would like to during your most recent past pregnancy?</i>		
No	248 (77.5%)	788 (66.8%)
Yes	65 (20.3%)	373 (31.6%)
<i>Why have you not exercised as much as you would like?</i>		
Unsure of what to do (nervous)	0.66 (0.25 – 1.77)	0.84 (0.51 – 1.38)
Told not to exercise by HCP (health concerns)	0.62 (0.17 – 2.17)	0.76 (0.47 – 1.23)
Too tired	0.53 (0.27 – 0.95)	0.83 (0.65 – 1.06)
Felt sick	0.73 (0.41 – 1.30)	0.90 (0.68 – 1.20)
Too much pain/discomfort	0.17 (0.08 – 0.35)	<i>0.77 (0.57 – 1.06)</i>
Lack of time	0.81 (0.45 – 1.47)	1.03 (0.79 – 1.33)
Lack of money	1.37 (0.16 – 11.8)	0.74 (0.34 – 1.61)
Difficulty obtaining childcare	1.25 (0.55 – 2.81)	<i>0.73 (0.49 – 1.10)</i>
No one to go with	1.79 (0.39 – 8.22)	0.39 (0.19 – 0.80)
No interest/motivation	2.08 (0.94 – 4.60)	0.96 (0.66 – 1.39)
Too self-conscious	0.07 (0.01 – 0.63)	<i>0.47 (0.20 – 1.10)</i>
Illness	0.67 (0.14 – 3.31)	0.76 (0.40 – 1.42)
<i>What do you believe has helped you exercise?</i>		
I am active person, so It was easy to continue	1.14 (0.50 – 2.59)	<i>1.26 (0.94 – 1.69)</i>
I felt fine while pregnant (no sickness or fatigue)	1.00 (0.33 – 2.95)	<i>1.38 (0.99 – 1.93)</i>
I had/ have support from family	<i>3.48 (0.94 – 12.9)</i>	1.09 (0.74 – 1.61)
I had/ have support from friends	1.37 (0.19 – 9.80)	1.48 (0.86 – 2.55)
I had the support of my employer	0.89 (0.15 – 5.13)	1.03 (0.48 – 2.25)
<i>What are your motivations for exercise?</i>		
Maintain/limit weight gain	0.93 (0.53 – 1.62)	1.04 (0.82 – 1.34)
Socialize	1.32 (0.65 – 2.67)	1.14 (0.83 – 1.57)
Competition	4.21 (0.41 – 43.4)	2.48 (1.00 – 6.14)
Release tension	0.73 (0.42 – 1.27)	0.90 (0.69 – 1.17)
Enhance mental health	0.75 (0.43 – 1.31)	0.97 (0.75 – 1.25)
Keep fit	0.88 (0.50 – 1.54)	1.11 (0.86 – 1.44)
For the health of my baby	1.07 (0.58 – 1.98)	0.97 (0.75 – 1.26)
For my health	1.14 (0.56 – 2.31)	0.99 (0.75 – 1.31)

Note. Statistically significant associations are **bolded** ($p < 0.05$). Associations approaching significance are *italicized*.

DISCUSSION

The purpose of this study was to examine the psychosocial factors (self-efficacy and perceived controllability of behaviours), along with the barriers and facilitators to physical activity practices during pregnancy and their associations with meeting IOM weight gain recommendations. Overall, we found that high self-efficacy and internal locus of control were associated with a greater likelihood of achieving guideline-concordant weight gain, whereas low self-efficacy and external locus of control were associated with a lower likelihood of adhering to weight gain recommendations. These associations continued to be significant even after adjusting for relevant sociodemographic covariates. Women who agreed that *care* for weight gain should be considered during pregnancy were nearly twice as likely to meet recommendations, demonstrating greater self-awareness and knowledge of recommendations. In contrast, weight-related concern or *worry* resulted in a reduced odds of meeting weight gain guidelines.

A woman's perception of self and sense of empowerment may impact maternal weight gain during pregnancy [29]. Our findings support this notion in that women who were concerned about gaining too much weight while pregnant were significantly less likely to meet IOM weight gain recommendations. Previous studies have found that concern about weight gain is a risk factor for excessive GWG [38, 39], however, studies in this area of research are limited. Accordingly, there is evidence to suggest that maternal pregnancy stress influences GWG through an elevation of cortisol levels [40, 41]. In fact, a study examining a stress reduction intervention to help promote healthy GWG found that women were highly interested in stress reduction interventions involving a variety of mindfulness techniques [42]. Stress or worry have been considered modifiable psychosocial risk factors; given that our findings demonstrate that worry is associated with weight gain, this risk factor should be taken into account when designing future interventions to help

reduce the likelihood of excessive GWG, and ultimately improving weight and health trajectories for both mother and infant.

In addition to perceived worry, pregnant and postpartum women's attitude towards weight gain during pregnancy was equally significant in predicting IOM guideline-concordant weight gain. Our data illustrated that women who perceived that care should be taken, with respect to gaining too much weight while pregnant, were twice as likely to meet IOM recommendations than those who failed to recognize this as a valuable concern throughout pregnancy. Although we cannot conclude with certainty, this attitude toward weight gain may be indicative of pregnant and postpartum women's knowledge of the health impact associated with excessive GWG and its potential to harm the health of either themselves, their baby, or both. This is in contrast to the findings from a recent systematic review and meta-analysis of qualitative research [43], which highlighted that women are motivated to improve fetal health albeit they may not be aware of the link between gaining excess weight during pregnancy and negative fetal health implications. The discrepancies between our findings and these results may be due to the methodological differences (quantitative versus qualitative) in research design along with differences in the level of education and socioeconomic status in our sample population. Importantly, our finding regarding care towards weight gain during pregnancy can be explained by well-versed psychological concepts from the Theory of Planned Behaviour (TPB) [44], whereby an attitude (i.e. care should be taken) towards a certain behaviour (i.e. too much weight gain during pregnancy) results in behavioural changes (i.e. monitoring weight gain, therefore greater odds of meeting guidelines). Previous work has found the TPB to be a useful framework in assessing women's weight-related intentions throughout pregnancy [45, 46]. Therefore, this attitude towards weight gain leading to an increased likelihood of meeting IOM recommendations, supports the contention that the understanding of women's perceptions during pregnancy can be used to inform future behavioural interventions.

The Electronic Maternal Health Survey's incorporation of Social Cognitive Theory (SCT) during development, allows for identification of pregnant and postpartum women most at risk of experiencing excessive GWG or guideline-discordant weight gain. The SCT takes into consideration personal, behavioural and environmental interactions that ultimately influence outcome behaviours [47]. Pregnant and postpartum women with a high self-efficacy, that is, their success in meeting IOM guidelines was attributed to an internal locus of control and associated with a significantly higher odds of meeting weight gain recommendations. In parallel to our current study, previous work has shown that high self-efficacy towards healthy weight gain during pregnancy served a protective role against excessive GWG [48]. Moreover, a study examining weight-related self-efficacy in relation to maternal body weight between early pregnancy and two years postpartum, found that greater self-efficacy towards weight control was associated with lower maternal body weight [49].

Along with our findings regarding internal locus of control, low self-efficacy and external locus of control, whereby the success of meeting IOM recommendations was attributed to factors beyond the individuals' control, was found to be significantly associated with a reduced odds of meeting weight gain guidelines. This finding is partially supported by a previous study examining the psychosocial determinants of GWG adequacy using a unique tool that assesses women's perceived fetal health locus of control. The researchers found that women who believed that external factors and chance were associated with fetal health were more likely to deviate from GWG guidelines [50]. To date, however, few studies have examined weight-related self-efficacy and locus of control as they relate to meeting IOM gestational weight gain guidelines, particularly in a predominantly Canadian sample. Our findings regarding self-efficacy and locus of control in relation to meeting IOM recommendations further contribute to current literature and encourage

future research on how an internal locus of control in relation to weight gain during pregnancy can be used to achieve healthful pregnancy outcomes.

Although not statistically significant, it is important to acknowledge that pregnant and postpartum women who reported that they did not feel that they could eat healthy foods and avoid foods that are not good for them, demonstrated a tendency towards a reduced odds of meeting IOM recommendations. In a study assessing pregnant Australian women's knowledge of appropriate GWG and dietary guidelines, it was found that these women demonstrated an adequate level of broad knowledge of dietary recommendations, but their detailed knowledge in this area was poor [28]. Notably, poor maternal nutritional practices have been associated with postpartum weight retention [51] and excessive GWG [52], thereby contributing to an intergenerational cycle of obesity [53]. Given our current understanding of the health ramifications associated with a trans-generational cycle of obesity, women continue to foster inaccurate beliefs in relation to nutritional requirements during pregnancy and report minimal counseling from their care providers [54]. Thus, this may partially explain why women who reported a perceived lack of an ability to control their eating habits and nutritional practices throughout pregnancy, presented with a tendency ($OR = 0.63, p = 0.08$) towards not achieving IOM weight gain guidelines.

Physical activity, similar to adopting healthy dietary practices during pregnancy, is paramount to achieving healthful prenatal outcomes such as appropriate GWG that serve numerous short- and long-term health benefits to both the mother and developing fetus. The SOGC and the American College of Obstetricians and Gynecologists (ACOG) recommend that women with uncomplicated pregnancies exercise prior to, during, and after pregnancy [55, 56]. According to the ACOG, few pregnant women, including those who are categorized as overweight and obese, are meeting current physical activity guidelines [57]. However, the reasons as to why women are not meeting guidelines remain unclear. Our findings show that among pregnant and postpartum

women, before commencing their pregnancies, both groups indicated that they planned on exercising during pregnancy. Albeit, when asked whether they exercised as much as they would have liked throughout pregnancy, most women indicated “No”.

For currently pregnant women, barriers related to physical discomfort, contraindications to exercise communicated by HCP, and self-perception were associated with a reduced likelihood of meeting IOM guidelines whereas, for postpartum women, barriers related to social support from family and friends were associated with a lower odds of meeting recommendations. A recent systematic review of qualitative and quantitative studies by Harrison and colleagues, on the attitudes, barriers, and enablers to physical activity during pregnancy found that intrapersonal factors (i.e. fatigue, lack of time, discomfort) served as barriers to physical activity whereas social support played an enabling role during pregnancy [58]. In accordance with the previous study, our findings are in agreement whereby women reported intrapersonal factors as barriers to achieving a healthy pregnancy weight gain and a supportive social environment as a significant facilitator to gestational weight gain guideline adherence.

Complementary to our findings in relation to barriers and facilitators of physical activity during pregnancy, we demonstrated that most women recognize the importance of exercising during pregnancy. This is interesting as the perceived attitude that exercise is important may influence future behaviour (i.e. physical activity) in agreement with the aforementioned Theory of Planned Behaviour [44]. Though, despite positive attitudes towards exercise, women continue to not meet physical activity guidelines during pregnancy. What is more, interventions based on goal setting strategies have been found to be useful in preventing excessive GWG [36]. As such, a plan to exercise during pregnancy and self-monitoring strategies may be the first necessary step to achieving optimal weight gain during pregnancy and to remain physical activity throughout. Given that physical activity during pregnancy plays a protective role against excessive GWG [31] and is

associated with numerous psychological benefits such as reduced anxiety, depression, fatigue and overall improved well-being [59], future interventions must consider intrapersonal factors and social support, along with goal setting strategies as a means of encouraging women to engage in physical activity prior to, during and after pregnancy.

Limitations and Strengths

The resulting sample was composed of predominantly educated women who received prenatal care in Canada or the USA, were employed, married, between the ages of 30 to 39, and of high socioeconomic status. Although this sample may not be representative of a diverse global population, understanding novel psychosocial factors such as weight-related self-efficacy in relation to meeting American IOM guidelines can help guide clinical practice and future interventions aimed at reducing excessive GWG in industrialized nations. Implementing such practices could better inform GWG interventions targeting psychosocial factors in developing nations. Further, it should be noted that BMI categories in the survey were self-reported. The use of self-reported data may be encouraged by a study that concluded that overweight and obesity is indeed associated with excessive GWG, nonetheless, this was not dependent on self-perception of weight status since approximately 20% of women with overweight or obesity accurately identified their weight status. Moreover, when comparing accurate to inaccurate reporters of weight status, the researchers found that the odds of excessive GWG were similar at approximately twice as likely in both groups [60].

This is the first study composed of the findings from a uniquely designed comprehensive survey. The Electronic Maternal Health Survey allowed for a complete analysis of barriers and facilitators surrounding the psychology of women's health during pregnancy. Given that the survey is grounded in SCT, this allowed for further understanding of self-efficacy and locus of control and how these factors contribute to healthy pregnancy weight gain. Many studies to date have failed to discover an association between psychological factors and GWG or neglect to examine

these factors altogether [32, 48]. Previous reviews have identified similar findings with respect to attitude towards weight gain during pregnancy and the protective effect of internal locus of control over weight gain [33, 34]. This study has identified key psychosocial risk factors associated with excessive or guideline-discordant GWG. However, it is essential to recognize the complexity of psychosocial factors associated with excessive GWG. At a time where excessive GWG has reached epidemic proportions, studies such as these that can help elucidate psychological and social contributors to weight gain outside of guidelines, will help develop adequate interventions to meet the immediate and long-term health needs of pregnant women and their offspring.

CONCLUSIONS

The findings from this study further contribute to the growing literature on deciphering what risk factors are associated with excessive GWG. We discovered firstly, that a high self-efficacy, associated with an internal locus of control served a protective role against exceeding IOM weight gain recommendations, whereas low self-efficacy and an external locus of control diminished the likelihood of meeting IOM guidelines. Secondly, pregnant women who described intrapersonal factors as barriers to exercise while pregnant and postpartum women who depicted social support/environment were significantly less likely to achieve guideline-concordant weight gain. Future work should investigate interventions that combine HCP guidance and consideration for psychosocial factors during prenatal care, to ultimately contribute towards healthier pregnancies and future generations.

DECLARATIONS

Ethics approval and consent to participate

Information on ethics approval and consent to participate is available and detailed in the study Methods. This study was approved by the University of Ottawa, Research Ethics Board and the Children's Hospital of Eastern Ontario Research Institute, Research Ethics Board.

Consent for publication

Informed consent was obtained from all participants who took part in the survey and detailed in the study Methods.

Availability of data and materials

The data that support the findings of this study are available from REDCap™ . Data are available on request from the authors.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

LH performed data analysis and assembly. LH drafted the manuscript, prepared the results and tables. LH, AW, RHL, KBA, and RD interpreted the study results. LH, AW, RHL, RD, and KBA, edited and revised the manuscript. All authors have read and approved the final version of the manuscript.

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CHAPTER 4

PREAMBLE TO ARTICLE 2

The following article titled, “Development and Pilot Evaluation of a Pregnancy-Specific Mobile Health Tool: Qualitative Investigation of *SmartMoms Canada*” was submitted to *BMC Medical Informatics and Decision Making* on August 20th, 2018. The manuscript ID provided by the journal upon submission was MIDM-D-18-00284. The format of the manuscript presented below is in accordance with the journal guidelines.

As of November 2018, the manuscript has been *published*.

RESEARCH ARTICLE

Open Access



Development and pilot evaluation of a pregnancy-specific mobile health tool: a qualitative investigation of *SmartMoms Canada*

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Abstract

Background: Mobile technology is ubiquitous. Women of childbearing age have embraced health information technology for pregnancy-related counsel as prenatal care provider communication is increasingly scarce and brief. Pregnant women and new mothers place high value in the use of online sources to support their pregnancy information needs. In Canada, over 300,000 women are pregnant annually, with approximately 60% exceeding evidence-based weight gain recommendations. Mobile health (mHealth) tools, such as mobile applications (app), have the potential to reduce excessive gestational weight gain, offering pregnant women trustworthy guidance, ultimately improving the health outcomes of mothers and infants. Therefore, the primary aim of this study was to implement a qualitative, descriptive research design to assess the receptiveness, functionality, and future prospective of the *SmartMoms Canada* mHealth app.

Methods: Two focus groups ($n = 13$) involving both currently pregnant and recently postpartum women were organized on the same day. Focus groups were transcribed verbatim and thematic analysis was undertaken using manual coding and NVivo software. Participants who took part in the focus groups ($n = 13$) and those who could not attend ($n = 4$) were asked to complete a Likert-scale survey. All survey responses ($n = 17$) were analyzed using simple tabulation and percentage analysis.

Results: Participants were technologically proficient and interacted with several mHealth tools prior to testing the *SmartMoms Canada* app. Six major themes emerged from thematic analysis: knowledge of pregnancy-specific mHealth services, knowledge and attitudes of weight gain guidelines, weight tracking, strengths of the app, critique and lastly, future suggestions for the app.

Conclusions: Our thematic analysis found that women positively viewed the future potential of our app and offered constructive feedback to improve the next version. Participants sought more personalization and enhanced app interactivity, along with promotion of overall maternal health including nutrition and mental health, in addition to weight tracking.

Keywords: *SmartMoms Canada*, Pregnancy, Mobile health

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Background

Worldwide, over 7 billion mobile cellular subscriptions were reported by the International Telecommunication Union in 2016 [1], rendering mobile technology near-ubiquitous. There is immense potential for mobile technology to provide a platform for initiation of large-scale health promotion interventions aimed at informing personal health parameters. Mobile health (mHealth) technologies, in particular, have already shown significant promise in delivering cost-effective health services in low-to-middle income countries [2], and their use is encouraged by the World Health Organization (WHO) as a means of improving maternal and child health [3, 4].

In Canada, over 300,000 women are pregnant annually [5], with greater than 50% entering pregnancy overweight or obese [6] and nearly 60% exceed Institute of Medicine (IOM) gestational weight gain (GWG) guidelines [7]. Weight gain above guidelines is associated with an intergenerational cycle of obesity [8], affecting the short- and long-term health of both mother and infant. Adverse maternal health outcomes of excessive GWG include pre-eclampsia [9], postpartum weight retention [10], and obesity [11]. Adverse fetal health outcomes include the risk of being born large-for-gestational age [12], downstream metabolic disorder, overweight and obesity [13]. Several epidemiological studies on fetal programming [14–16] have shown that environmental factors in utero (i.e. excessive GWG and maternal obesity) alter one's susceptibility to downstream disease [17, 18]. Thus, a healthy womb is essential for a healthy pregnancy and optimizing weight gain within guidelines is critical for improving maternal-fetal health outcomes.

Few women report being appropriately counselled on pregnancy weight gain guidelines from their healthcare providers (HCPs) [19, 20]. A recent review found that GWG counselling between healthcare provider (HCP) and patients is often infrequent and inaccurate [Weeks et al., 2018, *Obstetrical & Gynecological Survey*, in press]. Prenatal HCPs also report feeling unequipped to deliver adequate lifestyle counselling [20], including diet and exercise. This is likely a result of these services being resource-intensive, time-consuming, and impractical within the Canadian healthcare system [21]. A need to develop novel, cost-effective, and sustainable approaches to preventing excessive GWG are necessary in the technologically-driven environment of the twenty-first century. Fortunately, pregnant women and new mothers report value in using online sources and mHealth applications (apps) to support their information needs [22], viewing them as central to a healthy lifestyle [23]. The Internet also plays a significant role in women's pregnancy-related decision-making [24].

Thus, the use of mHealth interventions in prenatal care may increase patient empowerment, leading to efficient care and greater patient satisfaction [25].

Evidently, the development of reliable, evidence-based, health information services through mHealth technologies are necessary to meet the needs of the current and next generation of tech-savvy women. The *SmartMoms Canada* mHealth app, modeled after an earlier US-version [26], is one such app designed to improve weight outcomes during pregnancy. Unlike other pregnancy apps, *SmartMoms Canada*, is predominantly research-based and health-focused. It aims to integrate and maintain healthful lifestyle behaviours such as engaging in physical activity, a healthy diet, managing anxiety, and practicing adequate sleep hygiene. *SmartMoms Canada* offers cost-effective, real-time, personalized support in order to overcome the limitations of standard prenatal care encountered by Canadian women. Herein, the primary objective of this study was to conduct a preliminary exploration of women's attitudes towards the *SmartMoms Canada* app as a reliable source of information and ability to address lifestyle behaviours related to GWG. Secondly, this study explored women's receptiveness and critique towards the functionality and feasibility of *SmartMoms Canada* in order to inform the design and methodology for a future multi-centre assessment of the app.

Methods

Ethics approval

This study conformed to the regulations set forth by the Declaration of Helsinki. The University of Ottawa, Research Ethics Board (file number: H11–16-17) approved the facilitation of the focus groups. Informed consent was obtained from all interested and eligible participants.

Study design

A qualitative, descriptive research study design was implemented to assess the utility of the *SmartMoms Canada* mHealth app. A total of two focus groups, occurring on the same day, were organized to evaluate the receptiveness, functionality, and future prospective of the app. Following the completion of the two focus groups, participants were given a self-administered survey composed of only Likert-scale questions. Likert-scale questions were chosen to ensure simplicity of the survey so that participants may understand the questions without the need of guidance from the researchers.

Study setting, participants, and recruitment

Women who were pregnant or had given birth to a baby within six months of the first scheduled focus group were invited to participate in one of two focus groups at the University of Ottawa, Canada. The city of Ottawa is Canada's capital city. It is a bilingual city

where both official languages, English and French, can be used as desired as a means of communication. It is the fourth largest city in Canada by population (approximately 870,000 or 1,300,000 residents including both the Ottawa-Gatineau region) [27]. Annually, there are between 8000 and 9000 births in Ottawa and a total fertility rate of 1.43 births per woman [28]. Ottawa is an urban center with two major economies formed by the federal government and high technology. The population makeup of Ottawa is predominantly Caucasian [27]. Participants were recruited through a snowball recruitment technique whereby women who participated in other pregnancy-focused studies in our lab, informed their friends and family about the opportunity to participate in upcoming research studies. Social media advertisements were also made on Facebook and Twitter. Recruitment took place from July 2017 to September 2017. All correspondence with participants was completed through a designated *SmartMoms Canada* email operated by Google mail servers at canadasmartmoms@gmail.com. Pregnant and/or postpartum women included in the study were between the ages of 18 to 40 years, fluent in either English or French, had access to Wi-Fi™ and could dedicate at least one week to trial the *SmartMoms Canada* app and accessories. Excluded from the study were women who had a newborn greater than 6 months old by the first scheduled focus group. Women were offered beverages and catered food, were provided with childcare, and were given a \$10 gift card for their participation.

Development of the SmartMoms Canada Mobile health application

The *SmartMoms Canada* app is a new and innovative, evidence-based tool, modelled after an earlier US version [26] that allows mothers-to-be to monitor their GWG and attain a healthy pregnancy weight. This is made possible through stand-alone content with individualized nutrition, physical activity, sleep and other lifestyle recommendations. Women of childbearing age are increasingly tech-savvy and *SmartMoms* may become an important contributor to pregnancy-related mHealth technology. Further, in-person weight management interventions during pregnancy may not be cost-effective and cannot reach a national population. There are several key differences between *SmartMoms Canada* and the earlier US version, called *SmartMoms*. Our mHealth tool is offered in both official languages of Canada, that is, French and English. Further, our app includes synchronization with a newer ©Fitbit device, the Charge 2 fitness tracker, which offers sleep, exercise, and diet tracking in addition to daily step counts as well as mental health and mindfulness techniques that are complemented by app content. Lastly,

there is greater emphasis on physical activity within our app, whereby women are provided with thorough and visually-based exercise guidelines. Therefore, the *SmartMoms Canada* app is a proposed, cost-effective, solution to improve pregnancy outcomes across Canada.

Procedures and data collection

Participants were asked to take part in two sessions on two separate days. The two sessions were separated by a minimum of 2 weeks or a maximum of 4 weeks and each lasted approximately 90 min. The purpose of the first session was to gather preliminary information on the participating women, introduce them to the study, provide them with the *SmartMoms Canada* app and accompanying technological accessories, and offer detailed guidelines on how to use the study equipment. The purpose of the second session was to have the women participate in one of the two focus groups, scheduled on the same day. The focus groups sought to evaluate women's perspectives on their interactions with *SmartMoms*. All sessions took place at the Prevention in the Early Years Laboratory located at Lees Campus, University of Ottawa.

During the first session, participants were encouraged to ask questions and to complete a written informed consent document. A preliminary screening form was used to collect age, height, weight, gestational age (if applicable), and age of their newborn (if applicable). The *SmartMoms* app was developed for both Android (Google LLC, Mountainview, CA, USA), and IOS (Apple Inc., Cupertino CA, USA) devices, however, only the Android version was available to individuals participating in the focus groups. The app was downloaded on participants' personal phones or designated android devices, if necessary. A Fitbit Charge 2 fitness tracker (©Fitbit, Inc. San Francisco, CA, USA) and a BodyTrace scale (©BodyTrace, Inc. New York, NY, USA), were provided and participants were given a minimum of one week to become familiar with the technological accessories.

During the second session, participants arrived at the lab during their scheduled focus group. A 32-item checklist for interviews and focus groups, the Consolidated Criteria for Reporting Qualitative Research (COREQ), was utilized to support the second session [29]. An external expert from the Parriag Group [30] moderated the focus groups in accordance with a moderator's guide developed specifically for this study. Two members of the study team (LH and KH) were present to take detailed notes. The moderator's guide was informed by the literature on IOM weight gain recommendations [31], the use of mHealth technologies among pregnant women [32], along with HCP views on mHealth lifestyle interventions and current prenatal care practices and limitations [23]. At the

conclusion of each focus group, women completed a 5 to 10 min, self-administered questionnaire that evaluated information on weight tracking practices, diet, and physical activity along with women's experiences and overall impression of the *SmartMoms Canada* app.

Data management and analysis

Likert scale responses from the questionnaire were analyzed using simple tabulation. All focus groups were transcribed verbatim. Inductive content analysis [33] and NVivo 11 software for Windows (QSR International Pty Ltd., Doncaster, VIC, AUS) were used to analyze the transcribed data. Multiple complete read-throughs of each transcript were conducted independently by two members of the research team in a four-step process. Firstly, both team members read the combined focus group data independently. Secondly, the team members conducted manual/NVivo open coding of each transcript reading them line-by-line, and adding interpretive notes to the margins beside the text [34, 35] to ensure data immersion was achieved. Thirdly, similar words and codes were collected from the margins onto coding sheets and categorized to generate a coding list. A template analytic style of coding was used to create the coding lists, whereby codes were derived from the data [36]. Memos were made during coding to link observations and to make inferences [37]. Codes representing similar ideas within and across the interviews were clustered into sub-categories/themes. The collection of groups of codes and collapsing of similar or dissimilar groups was done to establish broader higher order categories [38–40]. In the final step, abstraction was used to confirm higher order categories and to establish emergent themes [41]. The two team members conferred regularly to discuss and resolve any differences in codes and themes at each stage. A third team member who had been present during the focus groups, participated in the final step of the analysis (abstraction) using NVivo to provide further validation of the themes that emerged from the other two authors. Consensus was sought to resolve any theme discrepancies among the three team members.

Results

Participant characteristics

A total of 18 (11 pregnant, 7 postpartum), women were interested and eligible to participate in the focus groups. Of these women, 1 could no longer dedicate the time to participate and 17 attended the first appointment and were given the app along with the necessary accessories. Following the first appointment, 4 women were lost to follow-up (3 participants had a scheduling conflict and 1 pregnant participant gave

birth on the day of the focus groups). Residents of the City of Ottawa are generally highly educated due to the two main sectors of the economy, the federal government and high technology, along with a large hospital sector. Of the occupational information shared with our research team by the participants, a resident physician in family medicine, a PhD in clinical psychology, an occupational therapist, a midwife, a registered practical nurse, and two employees of the federal government were present during the focus groups. The two focus groups included eight and five participants, respectively, for a total of 13 participants. Of the 13 participants, 11 were found to be recruited through a snowball approach and 2 were recruited through social media advertisements (1 via Facebook and 1 via Twitter). The women were on average 31 ± 3.28 years of age and categorized as having an overweight BMI (27.2 ± 4.16 kg/m²) prior to being pregnant. For participants that were pregnant, they were on average five months into their pregnancy and those who had already given birth, were approximately two months postpartum. A summary of participant characteristics is provided in Table 1.

Questionnaire responses

Participant responses on weight tracking practices, diet, and physical activity, along with the women's experience and overall impression of the *SmartMoms Canada* app are presented in Table 2. The survey response rate was 100%. Of the 17 women who were distributed the survey, 17 completed surveys were given back to the researchers for analysis. Greater than half of the pregnant and postpartum women believed tracking weight gain was 'somewhat important,' and maintaining a healthy diet during pregnancy was 'important.' It should be noted that

Table 1 Participant Characteristics

Characteristic	Mean (SD)
Age (yrs)	31.5 (3.28)
Height (m)	1.62 (0.07)
Pre-pregnancy weight (kg)	66.0 (10.5)
Pre-pregnancy BMI (kg/m ²)	25.1 (3.55)
Current weight (kg)	71.4 (11.0)
Current BMI (kg/m ²)	27.2 (4.16)
Gestational age (weeks and days, if pregnant)	20 weeks 2 days
Age of newborn (weeks and days, if postpartum)	9 weeks 2 days

Note. A total of 8 women (5 pregnant and 3 new mothers) participated in the first focus group and a total of 5 women (3 pregnant and 2 new mothers) participated in the second focus group. Altogether, a combined total of 13 women (8 pregnant and 5 new mothers) participated in one of the two focus groups. BMI was calculated using the following formula: [weight (kg)] ÷ [height (m)]². Independent sample t-tests (significance level set at alpha = 0.05) demonstrate that pregnant and postpartum women did not differ statistically with respect to age, pre-pregnancy BMI and current BMI. SD refers to standard deviation

Table 2 Attitudes of Pregnant and Postpartum Women who Attended the First Session Toward Weight Gain, Physical Activity, Nutrition, and the Prospective Use of the *SmartMoms Canada* App during Pregnancy

Survey Questions	Pregnant and Postpartum Women's Responses				
	Not at all important	Somewhat important	Important	Very important	Not sure
How important is/was it for you to keep track of your weight gain during pregnancy?	1 (6%)	10 (59%)	3 (18%)	3 (18%)	0 (0%)
How important is/was it for you to maintain a healthy diet during pregnancy?	0 (0%)	0 (0%)	10 (59%)	7 (41%)	0 (0%)
How important is/was it for you to be physically active throughout your pregnancy?	0 (0%)	2 (12%)	7 (41%)	8 (47%)	0 (0%)
	Not at all useful	Somewhat useful	Useful	Very useful	Not sure
Based on your experience so far, how useful is the <i>SmartMoms Canada</i> app?	0 (0%)	14 (82%)	3 (18%)	0 (0%)	0 (0%)
	Not at all likely	Somewhat likely	Likely	Very likely	Not sure
How likely are you to use the <i>SmartMoms Canada</i> app for your entire pregnancy?	2 (12%)	8 (47%)	6 (35%)	0 (0%)	1 (6%)
How likely are you to recommend the <i>SmartMoms Canada</i> app to someone else who is pregnant?	1 (6%)	9 (53%)	6 (35%)	1 (6%)	0 (0%)

Note. A total of 17 survey responses were collected after the completion of both focus groups. This total of 17 women includes the women who participated in the focus groups ($n = 13$) and those who completed the first session of the study but did not attend the focus groups ($n = 4$). Important: all responses are presented as n (%), indicating the number of participants who selected this response and percentage of the total in brackets

approximately one third of the participants believed keeping track of weight gain was 'important' and 'very important' and nearly half of the women believed being physically active throughout pregnancy was 'important' or 'very important.' The *SmartMoms Canada* app was found to be 'somewhat useful' to the participants (82%). Greater than half of the participants were 'somewhat likely' and 'likely,' respectively, to use the app throughout pregnancy. Similarly, nearly half of the participants were 'somewhat likely' (53%) and 'likely' (35%) to recommend the app to someone who was pregnant.

Thematic findings

Women were quite receptive to testing the content and functionality of the *SmartMoms Canada* app along with the accompanying technological accessories, for the duration allotted to them prior to attending the focus group. Overall, the app tested well with the sample population and was found to be a useful tool for pregnant women intending to monitor their health, particularly weight and physical activity, throughout pregnancy.

Six major themes and several associated sub-themes emerged from thematic analysis of the focus group transcripts and are presented in Table 3. The first theme was *Strengths of the SmartMoms app*. Participants were in accord that the app provided pregnancy guidance, support, and offered useful pregnancy-related information, particularly as a tool that can contribute to lowering stress levels and distribute informal support that HCPs may not have time to offer. Many women positively viewed the pregnancy-specific exercises and enjoyed the help of the visual provided. These exercises are demonstrated using a short graphics interchange format of a pregnant woman

performing a movement in addition to a text description of the exercise. Participants were keen on using the ©Fit-bit accessory to track their fitness and notably, their sleep patterns. Women agreed that the information provided in *SmartMoms* about sleep was helpful and provided a greater focus on overall health, in addition to physical activity practices.

A second theme derived from analysis was *Critique of the SmartMoms app*. Participants were critical, predominantly of the design and aesthetic of the app, such as colour schemes and the layout of the information provided. Women were interested in setting their own goals and interacting with the app in terms of creating their own checklists and to-do lists. Feedback on weight gain was commented upon by the majority of women. The app is designed to provide information on whether guideline-concordant weight gain has been achieved by informing women if they are within or outside the appropriate evidence-based, IOM, weight range. Women requested feedback on how to proceed if they are over or under the weight gain zone. Participants expressed that the app emphasized weight to a greater extent than they would have preferred and requested more emphasis on physical activity. Women also agreed that there were developmental coding errors and technical issues associated with the synchronization of the app and accessories.

The group of women who took part in the focus groups were technologically proficient and informed. From this, a third theme emerged which was the *Knowledge of Pregnancy-Specific mHealth Services*. The women used several mHealth services such as Baby-Center, TheBump, What to Expect, and Ovia health. A fourth theme to arise from analysis was *Knowledge and*

Table 3 Themes and Subthemes from Focus Groups regarding Content, Functionality, and Future Prospective of *SmartMoms Canada*

Thematic Analysis	Supportive Evidence
1. Strengths of the <i>SmartMoms</i> app	
Pregnancy guidance and support	"I definitely think that for people who haven't necessarily tried a whole bunch of fitness apps or haven't tried other pregnancy apps, it's a fantastic place to start. Because it's a tool, and when you're pregnant any tool [is] helpful because it answers your questions and it helps you lower your stress level and having some guidance is wonderful." "I think a lot of people [would] rather turn to apps in pregnancy because it gives them that informal support that their OB or their midwife may not have time to offer them, or they may not feel comfortable asking questions...and it can be a real asset." "I thought it was helpful to have...small pockets of information"
Pregnancy-specific exercises	"All the exercises...were great." "I didn't always read the entire text [associated with exercises], because the visual was a pretty good reminder." "I definitely like that you can see the image of the [pregnant] person"
Synchronization with ©Fitbit	"I never had a ©Fitbit before and really being mindful about how much I'm walking...if it had [synced] would've been more interesting."
Advice on sleep	"I found them [SmartTips] helpful in general, especially sleep is really interesting, because it's not something I prioritize or think of at the forefront of health, but it [SmartMoms] kind of explains that when you're not sleeping enough you're probably going to eat more, and [this] can be linked to gestational diabetes, so [it] is interesting...I found it was good and made me more well-rounded when it comes to health"
2. Critique of the <i>SmartMoms</i> app	
Design and aesthetic	"I think part of it is that in a lot of apps you get some visual to cue you to touch things and here because everything was kind of [in] squares...you didn't have that same visual cues." "I find other apps [have]...really bright colours, there's things that are standing out, whereas this [SmartMoms] is a little more muted."
Interactivity	"I find something big with [SmartMoms] is there's no real interactivity...it says, "set goals" but you can't put a goal in, and it says this is a checklist of things to do but you can't check off these are things I've done."
Feedback	"I think part of it is...it [SmartMoms] kept saying you're underweight...so [now] what should I be eating that's healthy?...what's the next recommendation? I think that little bit of [information on] how to eat more healthy so that I could be in the healthier range would have been... more helpful."
Emphasis on weight gain	"I do find the emphasis on the app, on the weight gain like I would have preferred more on the physical activity [such as] these are things good for your hips at this stage; your body is changing in this way so focus on these stretches."
Developmental and technical issues	"My weight would change 15 lbs depending on where I was taking my weight in my apartment. But it [©BodyTrace scale] was just not synching with the app. So, I did not use it as much as perhaps I should." "I found every time I'd go to settings that's when it would crash."
3. Knowledge of Pregnancy-Specific mHealth Services	
Technologically proficient group that interacted with several mHealth tools	"I used the BabyCentre app. It doesn't have any of the health tracking, but it does have a lot of good articles and forums to talk to other moms. [BabyCentre] has updates on where you are in the pregnancy." "...I started using Ovia because a friend of mine who was pregnant last year recommended it to me...and that app [Ovia] in particular helped replace a lot of the heavily been googled forums of "Is this normal?!"
4. Knowledge and Attitudes of Weight Gain Guidelines	
Strong familiarity of evidence-based guidelines	"I think we might be a very educated group, but other people aren't aware of that [IOM guidelines] and they're still on that perspective that oh I can eat for two"
Negative views of guidelines	"I think move away from the numbers and just more education about the concept of healthy weight gain and then healthy eating"
Positive views of guidelines	"I think the guidelines are good, but I think it's important to remember that they're guidelines." "I think it's important that people know [the guidelines] but there's a fine line between having people stressed about [them] and being aware that just because they're pregnant doesn't give them free range to gain as much weight as they can"
5. Weight Tracking	
Feedback on weight from HCP	"I was weighed at all my appointments, but I think my doctor would have raised it [weight measured] had it been a concern. These appointments are quick – okay, everything is good, okay, bye...do you

Table 3 Themes and Subthemes from Focus Groups regarding Content, Functionality, and Future Prospective of *SmartMoms Canada* (Continued)

Thematic Analysis	Supportive Evidence
Worry and stress associated with daily weight tracking	have any questions and if I don't have any questions then... I feel like the OB/GYN are really busy and ...I found that they were really quick appointments and there wasn't any concerns then there was nothing raised unless I had questions and in terms of me weighing myself at home, yes I would once in a while mainly just because I was curious." "I was followed by my GP up until 16 weeks and then referred but he never mentioned healthy weight gain or what to expect. He weighed me every time, but I think similarly he would have said something if there was something to worry about."
Weight tracking positively viewed	"I don't like to weigh myself daily because it makes me really anxious and I'm thinking any person with an eating disorder, weighing yourself daily is not good. So maybe just a...reminder once a week might be enough." "I've always weighed myself, once a week or once every two weeks. When I got pregnant I was on the cusp of BMI of overweight, so it was something that I was concerned about, because I don't want to gain too much. But, having the app...I wanted to test it a lot, I did usually weigh myself every day... but I would go back to weighing myself probably once a week."
6. Future Suggestions for <i>SmartMoms Canada</i>	
Greater focus on overall maternal health	"...if you have a baby section maybe have a "what's going on with your body this week" because for a lot us who are first pregnancies, I thought it's been a sharp learning curve" "I think more focus on the exercise, more focus on the healthy eating, healthy sleeping...[and] water intake. Weight is part of it [health] but...the other things are more important." "...I would have liked more of a healthy mind component as well."
Incorporate exercise routines based on time, availability, and trimester	"Have mini workouts instead of just pick random exercises" "Maybe when [SmartMoms] explains our routine, something is already built but that could change throughout the pregnancy. Because what you can do in your first semester is not what you can do in your third semester." "It would be nice to say how much time do I have? And you can have 5 min, 10 min [and then] pick something [or] try this? That sort of thing really engages you."
Reassuring feedback and enhanced interactivity	"Yeah! Some feedback would be good, reassuring." "I'd like if it [SmartMoms] had notifications like "remember to do this today" or exercise plans...okay, I have a plan, I can do this! Instead of, "well, what am I going to do today?"
Organize app content based on personal health preferences	"I think it [SmartMoms] could just be visualized based on your health priorities. So, like you said like if you don't want to see weight maybe it [can] go to the bottom of your dashboard or maybe it's something you can hide completely. If you're more focused on making sure you get your greens or your activity, then maybe that could be raised a little higher."
Connecting with other pregnant women, using forums, discussion boards, and blogs	"...on websites there are always discussion boards or a blog you kind of hear from other moms and what they've tried...with the app, it's okay, it's just what you should do...It's always nice to get different opinions and what worked a little bit easier for someone and what worked better for someone else." "Maybe it [SmartMoms] could even have a social aspect where you could link with other moms within the radius who have the app."

Attitudes of Weight Gain Guidelines. Women were knowledgeable of IOM or other evidence-based weight gain guidelines for pregnancy, however, some expressed a negative perspective regarding the guidelines whereas others expressed positive viewpoints. Those who portrayed negative views of the guidelines were critical of the emphasis on a target number as opposed to focusing on healthy eating. Contrarily, those who perceived the guidelines positively viewed them as an important reminder to be mindful of one's weight and eating habits throughout pregnancy.

Participants were near unanimous on their viewpoints regarding *Weight Tracking*, a fifth theme to emerge from transcript analysis. Most women reported that they often did not receive feedback on weight from their HCP and weight gain guidelines were not

discussed. Women made note of the quick nature of prenatal care appointments and emphasized the lack of time that HCPs have to allocate to their patients. Many participants highlighted that daily weight tracking was stress-inducing and would prefer to monitor their weight only once in a while. However, some participants considered themselves weight-centric and positively viewed daily weight tracking.

A final theme to emerge from thematic analysis was *Future Suggestions for SmartMoms Canada*. Participants provided wholesome feedback for the next version of the *SmartMoms Canada* app. Women predominantly viewed the app as a means of tracking weight throughout pregnancy and wanted greater focus on overall maternal health, emphasizing exercise, healthy eating, sleep, and mindfulness. Participants

were in consensus that the app should incorporate more feedback in the form of notifications, along with further interactivity that would allow women to input their own goals. Women thoroughly enjoyed the exercises in the app, however, they suggested including short workout routines based on time availability and stage of pregnancy. Participants also wanted to be able to organize the app content based on one's health preferences and were interested in connecting with other pregnant women who were using the app to discuss pregnancy-specific matters through an embedded discussion board, forum, or blog.

Discussion

This study explored pregnant and postpartum women's attitudes towards a novel pregnancy app, *SmartMoms Canada*. Principally, we found that women positively viewed the app with respect to its ability to provide pregnancy guidance, pregnancy-specific exercises, and advice on sleep. From our qualitative analysis, it is clear that pregnant women interact often with mHealth services and seek such tools to provide them with information and informal support that HCPs may not have time to offer. We also found that women who were not weight-centric prior to pregnancy, experience worry and stress with daily weight tracking. Participants highlighted the importance of organizing the app based on their personal health preferences and that emphasis on overall maternal health (i.e. combination of exercise, nutrition, and mindfulness) are included. In addition, women viewed the future prospective of the app to have potential for health promotion during pregnancy and limit excessive GWG given the design, aesthetic, developmental coding errors, and synchronization difficulties are resolved in the upcoming version.

It is of no surprise that women have already taken the lead in utilizing mHealth tools as key sources of information and actively access the Internet for pregnancy-related support, ultimately impacting their decision-making [24, 42]. In accordance with this evidence, the women in the focus groups made use of several pregnancy-specific mHealth tools for guidance. Women embraced the use of the Internet to provide them with efficient information in support of their decision-making that their care providers did not have the resources or time to offer. Future work, however, should focus on evaluating the reliability of information received from websites and apps [25]. Prenatal care providers have voiced concerns over the loss of information control and the health risks associated with exposure to inaccurate information through electronic health (eHealth) and mHealth services [23]. Our app, in particular, is a research-based, non-for-profit, health-focused tool developed by a team of experts in pregnancy lifestyle interventions and maternal-fetal health. Recognizing this, women in the study indicated that they were 'likely' and

'somewhat likely' to use the *SmartMoms* app throughout pregnancy and to recommend the app to others who are pregnant, thereby encouraging the development of the next version of *SmartMoms Canada*.

On average, the women in this study were categorized as having an overweight BMI prior to entering pregnancy. Our sample demographic is reflective of the Canadian pregnant population. The rate of obesity has significantly increased among Canadian women aged 18 years and older in recent years and is predicted to rise in the near future [43]. Thus, prevention of obesity during pregnancy is of high priority in the Canadian healthcare system. After being presented with the 2009 IOM weight gain guidelines, women in the focus groups recognized the guidelines and generally understood the importance of staying within recommendations. However, some women expressed negative views towards the guidelines in that they are too strict and should focus more on healthy eating and physical activity. Women who view IOM weight gain guidelines in a negative light, should recognize that the lifestyle interventions (i.e. healthy eating, physical activity, and mindfulness) they seek from guidelines are primarily developed to optimize healthier rates of GWG and prevent excess GWG across the entire pregnancy. Since the inception of the IOM guidelines, several studies and systematic reviews have stressed the negative health outcomes for both mother and baby associated with entering pregnancy overweight or obese and gaining above recommendations during pregnancy [44, 45]. Further, a systematic review of 22 research articles found that self-weighing interventions improve weight outcomes, wherein no negative psychological effects are associated with self-weighing at a frequency of daily or weekly [46]. As part of a strategy for gaining weight during pregnancy within the most recent guidelines, the IOM has set detailed recommendations of weight gain per week based on pre-pregnancy BMI [47]. Therefore, a minimum of weekly self-weighing is necessary to ensure positive pregnancy health outcomes. Given our enlightened understanding of women's thoughts of pregnancy weight gain guidelines from our analysis, the *SmartMoms Canada* app can help inform women of guidelines and further educate them on the importance of guideline adherence in addition to offering lifestyle support such as physical activity, nutrition, and mindfulness advice that women seek.

Healthcare providers have long been sought out to address issues regarding excessive GWG to their patients and provide them with evidence-based information. However, recent work has shown that many are failing to counsel on weight during pregnancy [48]. Importantly, HCPs report that weight is a sensitive topic to discuss with their pregnant patients [49]. A major theme to emerge from our study was the stress, worry, and sensitivity associated with weight tracking. This is in accordance with previous literature, which has found that weight gain may

indeed be a sensitive topic for many women during pregnancy [50]. Women in our study reported either a lack of time from HCPs to discuss weight-related concerns unless the women raised the issue or a lack of confidence from HCPs in adequately discussing healthy weight gain. These findings are consistent with the challenges and barriers perceived by HCPs when discussing GWG with patients. mHealth technologies, such as *SmartMoms* may alleviate these challenges thereby providing women with timely GWG counselling. Moreover, *SmartMoms* can provide patients with evidence-based information on weight, healthy eating, exercise, sleep, and mindfulness as an informal support during pregnancy in which women can follow-up with their HCPs.

Thematic analysis found that the future prospective of the *SmartMoms Canada* app was promising, however, several suggestions were offered. Focus group participants emphasised the need for greater interactivity with the app and a desire for enhanced feedback regarding weight, physical activity, nutrition, and mental health. Women suggested the inclusion of exercise routines based on time availability and per trimester, along with being able to organize app content based on personal health priorities. In support of our findings, previous work has found that pregnant patients present with a high demand for medical information and seek web-based pregnancy applications and tools that are personalized, interactive, trustworthy and secure, focused on maternal and mental health, motivational, and easy to use [42, 51]. Given the rapid proliferation of medical information technology, there is an increased need for future work on the health outcomes associated with eHealth and mHealth interventions [25] and a demand for patient groups to become involved in the development and testing of mHealth applications (as presented in this study), as well as to assess the feasibility of embedding such apps in a healthcare setting [42].

Strengths and limitations

Although the findings of the current study provided important insight on a pregnancy-specific mHealth tool, there are limitations that warrant mention. The relatively small, fairly educated, sample prevents the generalizability of findings to others and with participant recruitment limited to the surrounding region of Ottawa, this may further limit transferability of findings to other settings and participants. Given that women had to contact researchers of their interest to participate, it is possible the study was subject to volunteer bias containing a homogeneous group of women who were health conscious and proficient in mHealth technologies. Despite these limitations, it should be noted that as a pilot evaluation, a variety of constructive feedback was still received. In addition, the pilot feedback provided important insight which

will be incorporated into future trials of the *SmartMoms* app, targeting a larger sample size and geographical region. Some strengths to note in the current study include our rigorous procedure for thematic analysis and the use of multiple modalities to analyze the focus group transcripts. Manual coding and NVivo were used for data analysis, and a third team member was added to the analysis procedure to validate codes, categories, and to resolve any discrepancies among the other team members.

Perspectives

After incorporating qualitative feedback, we postulate that the *SmartMoms Canada* app may be a promising solution to address the gaps in HCP communication related to weight during pregnancy, along with support on physical activity, diet, and sleep. Importantly, *SmartMoms Canada* has been in continuous development since the completion of the focus groups. The integration and synchronization of Wi-Fi™ enabled accessories have been improved upon and will soon operate smoothly in combination with the app. The desire for greater feedback on weight gain expressed by the women in the focus groups, has been met. Women will now be notified on whether they are within or outside the zone of appropriate weight gain for gestational age using a validated mathematical model that takes into account pre-pregnancy weight, current weight gain, and caloric intake. The app then offers interactive suggestions on how to return to or stay within one's weight zone through advice on nutrition and exercise. The future of mHealth tools and their role in prenatal care will depend on the successful embedding of these evidence-based tools in daily health care routines and encouraging HCPs to integrate such tools in their practice. Such a demand will be fulfilled in the next version of the *SmartMoms Canada* app during a multi-centre, pan-Canadian assessment of the app. Findings from this study and future studies will contribute to offering home pregnancy care, patient empowerment, and revolutionizing prenatal care practices, ultimately contributing to improved maternal-fetal health outcomes.

Conclusions

Pregnancy is a critical and teachable period during a woman's lifespan. Women in our study were technologically proficient and comfortable using several pregnancy-specific mHealth tools to track their health. Generally, women found *SmartMoms* to be a useful tool with respect to monitoring GWG, offering exercise tips, and sleep guidance. Women sought greater feedback and interactivity from the app and the need for the next version to be free of developmental coding obstacles so as to ensure an aesthetically pleasing, smoothly functioning tool. Understanding women's

perspectives and attitudes towards a novel, health-focused pregnancy app, as presented here for *SmartMoms Canada*, will help inform future mHealth interventions and encourage healthful behaviours during pregnancy. We believe that such lifestyle interventions can help improve population health by halting downstream health risks associated with weight gain above IOM recommendations, providing women with efficient, informal guidance throughout pregnancy.

Abbreviations

App (s): Mobile Application (s); BMI: Body Mass Index; eHealth: Electronic Health; GWG: Gestational Weight Gain; HCP (s): Health Care Provider (s); IOM: Institute of Medicine; m-Health: Mobile Health; SD: Standard Deviation; WHO: World Health Organization

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Availability of data and materials

The data that support the findings of this study are available on request from the authors.

Authors' contributions

LH and RL primarily performed data analysis and assembly. KAH secondarily performed secondary data analysis and analysis. LR team at PBRC developed the original *SmartMoms* app after which *SmartMoms Canada* was modelled. LH drafted the manuscript, along with RL. LH, RL, KAH, KS, LMR, and KBA interpreted the study results. LH, RL, KAH, KS, LMR, and KBA edited and revised the manuscript. All authors have read and approved the final version of the manuscript.

Ethics approval and consent to participate

This study conformed to the regulations set forth by the Declaration of Helsinki. The University of Ottawa, Research Ethics Board (file number: H11-16-17), approved the facilitation of the focus groups. Ethics approval and written informed consent to participate was acquired from all participants.

Consent for publication

Written informed consent for publication was obtained from all interested and eligible participants who took part in the focus groups.

Competing interests

The authors declare that they have no competing interests.

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CHAPTER 5 – DISCUSSION AND GENERAL CONCLUSIONS OF THE THESIS

Pregnancy is a transformational period in a woman's lifespan, filled with physical, psychological, social, and behavioural complexities.^{38,39} Women's experiences during pregnancy and their perspectives on pregnancy-related factors have yet to be fully understood and investigated. A considerable number of studies have demonstrated that women of childbearing age are increasingly heavier and exceed evidence-based weight gain recommendations, posing an array of adverse short- and long-term maternal-fetal health outcomes.^{8,42} Given that entering pregnancy overweight or obese, or experiencing excessive GWG, can contribute to an intergenerational cycle of obesity⁸, adhering to weight gain recommendations and adopting healthy lifestyle behaviours are essential for population health. Thus, characterizing pregnant women's perspectives on weight gain and lifestyle behaviours are crucial in informing future interventions and research aimed at helping women achieve a healthy pregnancy. The following thesis presented two studies, a quantitative and qualitative investigation. This thesis sought to firstly, quantitatively assess women's perceptions of weight gain, physical activity, and diet during pregnancy as well as elucidate the barriers and facilitators associated with meeting IOM guidelines. Secondly, this thesis aimed to qualitatively evaluate women's attitudes and opinions towards utilizing a novel, mHealth tool, *SmartMoms Canada*, as a feasible and trustworthy source of information throughout pregnancy and possible future aid in achieving guideline-concordant weight gain.

Article one of this thesis was the first cross-sectional analysis with the purpose of investigating the findings from the Canadian Electronic Maternal health survey. The survey, grounded on social cognitive theory, allowed for a thorough understanding of women's self-efficacy and locus of control as well as barriers and facilitators associated with achieving a healthy pregnancy weight gain. The study identified significant psychosocial risk factors associated with excessive GWG and demonstrated the complexity of understanding such factors during pregnancy.

It was found that high self-efficacy, associated with an internal locus of control, played a protective role against exceeding IOM guidelines. This finding is in accordance with previous work, in which high self-efficacy towards a healthy weight gain throughout pregnancy was associated with reduced excessive GWG and lower maternal body weight.^{110,111} Contrarily, low self-efficacy coupled with an external locus of control, was found to reduce one's likelihood of meeting IOM recommendations. In like manner, a previous study has demonstrated that women who associated external factors with fetal health were more likely to succumb to guideline-discordant weight gain during pregnancy.¹¹² Pregnant and postpartum women who recounted intrapersonal factors as barriers to exercising during pregnancy, and postpartum women who described barriers related to social support, presented with a significantly reduced chance of achieving guideline-concordant weight gain. Similarly, several studies have found that fatigue, discomfort, and lack of time serve as barriers to physical activity during pregnancy, whereas social support plays an enabling role.¹¹³ Despite our current understanding of the psychosocial risk factors associated with healthy pregnancy weight gain, few studies have assessed weight-related self-efficacy and locus of control in relation to meeting IOM weight gain recommendations, as presented in this thesis. However, there are several gaps yet to be addressed. In particular, future work should look to examine the psychosocial factors associated with weight gain among pregnant women of low socioeconomic status (SES) who may face a myriad of psychological and social obstacles, unrelated to the sample population presented in article one. Further, despite women's attempts to be health conscious during pregnancy, evidence suggests that few women receive GWG advice from their HCPs and any counselling received is often infrequent and inaccurate.¹¹⁴ Such a lack of HCP weight management discussions can be a taxing barrier to women who already minimally interact with their HCPs throughout pregnancy, such as Indigenous women in Canada.⁶² Thus, prenatal HCPs should be encouraged to become well versed in the psychosocial risk factors associated with

excessive GWG so as to improve maternal healthcare experiences and outcomes, especially among vulnerable pregnant women. Overall, the findings from this first study presented in this thesis have attempted to understand the psychological and social contributors to weight gain outside of evidence-based guidelines and will serve to inform future pregnancy-related interventions.

Article two sought to explore pregnant and postpartum women's attitudes and receptiveness towards a novel pregnancy app, *SmartMoms Canada*. Through the organization of focus groups and using thematic analysis, it was found that women viewed *SmartMoms Canada* to be a useful tool in monitoring GWG, offering exercise advice, and sleep guidance. Women were tech-savvy and embraced the idea of interacting with mHealth tools during pregnancy. Similar to previous work, pregnant women frequently make use of mHealth tools, viewing them as essential sources of information for pregnancy-related support and decision-making.^{115,116} Further, women in the study sought greater feedback and interactivity with the *SmartMoms* app and requested more personalization depending on one's health priorities. Lastly, women saw immense potential in *SmartMoms Canada* and positively viewed the future prospects of the next version of the app. These findings from focus group analysis have aided immensely in the development of the most recent iteration of the *SmartMoms Canada* app, which will soon be tested for effectiveness in a multi-centre pan-Canadian assessment of the app. Such a proposed study, complemented by our focus group findings furthering our comprehension of women's maternal health experiences with mobile technology, will serve to fill a current gap in the literature; that is, directly testing the effectiveness of utilizing evidence-based mHealth apps among pregnant women.¹⁹ Additionally, women in our study reported receiving minimal recommendations from their HCPs on weight management, physical activity, and diet. As such, mHealth technologies like *SmartMoms Canada*, may alleviate the challenges faced by pregnant women during prenatal care by offering evidence-based GWG counselling and support. Importantly, in recent years, the use of mHealth technologies

has been vastly supported by the WHO as a means of improving maternal and child health, worldwide.^{96,108} Consequently, mHealth apps may be used to reach women in remote geographical locations who may not receive adequate maternal healthcare, possibly mitigating health disparities. Future work should seek to firstly, test the effectiveness of mHealth apps among pregnant women and integrating such tools in standard prenatal care practices, and secondly, seek to customize mHealth apps to meet women's unique vulnerabilities during pregnancy, such as weight sensitivity and a need for greater feedback and guidance.

Limitations and Delimitations of Thesis

The limitations of each study are outlined in detail in the submitted manuscripts above. There are, however, certain limitations and delimitations worthy of discussion that have set the parameters of both quantitative and qualitative investigations presented in this thesis. The EMat health survey was developed by an expert panel of researchers in 2014 and the preliminary validation of the survey was published by Ockenden and colleagues in 2016.⁹ Thus, the content of the survey could not be modified as data collection has been ongoing since 2014 through a secure data capture tool, REDCap™. Multiple linear logistic regression analyses of data were chosen as the primary means of analysis since the objective was to evaluate several potentially predictive factors associated with a binary outcome variable, that is, whether women met IOM weight gain guidelines. Therefore, there is a need to differentiate between associations and causations. All findings presented from the EMat survey above are associations, as they relate to the binary outcome variable, in which a correlation between two or more variables was discovered, and not causations or direct changes. Further, with respect to the sample characteristics of survey respondents, it is important to recognize that the sample was not entirely representative of the Canadian pregnant population. The women who responded to the survey were predominantly educated, employed, and of high SES. Indeed, a recent systematic review emphasized the complex

nature of the influence of SES on GWG, particularly how an association exists between low educational attainment and gaining weight outside of IOM guidelines.¹¹⁷ Previous work has also shown that women of lower SES lack the resources, knowledge, and support necessary to prevent gaining weight outside of pregnancy guidelines.¹¹⁸ Given our non-representative sample, the influence of SES on GWG was not assessed. However, education and income were accounted for in the linear logistical model used for the analysis. Further, a stratified analysis of education and income for the main findings of article one on self-efficacy, barriers, and facilitators to weight gain found no significant differences across education and income groups. Despite these findings, as previously mentioned, there is a need for future studies to assess the psychosocial factors related weight gain, specifically among pregnant women of low SES. Lastly, the terminology used in the survey, mainly regarding ‘worry’ and the notion of ‘control’ over behaviours, were conceptualised by the team of experts who developed the survey. Thus, our findings of women’s perceptions of their pregnancy-related behaviours are limited to this wording and specifically, the SCT as the primary theoretical framework.

The implementation of focus groups to evaluate the *SmartMoms Canada* mHealth tool were organized under certain funding-related time constraints. Therefore, the resulting sample of 13 pregnant and postpartum women was achieved under these conditions. Initially, focus groups were to be conducted separately, in both English and French so as to best reflect the Canadian pregnant population. However, given our available window of opportunity and low recruitment turnout of francophone pregnant women, we were unable to conduct separate English and French focus groups. Nonetheless, some women were bilingual and were able to comment on the French content presented in our app, further assisting with content development. Future work will seek to evaluate the *SmartMoms Canada* mHealth app among both English- and French-speaking pregnant women so as to adequately represent the diverse sample of pregnant women in Canada.

Final Thoughts

Together, these two studies have contributed to a growing body of literature surrounding our knowledge of women's unique experiences during pregnancy. Such an understanding will help inform the development of interventions aimed at improving future maternal and fetal health outcomes. Given our enlightened appreciation for the psychosocial factors associated with women's health-related behaviours during pregnancy, as presented in the first study, it is essential that we consider one's self-efficacy and locus of control in providing women with sufficient tools to adhere to weight gain recommendations and adopting a healthy lifestyle during pregnancy. Future studies should specifically examine how an internal locus of control relates to weight gain guideline adherence and willingness to take part in physical activity and healthy eating during pregnancy. Further, studies may directly examine how barriers such as intrapersonal factors along with facilitators hinder or encourage certain behaviours throughout pregnancy. Importantly, concerning the second study presented in this thesis, our consideration of the psychosocial factors associated with behaviour, may especially help inform future mHealth interventions for pregnancy. Pregnant women have taken the lead in utilizing mHealth and eHealth services for their pregnancy-related needs and information that may not be adequately communicated through their HCPs.^{101–103} The second study was in accord with this recent trend and demonstrated that women do perceive immense potential in mHealth technology. Thus, armed with our understanding of how high self-efficacy and internal locus of control are associated with an increased likelihood of meeting IOM weight gain recommendations, future mHealth interventions may look to incorporate such psychosocial factors during app development to ensure positive health and weight outcomes during pregnancy. Mainly, mHealth interventions should be interactive, feedback-driven, and motivational tools so that pregnant women believe in their capacity to exercise control over their weight gain, physical activity, and nutrition. Further linking the findings from both studies, future

mHealth interventions should help encourage women to see that the changes they observe in their weight, physical activity, and diet, presented through a mobile app, are in fact due to their abilities and actions as opposed to external factors, outside of their control.

As a final thought, the findings from the two studies presented here will serve to further our grasp of the psychosocial factors associated with weight gain and adoption of healthy lifestyle behaviours during pregnancy. Recognizing the significant contribution of psychosocial factors towards pregnancy-related behaviours will then guide our awareness of how mHealth technology may substantially contribute to a healthy pregnancy, ultimately leading to the development of interventions that can facilitate positive downstream maternal and fetal health outcomes.

CHAPTER 6 – REFERENCES

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RESEARCH INSTITUTE
INSTITUT DE RECHERCHE

Research Ethics Board 2017 Annual Renewal (Delegated)

Principal Investigator: Dr. Gary Goldfield

REB Protocol No: 14/183X

Romeo File No: 20140503

Project Title: CHEOREB# 14/183X - Women's Perceptions of the Current Weight Gain Guidelines during Pregnancy

Primary Affiliation: HALO\HALO

Protocol Status: Active

Approval Date: November 27, 2017 **Approval Valid Until:** December 15, 2018

Annual Renewal Submission Deadline: November 15, 2018

Documents Reviewed & Approved:

Document Name	Comments	Version Date
Protocol	Protocol unchanged	2014/10/17
Consent Form	Consent and questionnaire linked	2016/12/14

This is to notify you that the CHEO REB has granted approval to the renewal for the above named research study for a period of one year. The renewal was reviewed and approved by the Chair or a delegate of the Chair. Decisions made by the Chair under delegated review are ratified by the full Board at its subsequent meeting.

Approval is granted with the understanding that the investigator agrees to comply with the following requirements:

- 1 The investigator must conduct the study in compliance with the protocol and any additional conditions set out by the Board.
- 2 The investigator is responsible for complying with all applicable guidelines and regulations regarding human research ethics conduct, as applicable to the research project.
- 3 Investigators must submit an annual renewal report to the REB 30 days prior to the expiration date stated on the final approval letter.
- 4 The investigator must not implement any deviation from, or changes to, the protocol without the approval of the REB except where necessary to eliminate an immediate hazard to the research subject, or when the change involves only logistical or administrative aspects of the study (e.g., change of telephone number or research staff). As soon as possible, however, the implemented deviation or change, the reasons for it and, if appropriate, the proposed protocol amendment(s) should be submitted to the Board for review.
- 5 The investigator must, prior to use, submit to the Board changes to the study documentation, e.g., changes to the informed consent letters, recruitment materials.

- 6 Investigators must provide the Board with French version of the consent form, unless a waiver has been granted. An interpreter should be offered to participants as required or at the request of the participant throughout the course of research.
 - 7 For clinical drug or device trials, investigators must promptly report to the REB all adverse events that are both serious and unexpected (SAEs) or unexpected and untoward occurrences (including the loss or theft of study data and other such privacy breaches).
 - 8 For SAE reports on clinical drug trials, the investigator must also comply with the hospital-wide Policy regarding, Procedures for Considering Medical Error in the Differential Diagnosis of Severe Adverse Events (SAE) Associated with the Drugs Administered in a Clinical Trial .
 - 9 Investigators must promptly report to the REB any new information regarding the safety of research subjects (e.g., changes to the product monograph or investigator's brochure of drug trials). Where available, any reports produced by the Data Safety Monitoring Board should also be promptly submitted to the REB.
 - 10 Investigators must notify the REB of any study closures (closed to accrual, temporary, premature or permanent).
 - 11 Investigators must submit a final report at the conclusion of the study.
- If you have any questions, pertaining to this letter, please contact the Research Ethics Board Office at (613) 737-7600, ext. 3350 or 2128.

EMat Electronic Consent Form

Are you currently pregnant or have you given birth since May, 2009? If yes, you are eligible to take part in *The EMat Health Survey: Pregnancy Attitudes and Behaviours in women of childbearing age.*

This is a research project being conducted by The Children's Hospital of Eastern Ontario (CHEO), Healthy Active Living & Obesity Research Group (HALO). The purpose of this survey is to find out how women (who are currently pregnant or have been pregnant since May, 2009) feel about important prenatal health indicators.

The study involves filling out an online survey that will take approximately 15-25 minutes.

The ultimate goal of this survey is to gain information that could help improve the health and well-being of pregnant women, mothers, and infants in Canada and internationally. All information collected will be of interest to maternal and child health researchers, public health professionals, policy makers, women's groups, and professional organizations in the field of maternal and infant health.

Your participation is completely voluntary. You may choose not to participate. If you decide to participate in this research survey, you may withdraw at any time. If you decide not to participate in this study or if you withdraw from participating at any time, that is okay. You do not have to answer any question you do not wish to answer.

Confidentiality

Your survey answers will be sent to a link at www.REDCap.cheori.org where data will be stored in a password protected electronic format. This questionnaire does NOT collect any identifying information. Therefore, your responses will remain anonymous. All individual records and results will be analyzed and referred to by assigning a unique ID number code only, as required by law. The results of this study will be used for scholarly purposes only and may be shared with the study team from CHEO and the University of Ottawa.

Costs and Compensation

There is no cost for participating in this research study. Participants will not receive any financial compensation. If you have any questions about your participation requirements or content of this study, please contact Dr. Kristi Adamo at 613-737-7600, ext. 4190. This study has been reviewed and approved by the CHEO Research Ethics Board. The CHEO Research Ethics Board is a committee of the hospital that includes individuals from different professional backgrounds. The Board reviews all human research that takes place at the hospital. Its goal is to ensure the protection of the rights and welfare of people participating in research. You may contact the Chair of the Research Ethics Board, Dr. Carole Gentile, for information regarding your rights in research studies at (613) 737-7600 ext. 3272, although this person cannot provide any health-related information about the study.

If you are happy to participate in this study please read and complete the electronic consent form:

ELECTRONIC CONSENT:

Please select your choice below. Clicking on the "agree" button below indicates that:

- You have read and understand the information for participants taking part in this pregnancy health questionnaire.
- You understand that taking part in this study is voluntary, that you may withdraw from the study at any time.
- You know who to contact if you have any questions about the questionnaire.
- You are at least 18 years of age.

If you do not wish to participate in the research study, please decline participation by clicking on the "disagree" button.

Disagree

Agree



Université d'Ottawa
Bureau d'éthique et d'intégrité de la recherche

University of Ottawa
Office of Research Ethics and Integrity

Certificate of Ethics Approval

Health Sciences and Science REB

Principal Investigator / Supervisor / Co-investigator(s) / Student(s)

<u>First Name</u>	<u>Last Name</u>	<u>Affiliation</u>	<u>Role</u>
Kristi	Adamo	Health Sciences / Human Kinetics	Principal Investigator

File Number: H11-16-17

Type of Project: Professor

Title: SmartMoms-Canada Trial: a pilot evaluation of a pregnancy-specific mobile health application to manage gestational weight gain (focus group component)

Approval Date (mm/dd/yyyy)

02/08/2017

Expiry Date (mm/dd/yyyy)

02/07/2018

Special Conditions / Comments:

N/A



Université d'Ottawa

Faculté des sciences
de la santé

École des sciences de
l'activité physique

University of Ottawa

Faculty of Health Sciences

School of Human Kinetics

Background Information and Consent Form

***SmartMoms Canada*: a pilot evaluation of a pregnancy-specific mobile health application to manage gestational weight gain**

Principle Investigator:

Dr. Kristi Adamo

Associate Professor, University of Ottawa
200 Lees Avenue
Ottawa, ON K1N 6N5
kadamo@uottawa.ca
613-562-5800 x 1009

Funding Agency: Public Health Agency of Canada (PHAC)

Information to Participants

A healthy intrauterine environment is important to promote the life-long health of the child. Pre-pregnancy body mass index (BMI) and gestational weight gain (GWG) are important independent contributors to the healthy uterine environment. Excessive GWG can contribute to the development of obesity, type 2 diabetes, and other cardiometabolic diseases in the baby.

Currently, the majority of pregnant women are gaining more than the recommended GWG guidelines despite clinical practice recommendations calling for an 'ideal' weight gain to optimize health for mom and baby.

Purpose of this study

This is a pilot study to test the newly developed smart phone application (app), *SmartMoms Canada*, in pregnant women in Ontario. The app's goal is to improve the health of pregnant women and, subsequently, improve the well-being of their children. The *SmartMoms Canada* app will provide a more efficient and effective tool for delivery information to pregnant women, and increase engagement of women during their pregnancy in order to improve behaviours during this critical prenatal period.

Invitation to Participate

You have been invited to participate in this study because you are a pregnant woman or new mother within the ages of 18-40 years old, and have shown interest in trialing the *SmartMoms Canada* app. Your participation will be integral in helping us determine the potential of an eHealth initiative for improving maternal-fetal health. This study will involve you participating in a one-week trial with the *SmartMoms Canada* app and accessories, followed by a focus group to discuss the content and usability of the app. We are interested in testing the efficacy of the *SmartMoms Canada* app as a more effective and economical mode of delivering information to pregnant women compared to the traditional healthcare methods which currently create time and economic burdens on the health care system in Canada.

Participation in this study is strictly voluntary. Please read this **Participant Informed Consent Form** carefully before you decide if you would like to participate. Please ask the principal investigator and the study team as many questions as you like.

Site Visits

If you consent to participate, you will be asked to come to Dr. Adamo's Prevention in the Early Years lab (within the Behavioural and Metabolic Research Unit) at the University of Ottawa – Lees Campus. You will be required to come into the lab for two different sessions. The first visit will include obtaining informed consent, providing details about the app, and distributing the technology accessories. This visit should take about 45 minutes. For the second visit, you will participate in the focus group, which will be 90 minutes long. We ask that you please return all accessories during the second visit.

Visit Details

Equipment

You will be given a Fitbit® fitness tracker and a BodyTrace scale to use throughout the study. A demonstration on the use of this equipment will also be provided at this time. A Fitbit Charge HR® is a wearable fitness tracker that collects and displays information regarding your step

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count, heart rate, energy expenditure and sleep quality. The BodyTrace scale tracks body weight and syncs this information with the *SmartMoms Canada* app. Please note that you will not be liable for any damaged or lost equipment during your participation in this trial.

Focus Group

A focus group is used to collect descriptive data about a research topic. In this case, a focus group will be held to discuss the content, appearance and usability of the *SmartMoms Canada* app. The focus group will be lead by an external researcher (Amanda Parriag of Parriag Group) and will run for 90 minutes. This researcher has many years of experience leading focus groups and with the collection of qualitative data. During this time, the group will be video-recorded and detailed notes will be taken on the discussion by members of the research team.

Possible benefits and risks associated with participating in this study

The results of this study will allow the scientific community to understand the effectiveness of eHealth technology as a method to improve maternal-fetal health. Findings will help to improve the design of the *SmartMoms Canada* app, and benefit other pregnant women in the future across Canada. Participating in this study does not provide benefits directly to you, however, you will be contributing to a larger project that we hope will improve maternal-fetal outcomes in future pregnancies.

There is no direct harm involved in participating in the study. The focus group discussion will be based on the content, usability, functionality and appearance of the app. If at any time you do not feel comfortable discussing your experiences about the topic of discussion during the meeting, you do not have to participate in that discussion question.

Alternatives and right to withdraw from the evaluation process

Participation in this study is completely voluntary. You have the right to refuse any tasks or answer any questions asked of you at any time. You can decide to take part in this study now and change your mind later without any negative repercussions. If you withdraw your consent, the study team will no longer collect personal data and use for research purposes.

Information collected for the study before you cancel this consent may still be used unless you request for it to be destroyed. You have the right to request for the information to be destroyed.

Confidentiality of Data Collected

Your privacy and confidential data will be protected in a secure location at the University of Ottawa where only study staff members will have access to the documents. Your identity will be anonymous and only accessed and analyzed using a specific ID number that will be assigned to you (as required by law). Your name will not be found on any report, documents/forms or research papers. No data that discloses your identity will be presented.

Confidentiality of Focus Group

Your identity will be known to other focus group participants and we cannot guarantee that other members of the group will respect the confidentiality of the group. We ask you to sign below to indicate that you will keep all discussion during the meeting confidential, and do not discuss what happened during the focus group outside of the meeting. The leader of the meeting will emphasize confidentiality and anonymity at the beginning and end of the session. In addition, you will be assigned a pseudonym to be identified with instead of your name throughout the meeting.

Video/Audio Recording

We will be video recording the focus group for the sole purpose of transcribing and collecting data. This recording will only be used for analysis of the data, and will remain private and confidential.

Costs and Compensations

A parking voucher will be provided to you to cover bus or parking costs for all visits attended with the study team at the University of Ottawa-Lees Campus. In addition, there will be water and a light snack provided at the focus group meeting. You will also be receiving a gift card valued at \$10.

Contacts

The Research Ethics Board at the University of Ottawa could have access to study data. Should you have any questions about the study, please contact Dr. Kristi Adamo at 613-562-5800 extension 1009. If no one answers, please leave a message and we will get back to you. The ethical aspects of this study have been reviewed and approved by the University of Ottawa Research Ethics Board. This committee includes a group of professionals who review all human research at the institute. Their goal is to protect the welfare and rights of people involved and they by no means replace the judgement of your choices and decisions that are best for you.

You may contact the Office of Research Ethics and Integrity at 613-562-5387, via email at ethics@uottawa.ca or at 550 Cumberland St, Ottawa, ON, K1N 6N5 regarding participants' rights in research studies, but please be aware that this board member cannot provide any health-related knowledge about this study.

Thank you for taking the time to consider this study. We hope that through the review of the *SmartMoms Canada* app we can improve the health of mom and baby through a more efficient and involved pre-natal care regime.

We invite you to read, complete and sign the consent information on the following page. There are two copies of the following document, one which you will keep, and the other which we will keep on file.

Participant Consent Form for Participation in the “*SmartMoms Canada*: a pilot evaluation of a pregnancy-specific mobile health application to manage gestational weight gain”

I _____ (your name), give my consent to participate in the *SmartMoms Canada* pilot study.

By agreeing to participate, I agree to not disclose to others outside this event anything said within the context of the discussion. I agree to maintain the confidentiality and anonymity of all participants.

By agreeing to participate, I agree to have myself video recorded in the focus group.

Permission to Quote:

The research team may wish to quote your words directly in reports and publications resulting from this in the future. There is no consequence if you wish to not be quoted in published documents. You are still allowed to participate in the study if you check ‘no’ for both statements below. With regards to being quoted, please check yes or no for each of the following statements:

Researchers may publish documents that contain quotations by me under the following conditions:	
☐ Yes ☐ No	I agree to be quoted directly if I remain completely anonymous. (i.e., I will only be referred to as a “participant” or “respondent”).
☐ Yes ☐ No	I agree to be quoted directly if I am identified by something other than my name (i.e., my career role, a nickname, or a descriptive phrase).

I have read and understood this 5-page letter of information/consent to the *SmartMoms Canada* study and I have had any questions about the study answered to my satisfaction.

Name of Participant

Date of Birth (DD/MM/YY)

Signature of Participant

Date (DD/MM/YY)

(_____)_____
Home Telephone

(_____)_____
Mobile Telephone

Email address

SmartMoms Canada App Testing

Moderator's Guide

September 27th, 2017

Introduction

5 minutes

Welcome and thank you all for taking the time to participate in this focus group. My name is Amanda Parriag and I will be chatting with you this evening to get your feedback on the *SmartMoms Canada* app.

I'll go over some housekeeping items and then we can start.

- We will be chatting for about 90 minutes here today.
- Please let me know if you are not comfortable and we can sort out chairs and pillows and so on.
- The bathrooms are (indicate directions).
- I did not develop the *SmartMoms Canada* app so you can be as completely honest with me as you can. In fact, I would really appreciate you being honest with me since my clients are counting on me to provide honest feedback.
- We might not all agree on a certain point and that is great. As long as we are respectful, I want to hear all of your views.
- We are going to be videotaping the group so that this will help us with our notes afterward. No one will see the final video other than our research team. As soon as the report is written, we will destroy the recording. Do I have your permission to record this group?

Icebreaker

5 minutes

Before we really get started, let's introduce ourselves with our first names and a great descriptor. Also, since we are going to be talking about an app that improves the health of pregnant women, why don't we each mention the most helpful or most annoying piece of advice we have gotten about being pregnant or being a new mum.

I'll go first. My name is Amazing Amanda. The most helpful advice I got when my first baby was an infant and none of my post-pregnancy clothes fit was, "Go buy some new clothes." I was so appreciative that my friend did not tell me it was all in my head or that I was making this a big deal and it wasn't. He just got that my body wasn't working the way I wanted it to, in my clothes and he gave me solid advice. Okay, so who wants to go next?

Questions on content and usability:

35 minutes

Each of you is here because you stepped up to take part in this focus group on the *SmartMoms Canada* app – thanks again for doing this. You probably know that our own weight and the weight that we gain when we are pregnant both have a big impact on our babies. The *SmartMoms Canada* app is designed to help keep mums – and newborns – healthy. We want to know whether this app works in giving you the right support in the right way.

1. To start, what did you know about Smartphone apps and eHealth tech for pregnancy before you became involved in this focus group?

Describe e-health tech for pregnancy is any information on pregnancy from the Internet, social media, blogs, websites. Examples include Ottawa Doula Service, fitmomOttawa, Ottawa Parenting Times. M tech is apps such as OMama and this one.

Probe: Different types of pregnancy apps

Probe: Type of information

Probe: Who tends to use these apps? Location of women? Professionals vs. non-professionals?

Probe: Convenience? Reliability of information?

2. And just so I know, how long did everyone **really** spend on testing out the app?

Probe: Weeks? Days? One or twice a week? Once or twice a day?

3. Great. Now you can pull out your phone for this next part if you want. *Pause to allow for phones to come out.* Overall, what is your impression of this app?

4. Let's talk specifically about what is in the app. Did you see the *Dashboard*? What did you think of that? Does it work for you? Why or why not?

5. Did you go into the *Health* section? Why or why not? For those who explored it, what did you think of it?

6. What about the *Exercise* section? Do you feel that the app and accessories can motivate women to be physically active during pregnancy? Has the app made you more aware of how important it is to be physically activity during pregnancy?

7. Did anything stand out for you? Anything you wish you had seen? Too much? Too little?

8. Did you check out the *SmartTips*? What did you think of that feature?

Probe: Cannot go beyond current week of pregnancy

9. What about the *Your Baby* section? Did you like this section?

10. And what about the week by week details?

Probe: Fruit and vegetable theme, graphics

(If not already raised)

11. What works really well?

Probe: Usability, software compatibility, glitchiness

Probe: Colour scheme, font, language level, graphics

12. And where do you see challenges or gaps with this app?

Probe: Usability, software compatibility, glitchiness

Probe: Colour scheme, font, language level, graphics

(If not already raised)

13. For those who used the app in French, do you have any comments on the content and functionality?

Probe: Areas in the French version that function differently than has been identified in the English version

Probe: Language translation quality and accuracy

Questions on GWG, Diet, and Physical Activity:

35 minutes

14. Prior to testing the SmartMoms Canada app, did you know about the 2009 Institute of Medicine pregnancy-related weight gain guidelines?

TABLE 1 NEW RECOMMENDATIONS FOR TOTAL AND RATE OF WEIGHT GAIN DURING PREGNANCY, BY PREPREGNANCY BMI

Prepregnancy BMI	BMI* (kg/m ²) (WHO)	Total Weight Gain Range (lbs)	Rates of Weight Gain* 2nd and 3rd Trimester (Mean Range in lbs/wk)
Underweight	<18.5	28–40	1 (1–1.3)
Normal weight	18.5–24.9	25–35	1 (0.8–1)
Overweight	25.0–29.9	15–25	0.6 (0.5–0.7)
Obese (includes all classes)	≥30.0	11–20	0.5 (0.4–0.6)

Lyra will hand out guidelines.

15. If you knew these guidelines, do you think you would be more conscious of pregnancy-related weight gain?

Probe: Knowledge lead to change?

Probe: Guidelines realistic? Why or why not?

16. Many women say that they do not get advice on pregnancy-related weight gain from their health care providers. How many of you had your healthcare provider talk to you about pregnancy-related weight gain? What kinds of information did they give you?

Probe: Was this information helpful? Why or why not?

17. Do you/did you get weighed at each of your pregnancy-related check-ups? Do you/did you track your weight at home during your pregnancy? How important is it to you to track your weight gain during pregnancy?
18. Do you think the *SmartMoms Canada* app will help keep women's weight gain within the guidelines? Has this experience made you more aware of the importance of adhering to these guidelines?
19. Has your healthcare provider spoken to you about diet, physical activity or sleep during pregnancy?
20. Have you heard about "eating for two" during pregnancy? Do you think this is an accurate statement? Why or why not?
21. Do you feel that the *SmartMoms Canada* app has made you more aware of your diet and nutritional guidelines during pregnancy?

Anything else?

5 minutes

22. Do you want to mention anything else about the *SmartMoms Canada* app that we haven't already discussed?

Thank for participating. Ask to see Lyra on the way out to complete a short questionnaire and sign for receipt of \$10 card on the way out.

FOCUS GROUP QUESTIONNAIRE

Thank you very much for taking the time to be part of our SmartMoms focus group. Please circle one response to each question.

1. For your current pregnancy and/or past pregnancy, what sources of information do/did you use most often for your prenatal care? Please check all that apply.
 - Healthcare provider (obstetrician/gynaecologist, family doctor, midwife, nurse/nurse practitioner)
 - Family member(s)
 - Friends
 - Significant other/partner
 - Media/print sources/information from Internet (name website(s)) _____
2. How important is/was it for you to keep track of your weight gain during pregnancy?
 - 1 – Not at all important
 - 2 – Somewhat important
 - 3 – Important
 - 4 – Very important
 - 5 - Not sure
3. How important is/was it for you to maintain a healthy diet during your pregnancy?
 - 1 – Not at all important
 - 2 – Somewhat important
 - 3 – Important
 - 4 – Very important
 - 5 - Not sure
4. How important is/was it for you to be physically active throughout your pregnancy?
 - 1 – Not at all important
 - 2 – Somewhat important
 - 3 – Important
 - 4 – Very important
 - 5 - Not sure
5. Based on your experience so far, how useful is the *SmartMoms Canada* app?
 - 1 – Not at all useful
 - 2 – Somewhat useful
 - 3 – Useful
 - 4 – Very useful
 - 5 – Not sure
6. How likely are you to use the *SmartMoms Canada* app for your entire pregnancy?
 - 1 – Not at all likely
 - 2 – Somewhat likely
 - 3 – Likely
 - 4 – Very likely
 - 5 – Not sure
7. How likely are you to recommend the *SmartMoms Canada* app to someone else who is pregnant?
 - 1 – Not at all likely
 - 2 – Somewhat likely
 - 3 – Likely
 - 4 – Very likely
 - 5 – Not sure

Thank you for taking the time to complete this questionnaire!