Associations between mindfulness, psychological health and aspects of cardiovascular function in pregnancy

Serena Mennitto

Department of Psychology

McGill University, Montreal, QC

October 14, 2022

A thesis submitted to McGill University in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Table of Contents

Abstract

Pregnancy is usually experienced as a meaningful part of life, though this transition can be a turbulent time. Research suggests that psychological distress during pregnancy can contribute to the development of medical conditions. Recently, mindfulness-based interventions (MBIs) have been studied for their potential role in mitigating psychological and physical health conditions in pregnancy. However, the relationships between trait mindfulness, the characteristic which these interventions purport to develop, and maternal physical and mental health remain unclear. In addition, most research on this topic has focused on evaluating long-term MBIs. Thus, the immediate effects of MBIs are not well-understood in this population. This dissertation consists of three studies which address the following objectives: (1) to examine the relationship between trait mindfulness and psychological and physical health in pregnancy, (2) to determine whether trait mindfulness is predictive of maternal blood pressure trajectories across pregnancy, and (3) to investigate the in-the-moment effects of an MBI on maternal heart rate, heart rate variability and mood.

The purpose of Study One was to investigate the relationship between trait mindfulness to health outcomes throughout pregnancy. 510 women who were recruited at obstetrics clinics completed the Mindful Awareness and Attention Scale (MAAS) in the first or early second trimester. Higher MAAS scores predicted lower perceived stress, depression, and pregnancy-related distress scores and less severe physical discomforts throughout pregnancy. Trait mindfulness did not predict the diagnosis of diabetes or high blood pressure. These results indicate that trait mindfulness is a predictor of subjective stress during pregnancy.

Study Two was conducted to address a key limitation in Study One, the use of a binary outcome measure as an index of blood pressure. In Study Two, we examined the potential relationship between trait mindfulness and blood pressure trajectories across pregnancy. Clinical blood pressure observations were obtained from 370 pregnant participants in the longitudinal study examined in Study One. Functional data analysis was used to smooth and quantify blood pressure curves. Functional regression analyses showed that trait mindfulness did not predict systolic nor diastolic blood pressure trajectories. Further research using a more inclusive measure of trait mindfulness or higher risk samples may lead to more nuanced results.

Study Three examined the immediate effects of a presumably mindfulness-enhancing body scan meditation on maternal heart rate, heart rate variability (HRV), and mood, with particular attention to the moderating effects of trait mindfulness. It is possible that the effects of mindfulness on cardiovascular activity in pregnancy are more acute. 43 pregnant women participated in two sessions one week apart, where they were asked to follow a guided meditation recording or listen to an audiobook. Both the audiobook and the meditation increased high frequency HRV temporarily. Such activities may have cardiovascular benefits in women already predisposed to mindfulness, as these women experienced greater decreases in low frequency HRV and greater increases in high frequency HRV. In contrast, less mindful women experienced a greater decrease in negative affect, though the more mindful women reported less emotional distress overall. Heart rate was reduced to a greater degree by the meditation than the audiobook. These results suggest that MBIs may have beneficial effects on maternal health in pregnancy.

In the general discussion, issues related to the measurement of trait mindfulness and the study of maternal health are discussed. Directions for future research are proposed. Taken

together, this dissertation contributes to knowledge on how mindfulness might exert some influence on maternal cardiovascular and psychological health across pregnancy.

Résumé

La grossesse peut être une période importante et mouvementée. La détresse psychologique pendant la grossesse peut contribuer au développement de conditions médicales. Les interventions basées sur la pleine conscience (IBPC) ont été étudiées pour leur rôle potentiel dans l'atténuation des problèmes de santé pendant la grossesse. Cependant, les relations entre la pleine conscience dispositionnelle et la santé de la mère restent floues. De plus, la plupart des recherches sur ce sujet se sont concentrées sur l'évaluation des IBPC à long terme. Les effets immédiats des IBPC ne sont pas bien compris dans cette population. Cette thèse se compose de trois études qui répondent aux objectifs suivants : (1) examiner la relation entre la pleine conscience dispositionnelle et la santé psychologique et physique pendant la grossesse, (2) déterminer si la pleine conscience dispositionnelle prédit les trajectoires de la pression artérielle maternelle, et (3) étudier les effets instantanés d'une IBPC sur la fréquence cardiaque, la variabilité de la fréquence cardiaque et l'humeur.

La première étude a examiné la relation entre la pleine conscience dispositionnelle et la santé pendant la grossesse. 510 femmes recrutées dans des cliniques d'obstétrique ont rempli le Mindful Attention Awareness Scale (MAAS) au cours du premier ou au début du deuxième trimestre. Des scores MAAS plus élevés prédisaient des scores de stress perçu, de dépression et de détresse liés à la grossesse plus faibles et des inconforts physiques moins graves tout au long de la grossesse. La pleine conscience n'a pas prédit le diagnostic de diabète ou d'hypertension artérielle. Ces résultats indiquent que la pleine conscience est, au minimum, un prédicteur du stress subjectif pendant la grossesse.

La deuxième étude a remédié à une limitation clé de la première étude, l'utilisation d'un indice de la pression artérielle binaire. Nous avons examiné la relation entre la pleine conscience

dispositionnelle et les trajectoires de la pression artérielle pendant la grossesse. Des observations de la pression artérielle ont été obtenues auprès de 370 participantes enceintes. Les analyses de régression fonctionnelle ont montré que la pleine conscience ne prédisait pas les trajectoires de pression artérielle systolique ou diastolique. Des recherches utilisant une mesure plus inclusive de la pleine conscience ou des échantillons à risque plus élevé pourraient produire des résultats plus nuancés.

La troisième étude a examiné les effets immédiats d'une méditation sur la fréquence cardiaque, la variabilité de la fréquence cardiaque (VRC) et l'humeur, et les effets modérateurs de la pleine conscience. Il est possible que les effets de la pleine conscience sur l'activité cardiovasculaire soient plus aigus. 43 femmes enceintes ont participé à deux séances, où elles ont suivi une méditation guidée ou écouté un livre audio. Le livre audio et la méditation ont augmenté la VRC à haute fréquence. Ces activités peuvent avoir des avantages cardiovasculaires chez les femmes prédisposées à la pleine conscience, car ces femmes ont connu des diminutions plus importantes du VRC à basse fréquence et des augmentations plus importantes du VRC à haute fréquence. Les femmes moins conscientes ont connu une plus grande diminution de l’humeur négative, bien que les femmes les plus conscientes aient signalé moins de détresse émotionnelle. La fréquence cardiaque a été réduite davantage par la méditation que par le livre audio. Ces résultats suggèrent que les IBPC peuvent avoir des effets bénéfiques sur la santé maternelle pendant la grossesse.

Dans la discussion générale, les questions liées à la mesure de la pleine conscience et à l'étude de la santé maternelle sont discutées. Des pistes de recherches futures sont proposées. Dans l'ensemble, cette thèse démontre que la pleine conscience pourrait exercer une influence sur la santé cardiovasculaire et psychologique de la mère pendant la grossesse.

Acknowledgements

This research has been conducted at McGill University and affiliated hospitals. I would first like to acknowledge that McGill is situated on land which has long served as a site of meeting and exchange amongst Indigenous peoples, including the Haudenosaunee and Anishinabeg nations.

I am fortunate to have had many mentors throughout this doctoral journey, though there is no one to whom I owe more thanks than my supervisor Dr. Blaine Ditto. Thank you for your supervision, guidance, and unwavering presence as I made my way along my clinical and research paths. I would also like to thank my advisory committee members, Drs. Baerbel Knauper and Anna Weinberg, for their help and guidance. Thank you to my co-authors, Drs. Deborah Da Costa, Kristin Horsley and James Ramsay. Without you, this work would not have been possible.

To my clinical supervisors, Drs. Jonathan Keeley, Karen McGrath, Danit Nitka, David Sinyor, Debbie Sookman, Molly Moroz and Alissa Rubinfeld: you have had a tremendous impact on the way I think about the practice and study of clinical psychology.

I am grateful to have worked with my fellow labmates, Dr. Kristin Horsley, Monica Vaillancourt and Corrine Sejourne. Thank you for your support! I would like to acknowledge the work of the undergraduate students I have worked with over the past five years; I have grown from the experience of mentoring you as well. I would like to thank the administrative support staff in the Department of Psychology at McGill, Chantale Bousquet, Giovanna Locascio, Antonia Di Paolo, and Nina Pinzarrone for their guidance as I made my way through the Clinical Psychology Program.

Thank you to my family: my parents Joe and Toni, my brother Danny and my stepfather Larry, for never letting me forget that I can accomplish whatever I set my mind to! To my fiancé, Mitch: you have been a part of my life for most of this journey, and I strive to be as creative, thoughtful and discerning in my work as you are! Thank you for your endless support, kindness and patience as I prepared this dissertation and my future career.

I would also like to acknowledge that the Fonds de Recherche du Québec Santé provided financial support for this work through master's and doctoral training awards.

Contribution to Original Knowledge

The present dissertation is composed of three studies which contribute to the literature on the associations between mindfulness and maternal psychological and cardiovascular health during pregnancy.

Study One investigated the potential relationship between trait mindfulness assessed early in pregnancy with maternal psychological and physical health outcomes throughout gestation. Regression analyses showed that higher scores on the Mindful Attention Awareness Scale (MAAS) in the first or early second trimester predicted lower scores on the Perceived Stress Scale (PSS), Edinburgh Postnatal Depression Scale (EPDS) and Prenatal Distress Questionnaire-revised (PDQR), as well as less severe physical symptoms across all trimesters. MAAS scores were a stronger predictor of PSS scores earlier in pregnancy. Logistic regressions found that trait mindfulness did not predict the presence of physical discomforts, gestational diabetes, or high blood pressure. These results suggest that trait mindfulness is an important predictor of subjective stress, depression, anxiety and the severity of physical discomforts during pregnancy. These findings also suggest that interventions earlier in pregnancy may increase the impact of mindfulness on maternal health.

Study Two was designed to address a key limitation in Study One, the use of a binary, self-reported outcome measure as an index of maternal blood pressure. In Study Two, we examined the potential relationship between trait mindfulness and blood pressure trajectories across pregnancy using functional data analysis, a promising yet underutilized statistical procedure in the psychological sciences. Clinical blood pressure observations were obtained from the participants in the longitudinal cohort study examined in Study One. Functional regression analyses showed that trait mindfulness as measured with the MAAS did not

significantly predict systolic nor diastolic blood pressure trajectories across gestation. This finding was in line with the findings from Study One. Further research using a more inclusive measure of trait mindfulness or higher risk samples may lead to more nuanced results. While no significant results involving mindfulness were observed, this study also made a significant methodological contribution demonstrating the feasibility of functional data analysis to examine predictors of blood pressure in pregnancy.

Study Three built upon the first two studies by examining the immediate effects of a presumably mindfulness-enhancing body scan meditation on maternal heart rate, heart rate variability (HRV), and mood, with particular attention to the moderating effects of trait mindfulness. It is possible that the effects of mindfulness on cardiovascular activity in pregnancy are more acute, but still potentially important. Participants attended virtual two laboratory sessions approximately one week apart, where they were asked to follow a guided meditation recording or to listen to an audiobook. Trait mindfulness was assessed using the Five Facet Mindfulness Questionnaire (FFMQ), a more inclusive measure of trait mindfulness. Both practices increased high frequency HRV related to vagal activity. Trait mindfulness was found to be a significant moderator of response to the practices, such that more mindful women benefitted more from the practices in terms of cardiovascular outcomes, while less mindful women experienced greater reductions in negative affect during both activities. As well, though this was not significantly moderated by trait mindfulness, heart rate was reduced to a significantly greater degree by the mindfulness exercise than the audiobook. These results suggest that mindfulness-based practices may exert beneficial effects on maternal health in pregnancy, though further study in more diverse, higher risk populations is recommended. As well, the results were useful in terms of suggesting hypotheses for future research about causal mechanisms.

Apart from these three studies, this dissertation synthesizes and presents an overview of the current literature on mindfulness and health during pregnancy, underlines the importance of studying mindfulness in the pregnant population, and discusses issues related to the measurement and study of mindfulness.

Contribution of Authors

The present dissertation is comprised of three distinct manuscripts which represent the work I undertook as a doctoral student under the supervision of Dr. Blaine Ditto and in collaboration with many colleagues at McGill University.

The first and second manuscripts were prepared using data collected as part of the Healthy Behaviours in Pregnancy and Postpartum Study, which was led by Dr. Deborah Da Costa, affiliated with the Department of Epidemiology at the Research Institute of the McGill University Health Center. Funding for the project was secured by Dr. Da Costa from the Canadian Institutes of Health Research (grant #247035). She was responsible for study design, conceptualization, and preparation of the self-report questionnaire data for analysis. Participants were recruited by her research team at two McGill University-affiliated hospitals in Montreal, Quebec, Canada. Rebecca Wickett was responsible for the extraction of blood pressure data from participants' medical charts and for data entry.

For Study One, I determined my research questions and hypotheses, performed data analysis and was involved in all aspects of manuscript preparation. Drs. Ditto and Da Costa provided guidance with regards to data analysis and manuscript preparation. They were involved in the editing of the manuscript and provided support throughout the peer review process leading to the publication of the manuscript in the *Journal of Psychosomatic Obstetrics and Gynecology.*

For Study Two, I also determined my research questions and hypotheses, performed data analysis and was involved in all aspects of manuscript preparation. Dr. Kristin Horsley, then a graduate student also under Dr. Ditto's supervision, was responsible for data preparation and cleaning. She provided countless hours of practical support with the statistical analysis process.

Dr. Jim Ramsay, Professor Emeritus in the Department of Psychology at McGill University, provided statistical consultation and support for data analysis. Dr. Blaine Ditto provided invaluable guidance with regards to manuscript preparation, writing and editing.

For Study 3, I was responsible for study conceptualization, research proposal preparation and submission to the McGill University Ethics Review Board, data collection, data cleaning and preparation, statistical analysis and visualization, as well as the preparation and writing of the manuscript. Two undergraduate Honours students and two undergraduate volunteers were involved in study recruitment and data collection. Dr. Ditto provided significant support with study conceptualization, data analysis, manuscript preparation and editing. This study was financially supported by the G. W. Stairs Fund.

List of Tables

Manuscript One

Manuscript Two

Manuscript Three

List of Figures

Manuscript One

Manuscript Two

Manuscript Three

List of Abbreviations

BMI	Body mass index
CALM	Coping with Anxiety through Living Mindfully program
CAMS-R	Cognitive and Affective Mindfulness Scale-Revised
DBP	Diastolic blood pressure
EPDS	Edinburgh Postnatal Depression Scale
FFMQ	Five Facet Mindfulness Questionnaire
GCV	Generalized cross-validation criterion
HFnu	High frequency heart rate variability in normalized units
HR	Heart rate
HRV	Heart rate variability
LFnu	Low frequency heart rate variability in normalized units
LGBTQ2S+	Lesbian, gay, bisexual, transgender, queer/questioning, two-spirited
MAAS	Mindful Attention Awareness Scale
MBI	Mindfulness-based intervention
MBCT	Mindfulness-based cognitive therapy
MBSR	Mindfulness-based stress reduction
nu	Normalized units
PANAS	Positive and Negative Affect Schedule
PDQR	Prenatal Distress Questionnaire-revised
PSS	Perceived Stress Scale
SBP	Systolic blood pressure
TMS	Toronto Mindfulness Scale

General Introduction

Pregnancy is often touted as a wonderful time in a woman's life as she prepares to become a mother. In general, though it can also be a turbulent transition, people experience parenthood as a meaningful part of life and an opportunity for growth. Indeed, parenthood involves varying degrees of stress and rewards for those who pursue it (Umberson, Pudrovska, & Reczek, 2010). During pregnancy, women can be confronted with numerous practical sources of stress, including doctor's appointments, lifestyle changes, and worries about how their loved ones will react to the new addition to the family. They may also develop medical complications during pregnancy, such as gestational hypertension or diabetes, which can put the lives of both mother and child in danger. There is ample evidence that psychological distress and poor perinatal mental health can contribute to the development of medical conditions and poor birth outcomes (S. Zhang et al., 2013; Staneva, Bogossian, Pritchard & Wittkowski, 2015). Cardiovascular and mental health conditions can persist into the postnatal period as well, which has made the development and investigation of potential interventions critical.

Mindfulness-based interventions have been proposed as a potential treatment for both maternal mental health and cardiovascular difficulties in the perinatal period. Research on associations between mindfulness and mental and cardiovascular health in the non-pregnant population is promising. Preliminary evidence has emerged on the efficacy of various programs in pregnancy in the past two decades. However, there is little research on the potential relationship between trait mindfulness, the characteristic that these interventions purport to develop, and maternal cardiovascular and mental health outcomes. In addition, pregnancy is a time when the body adapts to the presence and growth of the fetus moment-to-moment. There exists an important gap in the literature regarding the in-the-moment effects of mindfulness-

based interventions and meditations on physical and mental health in pregnant people. These are questions which will be examined in this dissertation.

This dissertation begins with a review of the current literature relevant to these lingering questions. First, a general review of the body's cardiovascular adaptations to pregnancy, perinatal mental health, and the problems that may arise in these areas during pregnancy is presented. Second, definitions of the concepts of state and trait mindfulness will be discussed. Then, the previously examined effects of mindfulness-based interventions and trait mindfulness on maternal mental and physical health, as well as on birth outcomes, will be reported. Finally, there will be a critical analysis of the current state of the literature and common limitations in the study of mindfulness in the perinatal period.

Cardiovascular complications, perinatal mental health and birth outcomes

In healthy pregnancies, the body undergoes a series of changes to adapt to the presence of the fetus. For example, blood volume increases by 45%. Stroke volume and heart rate also increase. Collectively, these changes lead to cardiac output increasing by 30 to 50%. The largest increases in blood flow are to the uterus, kidneys, breasts and skin (de Weerth & Buitelaar, 2005). Despite the increase in cardiac output, because of a decrease in systemic vascular resistance, there is generally an initial drop in blood pressure at the beginning of pregnancy, which rises to pre-pregnancy levels toward the end of term (Christian, 2012). In healthy pregnancies, there is also evidence that, while heart rate variability drops, blood pressure variability increases throughout gestation (Garg et al., 2020). Some women do not experience a decrease in blood pressure in the first trimester, but rather show increases in blood pressure. This increase is predictive of several problems, the most worrisome being preeclampsia, a multi-organ disease characterized by hypertension, proteinuria and edema in the hands and feet, which poses

risk to the health of both mother and fetus, including death (Mammaro et al., 2009). In healthy women, the influence of the circadian rhythm on blood pressure is observed, as blood pressure drops during sleep at night. Women with preeclampsia are non-dippers. They have higher blood pressures in the day and at night, experiencing an attenuated decrease during nighttime (de Weerth & Buitelaar, 2005). Preeclampsia has also been found to be related to decreased heart rate variability in pregnancy, though there remains significant variability in the methods and results of investigations on this topic (Moors et al., 2020). Preeclampsia and other hypertensive disorders are associated with risk of maternal death as well as poorer birth outcomes, with complication rates directly linked to the severity and duration of abnormally high blood pressure levels (de Weerth & Buitelaar, 2005). For example, in one study it was found that a 1 mmHg increase in blood pressure above the mean is associated with a decrease of 80g in birth weight (McCubbin et al., 1996). Adverse long-term effects have also been studied in mothers. Women who were diagnosed with hypertensive disorders during pregnancy tend to have reduced lifespans and a higher risk of developing non-pregnancy-related hypertension later in life than women who did not receive that diagnosis (Craici, Wagner, & Garovic, 2008). It has also been found that preeclampsia continued to be associated with an increased risk of coronary heart disease, heart failure, and stroke post-pregnancy after adjusting for age, body mass index and a diagnosis of diabetes (Wu et al., 2017).

In healthy pregnancies, a protective adaptation of the stress response also occurs. Interestingly, this is not limited to the cardiovascular system. On average, healthy women have attenuated stress reactivity, as measured by cortisol, catecholamine and blood pressure responses to physical and psychological stressors (Christian, 2012). Cardiovascular and neuroendocrine reactivity to acute stress are predictive of health outcomes in non-pregnant populations.

Preliminary evidence suggests that, in pregnant women, the magnitude of physiological stress responses is associated with higher risk for hypertensive disorders (Woisetschläger et al., 2000) and depression (Nierop et al., 2006). Women with exaggerated patterns of physiological reactivity are more likely to deliver preterm (Christian, 2012). Women who respond with higher reactivity and slower physiological recovery from stressors are more at risk for adverse outcomes (de Weerth & Buitelaar, 2005). Due to the ways in which the pregnant body adapts, essentially leading to a metabolic syndrome with the potential to induce endothelial dysfunction persisting in the postnatal period, pregnancy has been referred to as a "stress test for life" (Williams, 2003).

Psychological stress has also been related to obstetric complications and the development of hypertensive disorders in pregnancy, but the definition of psychological stress has varied across studies (S. Zhang et al., 2013). Some researchers have focused on the roles of anxiety and depressive symptoms, which have been linked to the development of hypertensive disorders in pregnancy (Qiu, Williams, Calderon-Margalit, Cripe, & Sorensen, 2009). It seems that elevated levels of depression and anxiety during pregnancy predict birth outcomes, fetal outcomes and neonatal well-being independently of other medical risk factors (Alder, Fink, Bitzer, Hösli, & Holzgreve, 2007). For example, in one sample, 30% of women who met criteria for a depressive or anxiety disorder during their pregnancy had children with birth weights lower than the 10^{th} percentile for gestational age (Maina et al., 2008). This research was conducted in women without medical complications, as women with diseases like preeclampsia were excluded from the study (Maina et al., 2008). Other researchers have found decreased fetal growth and increased likelihood of preterm birth in newborns whose mothers had a diagnosis of depression (Hoffman & Hatch, 2000; Orr, James, & Blackmore Prince, 2002). Prenatal anxiety has also been linked to lower Apgar scores in newborns (Berle et al., 2005). The associations between

psychological distress, cardiovascular reactivity, cardiovascular complications and birth outcomes are unclear but seem to be pointing in the same direction.

In sum, while pregnancy may be a time of joy and anticipation for many women, it may be a more precarious time for others. Mindfulness-based interventions have been proposed as a potential solution to the issues described above, hypertension, stress reactivity, psychological stress, depression and anxiety, during pregnancy. Although not associated exclusively with Eastern philosophical and religious traditions such as Buddhism and Hinduism, the importance of mindfulness is especially strong in these areas and has contributed to the development of Western secular applications. Mindfulness may be especially useful for pregnant women, as it is an intervention that does not require women to take medications, which they are often reluctant to take during the perinatal period, or to make active behavioural change (Dimidjian et al., 2016). The approach is considered to be well-suited to address problems related to maternal depression and anxiety such as rumination (Hawley et al., 2014) and poor self-esteem (Pepping, O'Donovan, & Davis, 2013).

Definitions of Mindfulness

There are many competing definitions of mindfulness in the literature, which has complicated the synthesis and comparison of results across studies. There exist definitions based in traditional Eastern philosophy, as well as in contemporary Western thinking. Evidence has emerged that these concepts can be distinct from one another (Siegling & Petrides, 2014). The most commonly cited definition, based on Eastern tradition, is that of Kabat-Zinn, a pioneer in medicine-based mindfulness research. He defines mindfulness as "paying attention in a particular way: on purpose, in the present moment, and non-judgmentally" (Kabat-Zinn, 2006). Later, Kabat-Zinn (2009) also noted in an optimistic manner that "mindfulness is the aim, the methods

or practices, and the outcome or consequences all wrapped up together", though this could be viewed as a further complication of the problem of definition. For the purposes of this dissertation, we will consider two types of mindfulness, state and trait mindfulness, with definitions based in Eastern philosophy.

State mindfulness has been described as an active process through which attention is maintained on immediate experience in a spirit of curiosity and nonjudgment toward the self. Bishop and colleagues have proposed a model based on two components: the "self-regulation of attention", involving sustained attention, attention switching and the inhibition of elaborative processing, and "orientation to experience", which involves remaining open to gain insight about the subjectivity and transient nature of thoughts (Bishop et al., 2006). Mindfulness meditation is one common method to access mindful states. Many mindfulness guides also suggest that one can conduct any activity mindfully, including everyday tasks such as washing the dishes or walking (e.g., Harris & Hayes, 2019). To date, state mindfulness is assessed by self-report, using measures such as the Toronto Mindfulness Scale (Lau et al., 2006) or the Freiburg Mindfulness Inventory (Walach et al., 2006).

Trait mindfulness is described as a person's general tendency to enter mindful states in their everyday experience (Baer et al., 2008). Trait mindfulness is also assessed by self-report, though there is significantly more heterogeneity in the measurement of this construct than in the measurement of state mindfulness. There are six common scales which assess the Eastern conceptualization of trait mindfulness, which have poor to strong convergent validity. Various factor structures of trait mindfulness have been found. Some view it as a unitary construct (e.g., Chadwick et al., 2008), while others consider there to be multiple sub-facets of the trait (e.g., Baer et al., 2008; Cardaciotto et al., 2008). In their investigation of the dominant mindfulness

measures, Bergomi et al. (2013) identified nine sub-aspects of trait mindfulness which are present across the scales. These are: observing or attending to one's experiences, acting with awareness, non-judgment and acceptance of one's experiences, self-acceptance, willingness and readiness to expose oneself to experiences, non-reactivity, non-identification with experiences, insightful understanding and describing or labeling experiences (Bergomi et al., 2013).

Types of Mindfulness-Based Interventions

The most widely known mindfulness-based interventions are Mindfulness-Based Stress Reduction (MBSR) and Mindfulness-Based Cognitive Therapy (MBCT). MBSR is an 8 to 10-week program originally developed by Kabat-Zinn for the treatment of chronic pain and psychological stress that involves meditation to cultivate mindfulness (Kabat-Zinn, 1982; Kabat-Zinn, 2013). MBSR has been studied extensively in populations with chronic conditions such as pain, cancer, heart disease, depression and anxiety (e.g., Campbell et al., 2012; Schmidt et al., 2012; Alsubaie et al., 2017; Greeson et al., 2015). One review concluded that MBSR was effective in increasing psychological and functional quality of life, as well as reducing depressive and anxious symptomatology in people with these disorders (Grossman, Niemann, Schmidt, & Walach, 2004). Practices from MBSR and cognitive behavioural therapy were combined by Segal, Williams and Teasdale in the development of MBCT, whose primary aim is to reduce the risk of relapse in major depressive disorder (Segal, Williams, & Teasdale, 2013). This group therapy approach involves attentional control training, or teaching the patient to become more aware. Using a combination of mindful movement sequences and cognitive restructuring techniques, patients reduce rumination and decenter from the automatic thoughts, feelings and physical sensations that can lead to relapse of the disorder. Cognitive techniques are then used to target the negative thought patterns present in depression (Segal et al., 2013). In a pilot study of

MBCT, it was found that, in patients with at least three previous episodes of depression, rate of relapse in the MCBT group was half that of a treatment as usual group at a 60-week follow-up (Teasdale et al., 2000). Proposed mechanisms for the effects of MBCT include increased mindfulness, self-compassion and meta-awareness, as well as decreased worry and rumination (van der Velden et al., 2015).

Other mind-body interventions include mindful or integrative yoga, body scan meditation, transcendental meditation, guided imagery, relaxation training and progressive muscle relaxation. It is important to note that mindfulness-based interventions are not relaxation techniques per se. They must involve "mental training to reduce cognitive vulnerability" (Bishop et al., 2006).

In recent years, studies about the physiological mechanisms behind the effectiveness of mindfulness-based interventions have begun to emerge. Much of this research has focused on cardiovascular function. Nyklíček et al. (2013) found an effect of MBSR on blood pressure in a laboratory stress protocol. Participants completed mental arithmetic and speech tasks prior to beginning a two-month MBSR program and after it had ended. The researchers observed a larger decrease in resting blood pressure, as well as decreased blood pressure reactivity to stress, in the mindfulness condition than in the wait-list control group (Nyklíček, Mommersteeg, Van Beugen, Ramakers, & Van Boxtel, 2013). Steinhubl and colleagues (2015) studied the immediate physiological responses to meditation during a meditation retreat. Mean arterial blood pressure fell on average by 2-3 mmHg while meditating, a change that was most prominent in novice meditators. Using measures of heart rate variability during meditation and controlled respiration, Nijjar et al. (2014) determined that meditation improved autonomic balance by reducing sympathetic influence and increasing parasympathetic influence. Another study examined the

effects of meditation on respiratory sinus arrhythmia, or heart rate variability in synchrony with respiration, a measure of cardiac vagal tone. Meditation was associated with greater increases in respiratory sinus arrhythmia than was listening to a relaxing audiobook (Ditto, Eclache, & Goldman, 2006). In this study, gender differences emerged, whereby women experienced greater decreases in diastolic blood pressure during meditation than did men (Ditto et al., 2006).

Mindfulness-based interventions in pregnancy

While the results in non-pregnant populations are promising, it remains necessary to determine the effectiveness of these types of interventions specifically in pregnant women. As Christian (2012) noted, women in later stages of pregnancy show blunted physiological responses to stress, an effect which could extend to responses to mind-body interventions. There may be a subgroup of women who do not experience these blunted responses, who could be more at risk for adverse outcomes like HDP or infant and maternal death. A number of mindfulness-based programs have been adapted from MBSR and MBCT to address pregnancy-related mental and physical health concerns in the hopes of reducing psychopathology and rates of adverse birth outcomes. Most research has examined the effects of these types of interventions on mental health in pregnancy, while little work has been published on physiological mechanisms thus far.

Effects on perinatal mental health and psychological functioning

Much of the literature on perinatal mental health has focused on the reduction of depressive symptomatology in women at risk for the recurrence of mental illness during their pregnancy. Muzik et al. (2012) tested the effects of mindful yoga on mothers' depression and attachment to the fetus. The results of their pilot feasibility study showed that mindful yoga was

associated with a decrease in depressive symptoms and higher self-reported maternal-fetal attachment (Muzik, Hamilton, Lisa Rosenblum, Waxler, & Hadi, 2012). One group of researchers offered an online, web-based intervention to women at risk for depressive relapse during their pregnancy. This included videos from an in-person group session, weekly phone-coaching sessions, audio-guided practice and home practice. Over the course of treatment, there was no increase in depressive symptoms (Felder et al., 2017). MindBabyBody, a program incorporating mindful movement sequences, meditation and cognitive exercises, reduced depression and anxiety in high-risk women in a two-month-long open trial (Woolhouse, Mercuri, Judd, & Brown, 2014). Mindfulness increased over time as women participated in the program (Woolhouse et al., 2014). Several other studies have found similar results in terms of depressive symptom reduction in at-risk women (Dimidjian et al., 2016; Dunn, Hanieh, Roberts, & Powrie, 2012). In addition, others have also found some evidence to support the effectiveness of mind-body interventions during pregnancy for depressive symptoms in non-clinical populations (Beattie, Hall, Biro, East, & Lau, 2017; Duncan et al., 2017; Vieten & Astin, 2008). One study failed to find a difference in depressive symptomatology between the intervention and control group (Perez-Blasco, Viguer, & Rodrigo, 2013). In another, depressive symptoms were reduced in the treatment group at the end of the intervention, but the decrease was not maintained long-term (H. Zhang & Emory, 2015).

Another recent prospective study examined the relationship between dispositional mindfulness and pregnancy outcomes, including maternal depression in late pregnancy, gestational age and birth weight. It was found that the non-judging aspect of mindfulness predicted depressive symptomatology at 32 weeks of pregnancy when controlling for baseline

depressive symptoms. In addition, the non-reacting facet predicted normal birth weight (Nyklíček et al., 2018).

Another common outcome variable in research on this topic is anxiety in mothers-to-be, as its association with adverse birth outcomes has been well-documented (Alder et al., 2007). Several different programs have been created to address anxiety during pregnancy. One such program is the Mindful Motherhood program developed by Vieten and Astin (2008). Based on principles of MBSR, MBCT and acceptance and commitment therapy, the program consists of three approaches to developing mindfulness: breath awareness, body awareness meditation, and the presentation of concepts related to mindfulness such as acceptance (Vieten & Astin, 2008). Participants in the mindfulness group reported a greater decrease in state anxiety and negative affect than did participants in the wait-list control group, but these differences were no longer significant at a three-month follow-up (Vieten & Astin, 2008). More recently, Goodman and colleagues (2014) have developed the "Coping with Anxiety through Living Mindfully" (CALM) program, inspired by MBCT, MBSR, theories of self-compassion and the mindfulness-based anxiety treatments used in non-pregnant populations. In their pilot study, they observed that the majority of women who had met criteria for generalized anxiety disorder at baseline no longer qualified for the diagnosis after 8 weeks of the CALM program. Participants reported that they had experienced cognitive changes during the program, had developed insight into the development of their anxiety and had learned skills to cope with anxious thoughts as they arise (Goodman et al., 2014). Another group observed a decrease in anxiety after participation in a mindfulness training group or a reading group. Both of these interventions were found to increase trait mindfulness (Guardino, Dunkel Schetter, Bower, Lu, & Smalley, 2014). Other research has yielded similar findings that mindfulness-based interventions can lead to lower

anxiety levels in the mother (Perez-Blasco et al., 2013; Townshend, Caltabiano, Powrie & O'Grady, 2018).

Mindfulness-based childbirth preparation courses have been offered for a number of years. Their goals are to promote maternal satisfaction with childbirth, to increase communication and decision-making skills and to provide information about the birthing process in order to enhance mothers' ability to feel involved in the process (Fisher, Hauck, Bayes, & Byrne, 2012). These types of programs have been found to improve mothers' childbirth-related appraisals, childbirth self-efficacy and to decrease fear of childbirth (Byrne, Hauck, Fisher, Bayes, & Schutze, 2014; Duncan et al., 2017; Fisher et al., 2012).

While few have examined this so far, it appears that mindfulness-based programs may also lead to improvements in mood and life satisfaction in pregnant women (Guardino et al., 2014; Matvienko-Sikar & Dockray, 2017).

Effects on pregnancy outcomes and physiological function

While most research on the effectiveness of mindfulness interventions in pregnancy has focused on perinatal mental health outcomes, some studies have explored their impact on complications during pregnancy and birth. In a prospective observational design, Narendran and colleagues (2005) compared birth outcomes for women practicing a daily, one hour-long prenatal yoga program and those in an active control condition involving walking for the same length of time. They found higher birth weights and a lower rate of preterm birth in women in the yoga condition than in the control group (Narendran, Nagarathna, Narendran, Gunasheela, & Nagendra, 2005). They also found that intrauterine growth retardation and pregnancy-induced hypertension were less likely to occur in the yoga group than in the walking control group

(Narendran et al., 2005). Similarly, in a sample of Iranian women, a relaxation education program was found to reduce rates of low birth weight as compared to prenatal care as usual (Bastani, Hidarnia, Montgomery, Aguilar-Vafaei, & Kazemnejad, 2006). However, there was no difference between the relaxation group and control group for risk of preterm birth in this sample. During the birth process, women in the experimental condition were less likely to require a caesarean section or an instrumental extraction (Bastani et al., 2006). In another study, a trend toward lower analgesia use in labor was found in participants of the Mind in Labor course, an intensive prenatal preparation course with a strong mind-body component (Duncan et al., 2017). These women did not report lower childbirth-related pain ratings than women who had participated in a standard preparation course. The authors concluded that it may be possible that mindfulness-enhancing techniques could be used instead of analgesia by some women during childbirth (Duncan et al., 2017). It has also been found that participants in a seven-week long Iyengar yoga and MBSR-based program, in their second trimester of pregnancy, experienced a decrease in pain levels from baseline to post-intervention and reported less pain interference in their daily life (Beddoe, Paul Yang, Kennedy, Weiss, & Lee, 2009).

Some evidence has emerged that dispositional mindfulness is related to sympathetic and parasympathetic cardiovascular activity during pregnancy. More mindful mothers were found to experience an attenuated decrease in parasympathetic activity, as measured by high frequency heart rate variability, as well as an attenuated increase in sympathetic activity, inferred through pre-ejection period, during pregnancy than less mindful mothers (Braeken, Jones, Otte, Nyklíček, & Van den Bergh, 2017). It has been hypothesized that interventions designed to increase mindfulness could have immediate and long-term physiological effects in pregnant women.

Other research has focused on the longitudinal effects of mindfulness-based treatments on physical health and physiological function. One study found that women who practiced relaxation therapy or a combination of biofeedback and relaxation therapy for 6 weeks during their pregnancy were less likely to be admitted to hospital and had lower blood pressure than women in a control group (Little et al., 1984). A recent study of a four-week long adapted version of the Mindful Motherhood program showed that women assigned to the intervention group had a reduced cortisol response to stress post-treatment (H. Zhang & Emory, 2015). It has been found that meditation during pregnancy can alter autonomic function. Muthukrishnan and colleagues (2016) found a decreased systolic blood pressure response to a mental arithmetic task and a decrease in blood pressure response to the cold pressor test in pregnant women who participated in a meditation group for five weeks early in pregnancy. They also observed an increase in resting heart rate variability, a measure which reflects parasympathetic tone (Muthukrishnan, Jain, Kohli, & Batra, 2016). These results are consistent with those of Satyapriya et al. (2009), who found an increase in high frequency heart rate variability in pregnant participants of a yoga and deep relaxation program (Satyapriya, Nagendra, Nagarathna, & Padmalatha, 2009).

Urech and colleagues (2010) conducted a randomized control trial comparing the in-the-moment effects of progressive muscle relaxation, guided imagery and a passive relaxation technique. Progressive muscle relaxation and guided imagery were associated with a decrease in heart rate from baseline, but there was no significant change in blood pressure pre- to post-intervention. All three groups experienced a decline in cortisol, norepinephrine and adrenocorticotropic hormone levels during the 10-minute exercise (Urech et al., 2010).

Summary

In conclusion, mindfulness-based interventions appear to be at least somewhat effective at improving women's perinatal mental and physical health. They may also have a positive impact on birth outcomes such as birth weight and gestational age at birth. There is evidence that trait mindfulness, presumably the trait that these interventions target, may be related to maternal depression, maternal cardiovascular health and birth outcomes.

However, many of the studies discussed in this review have significant methodological weaknesses which limit the generalizability of their findings, including small sample sizes and high attrition rate (e.g., Dunn et al., 2012; Woolhouse et al., 2014). Many of the samples included in this review have been non-representative of the general population. Firstly, the way that women are recruited to these studies results in self-selection bias. Secondly, several authors reported that their samples were composed primarily of white women in high-income families (e.g., Guardino et al., 2014). Further research is required to determine how to better adapt these interventions for minority populations, who may have different needs than predominantly white, older and higher income samples.

There is also a lack of active control groups in many studies, which makes it difficult to determine whether the observed effects are due to the intervention itself or the attention received by the participants from the clinicians administering the interventions. In the future, large, adequately powered randomized control trials with active control groups should be utilized to further investigate the effectiveness and potential mechanisms of action of mindfulness-based interventions.

Due to the fact that dispositional mindfulness was not measured in several studies, it is difficult to determine whether the trait itself moderates treatment outcomes and whether increases in this trait are a mediator of treatment effects on outcomes. In one study, the intervention increased scores on certain mindfulness dimensions of the Five Facet Mindfulness Questionnaire (FFMQ), such as Non-judgment and Non-reactivity to inner experience, but not others (Perez-Blasco et al., 2013). In a non-pregnant population, Cebolla et al. (2017) found an association between practice variables such as time spent meditating, type of meditation and different facets of mindfulness. For example, scores on the Non-judgment to inner experience facet of the FFMQ were predicted by frequency of practice for focused attention and open-monitoring meditation, but the Observing facet was only predicted by minutes spent in focused attention meditation (Cebolla et al., 2017). Taken together, these results suggest that different interventions may be targeting different aspects of mindfulness, which could explain discrepancies between results across studies. Other proposed mechanisms of change include decreases in rumination behaviour, decentering and increases in self-compassion (Dimidjian et al., 2016).

In addition, the mindfulness interventions used in pregnant populations have been adapted and modified from evidence-based treatments such as MBSR and MCBT in various ways. The use of such varied treatments of different durations complicates the comparison of results across studies. However, the availability of such a wide variety of potential treatments can also be viewed as a strength, as some approaches may be more successful for certain women than others. Further research is needed to examine individual differences in response to the many types of treatment that have been developed thus far.

Despite the limitations listed above, mindfulness-based interventions in pregnancy show promise in improving perinatal mental and physical health. They have been found to reduce the symptoms of anxiety and depression, and have led to improvements in physiological function of the heart and better birth outcomes. In addition, these interventions are cost-effective, feasible to implement and well-attended. Several researchers have collected qualitative data from participants, indicating that, overall, women enjoyed participating in the interventions. They reported that they had acquired new knowledge and skills, such as how to better take care of themselves and greater awareness of stress in the moment that it occurs (Beddoe et al., 2009; Goodman et al., 2014). Pregnant people have also reported reluctance to use medications such as selective serotonin reuptake inhibitors during pregnancy for fear of adversely affecting fetal development, but discontinuation of these medications has been linked to depressive relapse and recurrence in pregnancy (Dimidjian et al., 2016). It is thus essential that effective, non-pharmacological interventions be made available for this population and that their effects be better understood.

There have been a number of interventions designed specifically for the pregnant population. In general, the literature suggests that there are positive effects of mindfulness-promoting interventions in pregnancy, though with such variety in the interventions studied, the mechanisms of action of such programs remain methodologically and conceptually unclear. One possible alternative is to examine the relationship between mental and physical health outcomes with trait mindfulness, which these interventions intend to develop.

The Current Dissertation

The current work is comprised of three manuscripts which examine the associations between mindfulness, psychological health and aspects of cardiovascular function in pregnancy.

The goal of the first study was to examine the associations between trait mindfulness, as assessed with the Mindful Attention and Awareness Scale, with psychological and physical health outcomes throughout all three trimesters of pregnancy. The second study addressed a key limitation in the first study, the use of a binary self-report measure of cardiovascular health. Instead, the second study examined the potential relationship between trait mindfulness and maternal blood pressure trajectories across gestation. The goal of the third study was to investigate the in-the-moment effects of a brief, mindfulness-based body scan meditation on maternal mood, cardiovascular function and state mindfulness, with particular attention to whether trait mindfulness moderated the effects of the body scan. A general discussion of the findings will follow, paying particular attention to issues of definition and measurement in mindfulness research and to issues in the study of health in pregnancy.

Manuscript One:

The Relationship of Trait Mindfulness to Physical and Psychological Health During Pregnancy

*Serena Mennitto, BA[1], Blaine Ditto, PhD.[1], Deborah Da Costa, PhD.[2]

From the [1]Department of Psychology, Faculty of Science, McGill University, Montreal, Quebec, Canada, and the [2]Department of Medicine, Faculty of Medicine, McGill University, Montreal, Quebec, Canada.

Publication citation:

Mennitto, S., Ditto, B., & Da Costa, D. (2021). The relationship of trait mindfulness to physical and psychological health during pregnancy. *Journal of Psychosomatic Obstetrics and Gynecology*, *42*(4), 313–319. https://doi.org/10.1080/0167482X.2020.1761320

Abstract

Introduction: Research on mindfulness has extended to the prevention of psychopathology and physical conditions during pregnancy. The purpose of this study was to investigate the relationship between trait mindfulness assessed in the first or early second trimester to health outcomes throughout pregnancy.

Methods: 510 women were recruited at McGill University-affiliated obstetrics clinics (average gestational age: 13.43 weeks, sd=1.2). The Mindful Awareness and Attention Scale (MAAS) was administered at baseline. At three timepoints during pregnancy, participants completed the Perceived Stress Scale (PSS), the Edinburgh Postnatal Depression Scale (EPDS), the Prenatal Distress Questionnaire-revised (PDQR) and a measure of pregnancy symptom intensity and indicated whether they had been diagnosed with gestational diabetes or high blood pressure.

Results: Higher MAAS scores predicted lower PSS, EPDS and PDQR scores and less severe physical discomforts throughout pregnancy. MAAS scores were a stronger predictor of PSS scores earlier in pregnancy. Logistic regressions found that trait mindfulness did not predict the presence of physical discomforts, diabetes or high blood pressure.

Conclusions: These results indicate that trait mindfulness is an important predictor of subjective stress, depression, anxiety and the severity of physical discomforts during pregnancy. These findings suggest that interventions earlier in pregnancy may increase the impact of mindfulness on maternal health.

Introduction

Pregnancy is often touted as a joyous time in a woman's life as she prepares to become a mother. In Western societies, many people experience parenthood as a meaningful part of life and an opportunity for growth. However, parenthood also involves varying degrees of stress and rewards for those who pursue it (Umberson, Pudrovska, & Reczek, 2010). During pregnancy, women can be confronted with numerous sources of stress, including frequent doctor's appointments, lifestyle changes, and worries about how their loved ones will react to the new addition to the family. They may also develop medical complications during pregnancy, such as gestational hypertension or diabetes, which can adversely impact maternal and infant health. There is ample evidence that psychological distress and poor maternal mental health during pregnancy can contribute to the development of medical conditions and poor birth outcomes (Zhang et al., 2013; Staneva, Bogossian, Pritchard & Wittkowski, 2015).

While pregnancy may be a time of joy and anticipation for many women, it may be a more precarious time for others. Mindfulness-based interventions during pregnancy may have potential to optimize maternal psychological and physical health. Mindfulness has been described as a process through which attention is maintained on immediate experience in a spirit of curiosity and acceptance toward the self (Kabat-Zinn, 2006). Bishop and colleagues have proposed a model based on two components: the "self-regulation of attention", involving sustained attention, attention switching and the inhibition of elaborative processing, and "orientation to experience", which involves remaining open to gain insight about the subjectivity and transient nature of thoughts (Bishop et al., 2006). The purpose of the present investigation is to determine the relationship of dispositional mindfulness and maternal health during pregnancy.

Mindfulness-based training programs have been found to reduce the risk for maternal depression in high-risk mothers (Muzik, Hamilton, Lisa Rosenblum, Waxler, & Hadi, 2012; Woolhouse, Mercuri, Judd, & Brown, 2014; Dimidjian et al., 2016; Townshend, Caltabiano, Powrie & O'Grady, 2018), as well as in non-clinical pregnant populations (Beattie, Hall, Biro, East, & Lau, 2017; Duncan et al., 2017). Similar results have been found in evaluating programs' effectiveness for the prevention of perinatal anxiety. For example, in a pilot study of the "Coping with Anxiety through Living Mindfully" (CALM) program, the authors observed that the majority of women who had met criteria for generalized anxiety disorder at baseline no longer qualified for the diagnosis after 8 weeks (Goodman et al., 2014). More recently, Townshend and colleagues (2018) found that the "Caring for Body and Mind in Pregnancy Program" reduced anxiety and pregnancy-related anxiety in a sample of women at high risk for perinatal depression. Mindfulness-based yoga has also been shown to reduce the risk for gestational hypertension (Narendran, Nagarathna, Narendran, Gunasheela, & Nagendra, 2005).

However, while many of these interventions have shown promise, little research has been conducted on the relation of the trait these interventions purport to develop, mindfulness, to maternal health in pregnancy. Some evidence has emerged that dispositional mindfulness is related to sympathetic and parasympathetic cardiovascular activity during pregnancy. More mindful mothers experience an attenuated decrease in parasympathetic activity, as well as an attenuated increase in sympathetic activity compared with less mindful mothers (Braeken, Jones, Otte, Nyklíček, & Van den Bergh, 2017).

Another recent, prospective study examined the relationship between mindfulness skills and pregnancy outcomes, including maternal depression in late pregnancy, gestational age and birth weight. It was found that the non-judging aspect of mindfulness predicted depressive

symptomatology at 32 weeks of pregnancy when controlling for baseline depressive symptoms. In addition, the non-reacting facet predicted normal birth weight (Nyklíček, Truijens, Spek, & Pop, 2018).

The purpose of the present study was to further investigate the relationship between trait mindfulness assessed during the first or early second trimester of pregnancy to psychological and physical health outcomes throughout pregnancy. It was hypothesized that more mindful women would experience less depression, less pregnancy-related distress, lower levels of perceived stress and fewer pregnancy discomforts. It was also predicted that more mindful mothers would be less likely to receive a diagnosis of gestational diabetes or high blood pressure.

Materials and Methods

Procedure

Data were obtained as part of the Healthy Behaviours During Pregnancy and Postpartum Study, a prospective cohort study investigating excessive weight gain in pregnancy. 763 women were recruited during routine prenatal visits at obstetrical and prenatal facilities affiliated with McGill University Potential participants were included if they were at fewer than 20 weeks gestation, if they had a singleton pregnancy, if they were older than 18 years of age, if they could communicate in either English or French and if they had access to the Internet. Women diagnosed with diabetes before pregnancy or with gestational diabetes were excluded from the study.

Once recruited, participants were emailed a link to a secure website, where they completed an informed consent form and the first set of questionnaires. This first assessment occurred on average at 13 weeks gestation (m=13.43, sd=1.20). Follow-up questionnaires were also completed during the second trimester at approximately 25 weeks (m=24.66, sd=1.09) and

during the third trimester at approximately 36 weeks (m=36.07, sd=1.17). Demographic information, including age, ethnicity, education, height and weight, and characteristics of the pregnancy, such as parity, were obtained at the first assessment.

Measures of Psychological Health

The Mindful Attention Awareness Scale (MAAS) was administered during the baseline assessment to obtain a measure of trait maternal mindfulness (Brown & Ryan, 2003). The MAAS is a measure of the frequency of mindful states and focuses on present-moment awareness, rather than the acceptance aspect of mindfulness. The self-report scale consists of 15 items rated on a 6-point Likert scale from 1 (almost always) to 6 (almost never). Higher scores reflect higher dispositional mindfulness. The MAAS has been shown to have good internal consistency, $\alpha = .86$ and .87 in the two samples studied by Brown and Ryan (2003). This measure has previously been used with other samples consisting of pregnant women (e.g., Luberto, Park, & Goodman, 2018; Vieten & Astin, 2008). Luberto et al. (2018) reported alpha levels of .94 and .93 at two separate timepoints in their study.

Maternal depression was assessed using the Edinburgh Postnatal Depression Scale (EPDS) (Cox, Holden, & Sagovsky, 1987). The scale is composed of 10 items concerning participants' emotional experience in the previous 7 days. The EPDS has been found to have good internal consistency, $\alpha = .87$ (Cox et al., 1987). While originally developed to assess depression during the postpartum period, the EPDS has also been validated for use during pregnancy (Bergink et al., 2011; Kozinksy & Dudas, 2015).

Participants completed the Prenatal Distress Questionnaire Revised (PDQR), a 17-item self-report measure of the extent to which they felt bothered, upset or worried about pregnancy-specific stressors, such as child health, parenting and physical symptoms of pregnancy (Lobel et

al., 2008). Items are rated on a 3-point Likert scale (0= not at all, 1= somewhat, 2= very much) such that total scores range from 0 to 34. This scale has been associated with health behaviours including eating, exercising and cigarette smoking, as well as birth outcomes such as earlier delivery (Lobel et. al, 2008). Previously reported scale reliabilities range from $\alpha = .73$ to .95 (Alderdice et al., 2012).

Perceived stress was measured using the 10-item Perceived Stress Scale (PSS) (Cohen, Kamarck, & Mermelstein, 1983). Women are asked to rate each item on a 4-point scale ranging from 0 (never) to 4 (very often). Four items are reverse-scored before the sum of all items is obtained. This scale has been demonstrated to have high internal consistency in pregnant women. Lobel and colleagues (2000) reported $\alpha = .86$ to .90.

The EPDS, PDQR and PSS were administered at each timepoint of the study.

Measures of Physical Health

During each of the online assessments, participants were asked about the presence (yes or no) of several common physical symptoms of pregnancy. This included morning sickness, cramping or abdominal pain, dizziness or lightheadedness, back pain, leg cramps, swelling, shortness of breath and vaginal bleeding. Participants also rated the severity of each symptom using a Likert scale from 1 to 4, 1 indicating that it caused no discomfort and 4 indicating that the symptom was severe. A total symptom severity score was created by summing the severity ratings of all eight discomforts.

In their second and third trimesters, women indicated whether their primary healthcare clinician informed them they had high blood pressure or gestational diabetes.

Statistical Analyses

Repeated measures general linear models were employed to investigate the relationship between trait mindfulness and psychological health across all three timepoints which was operationalized as EPDS, PDQR and PSS scores. Baseline MAAS was treated as a continuous variable to avoid the loss of information that might occur if participants were partitioned into several groups.

Another Time x MAAS score repeated measures general linear model investigated the relationship between mindfulness and the self-reported severity of discomforts throughout pregnancy (e.g., morning sickness, back pain, leg cramping). Two separate multiple logistic regressions were conducted to determine whether MAAS scores were associated with the development of gestational diabetes or high blood pressure. Given that both gestational diabetes and hypertension are risk factors for premature vascular disease in women after pregnancy (Nerenberg, Daskalopoulou, & Dasgupta, 2014), a third logistic regression was conducted to determine whether MAAS was associated with the development of these conditions when they were aggregated into a single variable.

Results

Participant Characteristics

At study entry, 763 women completed the baseline on-line questionnaires and 510 (66.8%) completed all three on-line assessments. There were no differences between those who did and did not complete all timepoints for pre-pregnancy BMI, baseline pregnancy symptom severity, education level, employment status, income, or baseline EPDS, PDQR, PSS or MAAS scores. Women who did not complete all assessments were younger, $F(1,517)=5.589$, $p=.033$

(30.31 years, sd=4.92 vs. 33.21, sd=4.22). The following analyses were conducted using the subset of participants who completed all three assessments.

Participant characteristics for the final sample are presented in Table 1. More than half of the participants were white (64.1%), and primiparous (60.0%). Average age at study entry was 33.21 (sd= 4.22) and most were married (75.7%). The mean MAAS score obtained in the first assessment was 4.54 (sd=0.82). This is slightly higher than the normative score of 4.00 (sd=0.85) in a healthy, non-pregnant sample of men and women (MacKillop & Anderson, 2007) and the mean scores obtained in previously studied samples of pregnant women (Luberto et al., 2018; Vieten & Astin, 2008). Trait mindfulness was not associated with maternal age, ethnicity, education level, marital status, employment status, total household income or parity.

Trait Mindfulness and Psychological Health During Pregnancy

Mean participant scores on the EPDS, PDQR and PSS are presented in Table 2. The results of the general linear models showed that MAAS scores significantly predicted EPDS scores, $F(1,508)=106.82$, $p<.001$, PDQR scores, $F(1,507)=74.22$, $p<.001$, and PSS scores, $F(1,507)=136.94$, $p<.001$, at all timepoints of the study. Less mindful individuals reported more depressive symptoms, higher pregnancy-related distress and higher perceived stress (Figure 1). Mauchly's test indicated that the assumption of sphericity for the time variable was violated in the analysis of PSS score, $X^2(2)= 8.59$, $p=.014$. Therefore, Greenhouse-Geisser corrected estimates of significance were used to evaluate the interaction between Time and MAAS scores for PSS scores. MAAS scores were a stronger predictor of PSS scores in early than in late pregnancy, $F(2,1014)=4.631$, $p=0.10$. This finding appears to be due to women lower on trait mindfulness experiencing a small decrease in PSS scores over time (see figure 1, bottom panel). No interactions were found for EPDS or PDQR scores.

Trait Mindfulness and Physical Health During Pregnancy

A 3 Time x MAAS score repeated measures general linear model showed that trait mindfulness was associated with the self-reported severity of symptoms throughout pregnancy, $F(1,508)=40.67$, $p<.001$. Less mindful women experienced more severe pregnancy symptoms than more mindful mothers, though both groups experienced more severe symptoms as pregnancy progressed (Figure 2). The results of the multiple logistic regressions revealed that MAAS scores were unrelated to either gestational diabetes or high blood pressure alone in the second or third trimester. This pattern of results may be due to their low prevalence in the sample (Table 3 shows the prevalence of these conditions as reported in the third trimester). The results of the final logistic regression analysis using the combined gestational diabetes and hypertension variable were also statistically non-significant.

Discussion

The present study investigated the link between maternal trait mindfulness and mental and physical health during pregnancy. As hypothesized, higher mindfulness in the first to early second trimester of pregnancy was associated with fewer depressive symptoms, less pregnancy-related distress and lower perceived stress throughout pregnancy. In addition, the severity of discomforts such as morning sickness and back pain was lower in women with higher baseline mindfulness than less mindful mothers throughout pregnancy. The development of gestational diabetes or hypertension was not related to this trait.

In previous research, it has been shown that programs based on meditation practices to increase mindfulness lead to improvements in depressive (Beattie et al., 2017; Duncan et al., 2017; Muzik et al., 2012; Woolhouse et al., 2014; Dimidjian et al., 2016; Townshend et al., 2018) and anxious (Goodman et al., 2014; Townshend et al., 2018) symptomatology in pregnant

samples. The present findings are consistent with this body of research and suggest that earlier, pre-pregnancy interventions could possibly increase the impact of what appears to be a protective characteristic. Creswell and Lindsay's (2014) stress buffering account posits that mindfulness alters stress appraisals and stress reactivity responses. The resulting reduction in stress levels could explain the relationship between mindfulness and health. Thus, the effects on health would be indirect (Creswell & Lindsay, 2014). While the present study did not measure stress-related appraisals and reactivity specifically, more mindful mothers did report lower levels of pregnancy-related distress and subjective stress, consistent with this theory.

Interestingly, the relationship between mindfulness and perceived stress differed over time. Mindfulness was a stronger predictor of perceived stress in early compared to late pregnancy. Given that perceived stress scores did not differ significantly between trimesters, it is possible that mothers' mindfulness scores varied throughout their pregnancies. Trait mindfulness may change during pregnancy, because women may become more attuned to and aware of their bodies. Further research should be conducted to examine how mindfulness evolves during this period.

The lack of an observable relationship between mindfulness and the development of gestational hypertension and diabetes was not in line with other recent work, which has found that mindfulness interventions may have beneficial effects for the cardiovascular system of pregnant women (Satyapriya, Nagendra, Nagarathna, & Padmalatha, 2009), reduce the risk for gestational hypertension (Narendran et al., 2005), lower fasting blood glucose in pregnant women with diabetes (Youngwanichsetha, Phumdoung, & Ingkathawornwong, 2014). They have also been found to exert beneficial effects on inflammatory processes in non-pregnant populations (Black & Slavich, 2016), which have previously been linked with the development

of gestational hypertension (Mtali, Lyimo, Luzzato & Massawe, 2019) and diabetes in pregnancy (Lekva, Norwitz, Aukrust & Ueland, 2016). However, this could be due to the fact that participants self-reported whether they had received a diagnosis from their primary care clinician and that their medical records were not consulted. According to the stress buffering account, the effects of mindfulness would be larger in samples for which stress can lead to the development or to the exacerbation of diseases (Creswell & Lindsay, 2014). The sample recruited for the purposes of the present investigation was relatively healthy; the prevalence of high blood pressure (2.4%) and of gestational diabetes (5.6%) were quite low. It is possible that a relationship would be observed in women with higher risk pregnancies.

Future work could also examine whether trait mindfulness is related to the degree of blood pressure change throughout pregnancy. In non-pregnant populations, it has been shown that mindfulness-based interventions can lead to reductions in blood pressure (Gotink et al., 2017). Higher dispositional mindfulness was found to be associated with cardiovascular risk factors in a non-pregnant sample of healthy adults (Loucks et al., 2015). Further research is required to determine whether this is also the case for pregnant women. Another promising avenue of study is the relationship of trait mindfulness to inflammatory processes in pregnancy, given that evidence has emerged for this link in non-pregnant populations (Tomfohr-Madsen et al., 2015).

A limitation of this investigation is that health outcomes were obtained by self-report. However, maternal self-reports have previously been shown to be a valid method of collecting perinatal outcome data (Gresham et al., 2015; van Gelder et al., 2017). Additionally, the findings may only be generalizable to populations of women with higher-than-average levels of trait mindfulness. The sample was primarily white, upper-middle class and married, which may also

limit the generalizability of the results. A key strength of the study is the large sample size. While the longitudinal design is also a key strength, causality cannot be inferred without an experimental approach.

The current findings support further efforts to develop and test mindfulness-based interventions in pregnancy. The results of this investigation suggest that mindfulness-based interventions earlier in pregnancy could increase the positive effects of dispositional mindfulness on maternal health. Future research could extend to other pregnancy and infant outcomes, with an emphasis on potential mechanisms. Other directions for future research include the stability of trait mindfulness during pregnancy, its associations with blood pressure change and inflammatory processes and stress-related appraisals, especially in women with high-risk pregnancies.

References

Alderdice, F., Lynn, F., & Lobel, M. (2012). A review and psychometric evaluation of pregnancy-specific stress measures. *Journal of Psychosomatic Obstetrics & Gynecology, 33*(2), 62-77.

Beattie, J., Hall, H., Biro, M. A., East, C., & Lau, R. (2017). Effects of mindfulness on maternal stress, depressive symptoms and awareness of present moment experience: A pilot randomised trial. *Midwifery*, *50*, 174–183. https://doi.org/10.1016/j.midw.2017.04.006

Bergink, V., Kooistra, L., Lambregtse-van den Berg, M. P., Wijnen, H., Bunevicius, R., Van Baar, A., & Pop, V. (2011). Validation of the Edinburgh Depression Scale during pregnancy. *Journal of psychosomatic research*, *70*(4), 385-389.

Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., Carmody, J., … Devins, G. (2006). Mindfulness: A Proposed Operational Definition. *Clinical Psychology: Science and Practice*, *11*(3), 230–241. https://doi.org/10.1093/clipsy.bph077

Black, D. S., & Slavich, G. M. (2016). Mindfulness meditation and the immune system: a systematic review of randomized controlled trials. *Annals of the New York Academy of Sciences*, *1373*(1), 13–24. https://doi.org/10.1111/nyas.12998

Braeken, M. A. K. A., Jones, A., Otte, R. A., Nyklíček, I., & Van den Bergh, B. R. H. (2017). Potential benefits of mindfulness during pregnancy on maternal autonomic nervous system function and infant development. *Psychophysiology*, *54*(2), 279–288. https://doi.org/10.1111/psyp.12782

Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology*, *84*(4), 822–848. https://doi.org/10.1037/0022-3514.84.4.822

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A Global Measure of Perceived Stress. *Journal of Health and Social Behavior*, *24*(4), 385. https://doi.org/10.2307/2136404

Cox, J. L., Holden, J. M., & Sagovsky, R. (1987). Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. *The British Journal of Psychiatry : The Journal of Mental Science*, *150*(6), 782–786. https://doi.org/10.1192/BJP.150.6.782

Creswell, J. D., & Lindsay, E. K. (2014). How Does Mindfulness Training Affect Health? A Mindfulness Stress Buffering Account. *Current Directions in Psychological Science*, *23*(6), 401–407. https://doi.org/10.1177/0963721414547415

Dimidjian, S., Goodman, S. H., Felder, J. N., Gallop, R., Brown, A. P., & Beck, A. (2016). Staying well during pregnancy and the postpartum: A pilot randomized trial of mindfulness-based cognitive therapy for the prevention of depressive relapse/recurrence. *Journal of Consulting and Clinical Psychology*, *84*(2), 134–45. https://doi.org/10.1037/ccp0000068

Duncan, L. G., Cohn, M. A., Chao, M. T., Cook, J. G., Riccobono, J., & Bardacke, N. (2017). Benefits of preparing for childbirth with mindfulness training: a randomized controlled trial with active comparison. *BMC Pregnancy and Childbirth*, *17*(1), 140. https://doi.org/10.1186/s12884-017-1319-3

Goodman, J. H., Guarino, A., Chenausky, K., Klein, L., Prager, J., Petersen, R., … Freeman, M. (2014). CALM Pregnancy: results of a pilot study of mindfulness-based cognitive therapy for perinatal anxiety. *Archives of Women's Mental Health*, *17*(5), 373–387. https://doi.org/10.1007/s00737-013-0402-7

Gotink, R. A., Younge, J. O., Wery, M. F., Utens, E. M. W. J., Michels, M., Rizopoulos, D., … Hunink, M. M. G. (2017). Online mindfulness as a promising method to improve exercise

capacity in heart disease: 12-month follow-up of a randomized controlled trial. *PLoS ONE*, *12*(5). https://doi.org/10.1371/journal.pone.0175923

Gresham, E., Forder, P., Chojenta, C. L., Byles, J. E., Loxton, D. J., & Hure, A. J. (2015). Agreement between self-reported perinatal outcomes and administrative data in New South Wales, Australia. *BMC Pregnancy and Childbirth*, *15*(1), 161. https://doi.org/10.1186/s12884-015-0597-x

Kabat-Zinn, J. (2006). Mindfulness-Based Interventions in Context: Past, Present, and Future. *Clinical Psychology: Science and Practice*, *10*(2), 144–156. https://doi.org/10.1093/clipsy.bpg016

Kozinszky, Z., & Dudas, R. B. (2015). Validation studies of the Edinburgh Postnatal Depression Scale for the antenatal period. *Journal of affective disorders*, *176*, 95-105.

Lekva, T., Norwitz, E. R., Aukrust, P., & Ueland, T. (2016). Impact of Systemic Inflammation on the Progression of Gestational Diabetes Mellitus. *Current Diabetes Reports*, *16*(4), 1–11. https://doi.org/10.1007/s11892-016-0715-9

Lobel, M., Cannella, D. L., Graham, J. E., DeVincent, C., Schneider, J., & Meyer, B. A. (2008). Pregnancy-specific stress, prenatal health behaviors, and birth outcomes. *Health Psychology*, *27*(5), 604–615. https://doi.org/10.1037/a0013242

Loucks, E. B., Britton, W. B., Howe, C. J., Eaton, C. B., & Buka, S. L. (2015). Positive Associations of Dispositional Mindfulness with Cardiovascular Health: the New England Family Study. *International Journal of Behavioral Medicine*, *22*(4), 540–550. https://doi.org/10.1007/s12529-014-9448-9

Luberto, C. M., Park, E. R., & Goodman, J. H. (2018). Postpartum Outcomes and Formal Mindfulness Practice in Mindfulness-Based Cognitive Therapy for Perinatal Women.

Mindfulness, *9*(3), 850–859. https://doi.org/10.1007/s12671-017-0825-8

MacKillop, J., & Anderson, E. J. (2007). Further Psychometric Validation of the Mindful Attention Awareness Scale (MAAS). *Journal of Psychopathology and Behavioral Assessment*, *29*(4), 289–293. https://doi.org/10.1007/s10862-007-9045-1

Mtali, Y. S., Lyimo, M. A., Luzzatto, L., & Massawe, S. N. (2019). Hypertensive disorders of pregnancy are associated with an inflammatory state: Evidence from hematological findings and cytokine levels. *BMC Pregnancy and Childbirth*, *19*(1), 237. https://doi.org/10.1186/s12884-019-2383-7

Muzik, M., Hamilton, S. E., Lisa Rosenblum, K., Waxler, E., & Hadi, Z. (2012). Mindfulness yoga during pregnancy for psychiatrically at-risk women: Preliminary results from a pilot feasibility study. *Complementary Therapies in Clinical Practice*, *18*(4), 235–240. https://doi.org/10.1016/j.ctcp.2012.06.006

Narendran, S., Nagarathna, R., Narendran, V., Gunasheela, S., & Nagendra, H. R. R. (2005). Efficacy of Yoga on Pregnancy Outcome. *The Journal of Alternative and Complementary Medicine*, *11*(2), 237–244. https://doi.org/10.1089/acm.2005.11.237

Nerenberg, K., Daskalopoulou, S. S., & Dasgupta, K. (2014). Gestational Diabetes and Hypertensive Disorders of Pregnancy as Vascular Risk Signals: An Overview and Grading of the Evidence. *Canadian Journal of Cardiology*, *30*(7), 765–773. https://doi.org/10.1016/J.CJCA.2013.12.030

Nyklíček, I., Truijens, S. E. M., Spek, V., & Pop, V. J. M. (2018). Mindfulness skills during pregnancy: Prospective associations with mother's mood and neonatal birth weight. *Journal of Psychosomatic Research*, *107*, 14–19. https://doi.org/10.1016/j.jpsychores.2018.01.012

Satyapriya, M., Nagendra, H. R., Nagarathna, R., & Padmalatha, V. (2009). Effect of integrated

yoga on stress and heart rate variability in pregnant women. *International Journal of Gynecology & Obstetrics*, *104*(3), 218–222. https://doi.org/10.1016/j.ijgo.2008.11.013

Staneva, A., Bogossian, F., Pritchard, M., & Wittkowski, A. (2015). The effects of maternal depression, anxiety, and perceived stress during pregnancy on preterm birth: A systematic review. *Women and Birth*, *28*(3), 179-193.

Tomfohr, L. M., Pung, M. A., Mills, P. J., & Edwards, K. (2015). Trait mindfulness is associated with blood pressure and interleukin-6: exploring interactions among subscales of the Five Facet Mindfulness Questionnaire to better understand relationships between mindfulness and health. *Journal of Behavioral Medicine*, *38*(1), 28–38. https://doi.org/10.1007/S10865-014-9575-4

Townshend, K., Caltabiano, N., Powrie, R., & O'Grady, H. (2018). A preliminary study investigating the effectiveness of the caring for body and mind in pregnancy (CBMP) in reducing perinatal depression, anxiety and stress. *Journal of Child and Family Studies, 27*(5), 1556-1566. doi:10.1007/s10826-017-0978-z

Umberson, D., Pudrovska, T., & Reczek, C. (2010). Parenthood, Childlessness, and Well-Being: A Life Course Perspective. *Journal of Marriage and Family*, *72*(3), 612–629. https://doi.org/10.1111/j.1741-3737.2010.00721.x

van Gelder, M. M. H. J., Vorstenbosch, S., Derks, L., te Winkel, B., van Puijenbroek, E. P., & Roeleveld, N. (2017). Web-based questionnaires to assess perinatal outcome proved to be valid. *Journal of Clinical Epidemiology*, *90*, 136–143. https://doi.org/10.1016/J.JCLINEPI.2017.07.004

Vieten, C., & Astin, J. (2008). Effects of a mindfulness-based intervention during pregnancy on prenatal stress and mood: results of a pilot study. *Archives of Women's Mental Health*,

11(1), 67–74. https://doi.org/10.1007/s00737-008-0214-3

Woolhouse, H., Mercuri, K., Judd, F., & Brown, S. J. (2014). Antenatal mindfulness intervention to reduce depression, anxiety and stress: a pilot randomised controlled trial of the MindBabyBody program in an Australian tertiary maternity hospital. *BMC Pregnancy and Childbirth*, *14*(1), 369. https://doi.org/10.1186/s12884-014-0369-z

Youngwanichsetha, S., Phumdoung, S., & Ingkathawornwong, T. (2014). The effects of mindfulness eating and yoga exercise on blood sugar levels of pregnant women with gestational diabetes mellitus. *Applied Nursing Research*, *27*(4), 227–230. https://doi.org/10.1016/J.APNR.2014.02.002

Zhang, S., Ding, Z., Liu, H., Chen, Z., Wu, J., Zhang, Y., & Yu, Y. (2013). Association Between Mental Stress and Gestational Hypertension/Preeclampsia. *Obstetrical & Gynecological Survey*, *68*(12), 825–834. https://doi.org/10.1097/OGX.0000000000000009

Table 1.1

Participant Characteristics at Baseline

Variable	Value
Maternal age (years/sd)	33.21 (4.22)
Pre-pregnancy Body Mass Index (units/sd)	23.51 (4.67)
Ethnicity (*n*/%)	
White	325 (64.1)
Latin American	40 (7.9)
Chinese	34 (6.7)
Arab	34 (6.7)
Black	17 (3.3)
Other	57 (11.3)
Education (*n*/%)	
High school	39 (7.7)
> High school	469 (92.3)
Marital status (*n*/%)	
Married	386 (75.7)
Co-habiting	99 (19.4)
Single	22 (4.3)
Separated	3 (0.6)
Employment status (*n*/%)	
Full-time	317 (62.2)

Part-time	37 (7.3)
Student	41 (8.0)
Unemployed	38 (7.5)
Maternity leave	16 (3.1)
Other	61 (12.0)
Income (*n*/%)	
More than $120,000	120 (23.9)
81,000 - $120,000	163 (32.4)
41,000 - $80,000	135 (26.8)
Less than $40,000	85 (16.9)
Did not disclose	7 (1.4)
Parity (*n/%*)	
Primiparous	306 (60.0)
Multiparous	204 (40.0)

Table 1.2

Mean Scores for Psychological Outcomes in Each Trimester

Variable	Trimester 1	Trimester 2	Trimester 3
	Mean (sd)	Mean (sd)	Mean (sd)
Edinburgh Postnatal Depression Scale (EPDS)	7.09 (4.35)	7.04 (4.70)	6.77 (4.69)
Prenatal Distress Questionnaire-Revised (PDQR)	10.66 (5.68)	10.38 (5.76)	10.64 (5.37)
Perceived Stress Scale (PSS)	15.29 (5.98)	15.05 (5.91)	15.01 (6.17)

Table 1.3

Prevalence of Pregnancy-Related Conditions in Trimester 3

Condition	Prevalence Total (%)
Gestational Diabetes	28 (5.6)
High Blood Pressure	12 (2.4)
Gestational Diabetes or High Blood Pressure	39 (7.8)

Figure 1.1

Psychological Health Outcomes Based on Trait Mindfulness Across Pregnancy

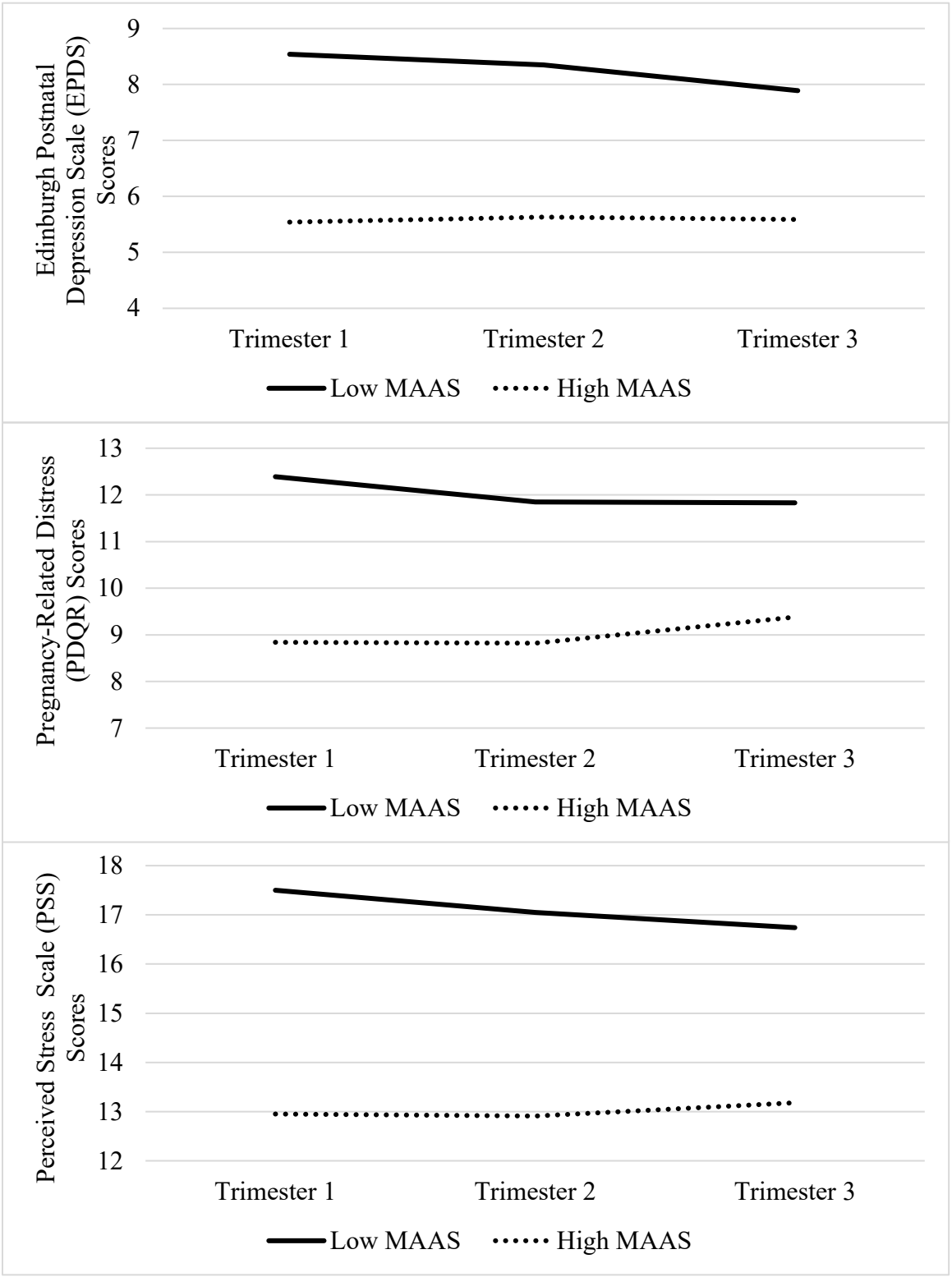
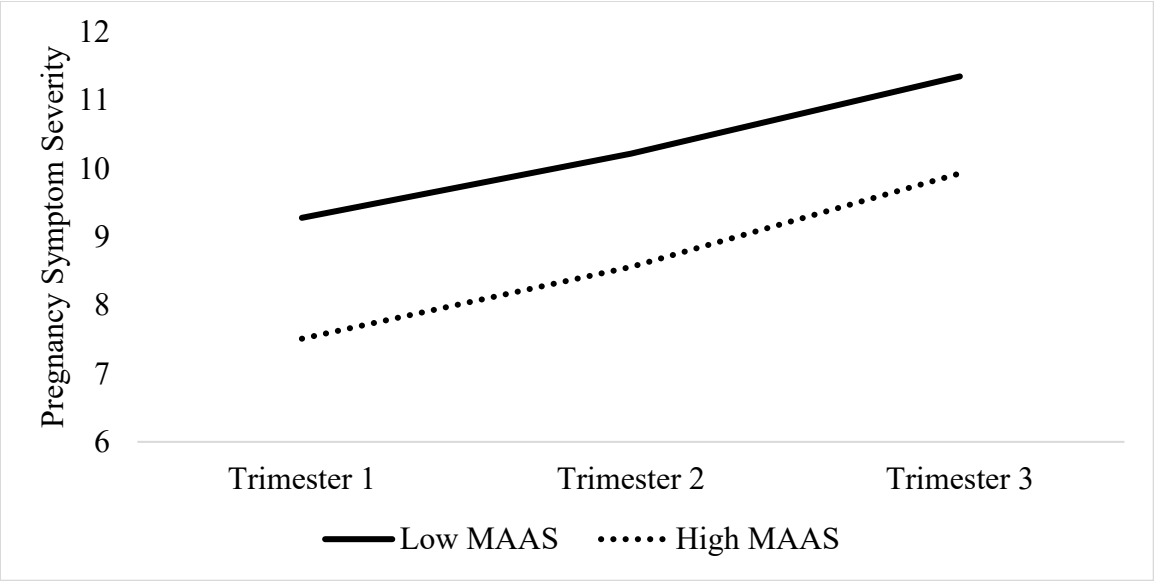


Figure 1.2

Pregnancy Symptom Severity Based on Trait Mindfulness Across Pregnancy



Bridge to Manuscript Two

The goal of the first study was to investigate the potential associations between trait mindfulness and indices of maternal psychological and physical health throughout gestation. It was found that trait mindfulness measured in the late first or early second trimester was a significant predictor of subjective stress, depression, pregnancy-related distress, as well as the severity of physical symptoms of pregnancy. On the other hand, logistic regression analyses showed that trait mindfulness was not related to the presence of physical symptoms, nor to the diagnosis of gestational diabetes or high blood pressure. Taken together, this first set of results suggests that trait mindfulness is, at the very least, an important predictor of subjective experiences during pregnancy.

One limitation of the first study was the use of a binary, self-reported measure as an index of maternal blood pressure, which may have resulted in an important loss of information. As well, the self reports may have been inaccurate. Manuscript Two addressed these limitations by examining the potential links between trait mindfulness and trajectories of maternal systolic and diastolic blood pressure across gestation. Blood pressure is a complex phenomenon; it can change over different time periods based on a person's internal experiences (e.g., psychological and physical health) and their external environment (e.g., temperature). As a result, repeated measures of blood pressure during pregnancy must be obtained to acquire a full picture. Much of the literature on blood pressure in pregnancy has used multivariate statistical methodologies, which have significant limitations in the study of blood pressure in particular. The functional data analytic approach utilized in Manuscript Two allows for the more accurate modeling of changes in blood pressure over time. It models repeated measures data such that each participant's observations are represented in the form of one curve representing the underlying

function contributing to each blood pressure measurement. Study Two examined a subsample of the sample from Study One to determine whether trait mindfulness measured during the first or second trimester of pregnancy is a predictor of maternal blood pressure trajectory across pregnancy using a functional data analytic approach.

Manuscript Two:

Associations between Trait Mindfulness and Maternal Blood Pressure Trajectories Across Pregnancy using Functional Data Analysis

*Serena Mennitto, B.A.[1], Kristin Horsley, PhD.[2], James Ramsay, PhD.[1], Blaine Ditto, PhD.[1], & Deborah Da Costa, PhD.[3]

From the [1]Department of Psychology, McGill University, Montreal, Quebec, Canada, the [2]Department of Obstetrics and Gynecology, McMaster University, Hamilton, Ontario, Canada and the [3]Department of Medicine, McGill University, Montreal, Quebec, Canada.

Abstract

Background: Previous research has found that there are significant individual differences in blood pressure trajectory across gestation. Mindfulness-based interventions have been proposed as potential preventative treatments for high blood pressure in expectant mothers. However, little research has been conducted on associations between trait mindfulness and blood pressure across pregnancy.

Methods: Clinical blood pressure observations were obtained from 370 pregnant participants in a longitudinal cohort study. Participants completed the Mindful Attention Awareness Scale at the end of the first trimester as a measure of trait mindfulness.

Results: Functional data analysis was used to smooth and quantify individual systolic and diastolic blood pressure curves. Functional regression analyses were conducted to determine whether trait mindfulness was a predictor of blood pressure trajectory during pregnancy. Pre-pregnancy body mass index, parity and visible minority status were entered as covariates given that they have been found to predict blood pressure in pregnancy in previous research. It was found that trait mindfulness did not significantly predict systolic nor diastolic blood pressure trajectories.

Conclusions: In the present sample, trait mindfulness was not statistically predictive of maternal blood pressure across pregnancy. Further studies using more inclusive measures of trait and state mindfulness may yield more nuanced results. Given that this sample was at low risk for hypertensive disorders of pregnancy, further research is also required to determine whether trait mindfulness is related to blood pressure in this period in higher risk samples.

Introduction

One of the leading causes of maternal morbidity are hypertensive disorders of pregnancy, which have an estimated prevalence of 7 to 10% (Hutcheon et al., 2011; Magee et al., 2014; Magnussen et al., 2007). There has been increasing interest in identifying variables which might influence the development of hypertensive disorders in this period, including both risk and protective factors. The goal of the current investigation was to examine the relationship between trait mindfulness and blood pressure trajectory across gestation, given that mindfulness has been proposed as a protective factor against physical and mental health difficulties in pregnancy.

In healthy pregnancies, the body undergoes a series of changes to adapt to the presence of the fetus. For example, blood volume increases by 45%. Stroke volume and heart rate also increase. Collectively, these changes lead to cardiac output increasing by 30 to 50%. The largest increases in blood flow are to the uterus, kidneys, breasts and skin (de Weerth & Buitelaar, 2005). Despite the increase in cardiac output, because of a decrease in systemic vascular resistance, there is generally an initial drop in blood pressure at the beginning of pregnancy, which rises to pre-pregnancy levels toward the end of term (Christian, 2012). In healthy pregnancies there is also evidence that, while heart rate variability drops, blood pressure variability increases throughout gestation (Garg et al., 2020). Thus, individual differences in blood pressure and blood pressure trajectory are common. That said, on average, women diagnosed with a hypertensive disorder tend to have higher blood pressure throughout gestation, and steeper blood pressure increases in late pregnancy, relative to normotensive controls (Macdonald-Wallis et al., 2014). In fact, some women do not experience a decrease in blood pressure in the first trimester, but rather show increases in blood pressure. This increase is predictive of several problems, the most worrisome being preeclampsia, a multi-organ disease

characterized by hypertension, proteinuria and edema in the hands and feet. Pre-eclampsia poses risk to the health of both mother and fetus, including death (Mammaro et al., 2009). Preeclampsia and other hypertensive disorders are associated with risk of maternal death as well as poorer birth outcomes, with complication rates directly linked to the severity and duration of abnormally high blood pressure levels (de Weerth & Buitelaar, 2005). For example, in one study it was found that a 1 mmHg increase in blood pressure above the mean was associated with a decrease of 80g in birth weight (McCubbin et al., 1996). Adverse long-term effects have also been studied in mothers. Women diagnosed with a hypertensive disorder during pregnancy tend to have reduced lifespans and a higher risk of developing non-pregnancy-related hypertension later in life than women who did not receive that diagnosis (Craici et al., 2008).

In sum, while pregnancy can represent a joyous time in the lives of many women, for others, it can be fraught with medical complications. Mindfulness has been proposed as a potential solution to improve mental and physical health in pregnancy, including cardiovascular health. Mindfulness has been described as a process through which attention is maintained on immediate experience in a spirit of curiosity and acceptance toward the self (Bishop et al., 2006). Bishop and colleagues (2006) have proposed a model based on two components: the "self-regulation of attention", involving sustained attention, the reorientation of attention and the inhibition of elaborative processing, and "orientation to experience", which involves remaining open to gain insight about the subjectivity and transient nature of thoughts. Trait mindfulness is considered to be a person's general tendency to enter mindful states in their day-to-day life (Baer, 2011).

However, the precise relationship between mindfulness and blood pressure in pregnancy has not been determined. A number of intervention studies have been conducted to examine the

effects of mindfulness on cardiovascular health in pregnancy. One early study found that women who practiced relaxation therapy or a combination of biofeedback and relaxation therapy for 6 weeks during their pregnancy had lower blood pressure than women in a control group (Little et al., 1984). In a prospective observational design, Narendran and colleagues (2005) compared birth outcomes between women practicing a daily, one hour-long prenatal yoga program and those in an active control condition involving walking for the same length of time. They determined that pregnancy-induced hypertension was less likely to occur in the yoga group than in the walking control group (Narendran et al., 2005). In addition, Muthukrishnan and colleagues (2016) found a decreased systolic blood pressure response to a mental arithmetic task and a decrease in the systolic and diastolic blood pressure response to the cold pressor test in pregnant women who participated in a meditation group for five weeks early in pregnancy (Muthukrishnan et al., 2016).

The effects of mindfulness on cardiovascular health in pregnancy have usually been examined in intervention studies, though the degree to which effects such as noted above were actually due to changes in mindfulness requires clarification. Relatedly, using a different approach, some evidence has emerged that dispositional mindfulness is related to cardiovascular function in both non-pregnant and pregnant samples. For example, it has been found that higher trait mindfulness is predictive of lower resting blood pressure in healthy adults, even when controlling for risk factors such as age, gender, body mass index, race/ethnicity, depressive symptoms and perceived stress (Tomfohr et al., 2015). In contrast, while Loucks et al. (2015) found that trait mindfulness is positively associated with cardiovascular health and risk factors of cardiovascular disease, they did not find an association between trait mindfulness and blood pressure itself.

Research on the relation between trait mindfulness and cardiovascular health in pregnancy is limited and mixed. The results of one study suggest that sympathetic and parasympathetic cardiovascular activity may be influenced by trait mindfulness. More mindful mothers were found to experience an attenuated decrease in parasympathetic activity, as measured by high frequency heart rate variability, as well as an attenuated increase in sympathetic activity, inferred through pre-ejection period, than less mindful mothers (Braeken et al., 2017). On the other hand, it was found that trait mindfulness was not a significant predictor of whether expectant mothers were diagnosed with a hypertensive disorder of pregnancy by the third trimester (Mennitto et al., 2021). However, it is possible that information was lost due to the self-reported and binary nature of the outcome variable (diagnosed with hypertension or not), which could have affected the results.

Indeed, most research using repeated measurements of blood pressure during pregnancy has used multivariate methods, which have significant statistical limitations in the analysis of clinical blood pressure data in particular. Between and within participants, there are variations in the timing, frequency and number of blood pressure observations throughout pregnancy. For example, women who experience complications in their pregnancies are followed more closely and thus have more observations taken by clinical staff (Thompson et al., 2009). In addition, observations at different timepoints are intercorrelated. Functional data analysis is an underused statistical approach which has been found to be suitable for the analysis of clinical blood pressure data. It models repeated measures data such that each participant's unique set of observations is represented in the form of a curve representing the underlying function contributing to each blood pressure observation (Horsley et al., 2022).

The current study examined a subsample of the sample studied in Mennitto et al. (2021) to determine whether trait mindfulness measured during the first or second trimester of pregnancy is a predictor of maternal blood pressure trajectory across pregnancy using a functional data analytic approach. It was hypothesized that trait mindfulness would significantly predict variation in both systolic blood pressure (SBP) and diastolic blood pressure (DBP), such that women who report higher levels of mindfulness would be observed to have lower blood pressure across time.

Materials and Methods

Procedure

Data were obtained as part of a prospective cohort study, the Healthy Behaviours During Pregnancy and Postpartum Study. While the primary goal of the study was to examine the effects of excessive weight gain on maternal health, data on other maternal health outcomes, including maternal blood pressure, were also obtained. Potential participants were recruited during routine, prenatal visits at obstetrical and prenatal clinics associated with McGill University in Montreal, Quebec, Canada. Participants were included if they were at fewer than 20 weeks gestation, if they were older than 18 years of age, if they had a singleton pregnancy, if they had access to the Internet and if they could communicate in English or French. Exclusion criteria included a diagnosis of diabetes before pregnancy or a diagnosis of gestational diabetes in the current pregnancy.

Once recruited, participants were emailed a link to a secure website, where they provided informed consent and completed the baseline questionnaires. The use of online self-report measures was intended to reduce participant burden and to maximize study participation,

especially as the perinatal period is a period of unique challenges for many women. The completion of the first assessment occurred on average at 13 weeks gestation (m = 13.4, sd = 1.2). Follow-up questionnaires were administered once during each trimester and at 6 weeks postpartum. During the postpartum assessment, participants indicated whether they had a live birth and reported infant birth date, if applicable. Other measures not relevant to the current study are described elsewhere (e.g., Horsley et al., 2019; Mennitto et al., 2021). Blood pressure measurements during gestation were retrieved from the participants' medical files. Similarly, information on pregnancy complications (i.e., gestational hypertension, preeclampsia, gestational diabetes) were retrieved from medical chart review of data from the first postpartum visit.

Self-Report Measures

Demographic information, including maternal age, ethnicity, education, height and weight, and characteristics of the pregnancy, including parity, were obtained at the baseline assessment. Maternal self-reported height and weight were used to calculate pre-pregnancy body mass index (BMI) in kg/m^2.

Participants were asked to complete the Mindful Attention Awareness Scale (MAAS) during the baseline assessment to obtain a measure of trait maternal mindfulness (Brown & Ryan, 2003). The MAAS is a self-report measure of the frequency of mindful states, with an emphasis on present-moment awareness rather than on the acceptance aspect of trait mindfulness. It consists of 15 items rated on a 6-point Likert scale, ranging from 1 (Almost Always) to 6 (Almost Never), with higher scores indicating higher dispositional mindfulness. Previously, the MAAS has been found to have good internal consistency, as Brown and Ryan reported alpha levels of 0.86 and 0.87 in two samples of non-pregnant individuals (2003). In addition, the MAAS has been administered to samples of pregnant women (Luberto et al., 2018;

Vieten & Astin, 2008). When administered at two separate timepoints in the study by Luberto et al., the MAAS was found to have strong internal consistency, with $\alpha = 0.94$ and 0.93.

Maternal depression was assessed using the Edinburgh Postnatal Depression Scale (EPDS; Cox, Holden, & Sagovsky, 1987). Participants were asked to complete the Prenatal Distress Questionnaire-Revised (PDQR) a measure of the extent to which they felt bothered, upset or worried about pregnancy-specific stressors (Lobel et al., 2008). Perceived stress was measured using the 10-item Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983).

Blood Pressure Measurements

At each routine obstetrical appointment, clinical staff obtained measures of SBP and DBP using an automated oscillometric blood pressure monitor (HEM-7320T-CACS, Omron Healthcare, Kyoto, Japan; Lifesource UA-787 AC, A&D Medical, San Jose, California, USA). Clinic staff reported that their protocol is to obtain blood pressure from the upper left arm resting at heart level. Given that these measures were obtained as part of routine obstetrical appointments, the total number of readings was not standardized across participants, as the number of appointments was determined based on the assessment of each participant's needs.

Information on appointment dates, blood pressure and pregnancy complications were retrieved through a medical chart review, which was conducted by the study coordinator and a research assistant.

Statistical Analyses

A total of 758 women provided informed consent to participate in the study and completed the baseline questionnaire. Blood pressure data were available for 395 participants,

which represents 52% of the total sample. Participants were included in the following analyses if at least four blood pressure observations, including at least one measurement from each trimester of pregnancy, were obtained from the chart review and if they reported a live birth. This resulted in a final sample of 370 participants for the blood pressure trajectory analyses. The BaylorEdPsych and Functional Data Analysis (fda) packages in RStudio were used to perform all statistical analyses (Beaujean, 2012; Ramsay et al., 2018).

In sum, 3387 SBP and 3384 DBP measurements were retrieved from participants' medical charts. In the data preparation stage, a lower boundary timepoint was determined using the average gestational age at the first blood pressure observation (M = 11.8 weeks). Similarly, an upper boundary timepoint was selected by calculating the average gestational age for blood pressure observations taken between 38 and 40 weeks of gestation (M = 39.0 weeks). Any observations outside of this window were excluded from statistical analyses. Thus, the final total of observations was 3212 SBP and 3208 DBP measurements.

Through the creation of functional data objects, each participant's repeated blood pressure data was transformed and represented by a single curve. This process of transforming the data is key, given that it permits the extraction of information from the whole temporal process of gestation instead of at discrete observation timepoints. Functional data objects of SBP and DBP observations were created using an Order four B-spline basis function with seven basis coefficients, corresponding to three equally spaced interior knots over the window of 11.8 to 39.0 weeks of gestation. A smoothing parameter of $\lambda = 10$ was selected by examination of the generalized cross-validation criterion (GCV) and a visual observation of the constructed curves at log10 (λ) of -2, -1, 1, and 2 (Ramsay et al., 2009). For SBP, the GCV score was minimized at $\lambda = 10^{-1}$. For DBP, the GVC score was minimized at was minimized at $\lambda = 10^{1}$. When the

smoothing parameter of $\lambda = 10^1$ was applied to the SBP curve, the GCV value did not change significantly. In addition, the authors observed each resulting curve. This observation showed that, with a parameter of $\lambda = 10^{-1}$, there were many instances where the approximating function displayed irregular changes between the SBP timepoints. Therefore, the smoothing parameter was set at $\lambda = 10^1$ for SBP and DBP.

Mean and standard deviation functions were estimated based on the smoothed data objects from all participants. A functional, linear regression model was built from the functional data objects to examine effects of baseline trait mindfulness on SBP and DBP trajectories across gestation. Because the discrete SBP and DBP observations have been transformed into functions, the regression coefficients are curves which provide information about how the effect of a predictor differs across time. Regression coefficients, presented as unstandardized beta coefficients (*b*), represent the change in blood pressure associated with a one-unit increase in the independent variable. The regression analysis yields pointwise standard error functions to calculate 95% confidence intervals of the regression coefficients.

In the functional regression analyses, pre-pregnancy BMI, parity and visible minority status were entered as covariates given that they were found to predict blood pressure in pregnancy in a previous study conducted using the same sample (Horsley, 2021).

Results

Characteristics of the sample retained for analysis are presented in Table 1. More than half of participants identified as White (61.4%) and primiparous (63.5%). Average maternal age at baseline was 32.7 years (sd = 4.6). Most were married (75.7%). The mean MAAS score obtained in the first assessment was 5.6. This score is higher than the normative score of 4.0 (sd

= 0.9) in a healthy, non-pregnant sample consisting of women and men (MacKillop & Anderson, 2007) and the mean scores reported in other samples of pregnant women (Luberto et al., 2018; Vieten & Astin, 2008). Baseline trait mindfulness was not correlated with maternal age, ethnicity, education level, marital status, employment status, total household income nor parity. MAAS scores were correlated with maternal depression (r = -.39), perceived stress (r = -.42) and pregnancy-related distress (r = -.25). The sample was at low risk of developing pregnancy-related medical conditions. Only 5.7% of participants were diagnosed with a hypertensive disorder of pregnancy. 3.8% of participants were diagnosed with gestational diabetes.

Means and standard deviations for SBP and DBP are plotted in Figure 1. In general, SBP and DBP decreased from the selected lower boundary timepoint of 11.8 weeks gestation to the midpoint of the second trimester. Both SBP and DBP showed greater variability in the early and late periods of pregnancy than in the middle of gestation. There was significant variation in blood pressure trajectory across participants. In a previous study using the same sample, a principal component analysis showed that there were three main modes of variation (Horsley et al., 2022). The first reflected a prolonged-decrease in blood pressure, which may represent an adaptive pattern. The second was characterized by an increase in blood pressure late in pregnancy, which has been associated with risk for hypertensive disorders of pregnancy. The third represented a trajectory where women experienced a decrease in blood pressure midway through gestation (Horsley et al., 2022).

The functional F-test statistic for systolic and diastolic blood pressure is plotted in Figure 2. This demonstrates the pointwise and maximal F-statistic (highest value of the full line) and the corresponding permutation critical values (dashed line, determined using 200 permutations) for the models. The model using SBP as the outcome variable was significant across gestation, given

that the maximum observed statistic was 0.13 and the minimum observed statistic was 0.06 with a critical value of 0.04. The model for DBP was also statistically significant throughout pregnancy. The maximum observed statistic was 0.15, while the minimum observed statistic was 0.08 with a critical value of 0.04.

The regression coefficients and corresponding 95% pointwise confidence interval functions for the intercept and the effects of trait mindfulness, pre-pregnancy BMI, parity and visible minority status on systolic blood pressure are presented in Figure 3. As is the case in other statistical methods, the effect of an independent variable is statistically significant if the confidence interval does not include 0. In the model of SBP, trait mindfulness was not a statistically significant predictor, while pre-pregnancy BMI, parity and visible minority status were significant predictors. Greater pre-pregnancy BMI and nulliparity were associated with higher SBP throughout pregnancy, while women identifying as a visible minority had lower SBP throughout gestation. Similarly, it was found that trait mindfulness did not significantly predict DBP trajectories across pregnancy, although all three covariate variables did significantly predict DBP. Greater pre-pregnancy BMI was associated with higher DBP. Primiparous women had higher DBP in the second half of gestation. Visible minority women had lower DBP mid-gestation. The regression coefficients and corresponding 95% pointwise confidence interval functions in the model predicting diastolic blood pressure are plotted in Figure 4.

Discussion

The current study investigated whether trait mindfulness was a predictor of maternal blood pressure trajectory during pregnancy using a functional data analytic approach. Contrary to what was hypothesized, it was found that trait mindfulness was not a significant predictor of SBP or DBP across gestation.

The lack of a statistically significant relationship was inconsistent with other recent findings in both non-pregnant and pregnant samples about mindfulness and cardiovascular function. In a sample of non-pregnant adults diagnosed with heart disease, it was found that mindfulness-based interventions can have a beneficial effect on blood pressure (Gotink et al., 2017). Similarly, mindfulness-based interventions have been shown to reduce the risk for gestational hypertension (Narendran et al., 2005) and to increase heart rate variability in pregnancy (Satyapriya et al., 2009).

The main outcome measure in the present study was trait mindfulness as assessed with the MAAS (Brown & Ryan, 2003). This measure focuses mainly on the attentional component of mindfulness, rather than the attitude with which one pays attention to inner and outer experience (non-judgmental and accepting). Future research could be conducted using a more inclusive measure of trait mindfulness, such as the Five Facet Mindfulness Questionnaire (Baer et al., 2008) which has previously been administered in pregnant samples (e.g., Pan et al., 2019). This measure includes five subscales: Observing, Describing, Acting with awareness, Non-judging of inner experience, and Non-reactivity to inner experience. It is possible that some facets are more predictive of blood pressure trajectory than others. In addition, functional data analysis makes it possible to determine the effects of a predictor variable at different points in time. Perhaps some facets are more important predictors at different timepoints in gestation. As well, trait mindfulness was assessed at one timepoint in the present study. To our knowledge, the stability of the trait during pregnancy has not been assessed. Further research is necessary to address these questions.

It is also possible that mindfulness is more relevant in higher risk populations reporting higher levels of distress. The current sample was at relatively low risk for the development of

cardiovascular complications, as only 5.7% of participants were diagnosed with a hypertensive disorder of pregnancy. According to Creswell and Lindsay's stress buffering theory of mindfulness, the effects of mindfulness on physical health would be largest in samples for which stress can lead to the development or exacerbation of disease (Creswell & Lindsay, 2014). Given that the present sample was at low risk for the development of hypertensive disorders, it is possible that a relationship between trait mindfulness and blood pressure trajectory would be observed in a higher risk sample.

The large sample size and number of blood pressure observations were key strengths of the investigation. The use of a functional data analytic approach was also a strength, as it allowed for the preservation of most blood pressure observations obtained throughout pregnancy. One limitation of this study is that the findings may only generalize to populations of pregnant women with higher self-reported levels of trait mindfulness. The sample was also mainly white (61.6%) and married (75.7%) with relatively high socioeconomic status; over a third of participants reported a family income of over $81,000. This might also limit the generalizability of results.

In conclusion, in the present study, trait mindfulness measured at approximately 13 weeks gestation was not statistically predictive of maternal blood pressure across pregnancy. Further study using a more inclusive measure of trait mindfulness may yield more nuanced results. Given that this sample was at low risk for hypertensive disorders of pregnancy, further research is required to determine whether trait mindfulness is related to blood pressure in this period in higher risk and more culturally and socioeconomically diverse samples.

References

Baer, R. A. (2011). Measuring mindfulness. *Contemporary Buddhism*, *12*(1), 241–261. https://doi.org/10.1080/14639947.2011.564842

Baer, R. A., Smith, G. T., Lykins, E., Button, D., Krietemeyer, J., Sauer, S., Walsh, E., Duggan, D., & Williams, J. M. G. (2008). Construct Validity of the Five Facet Mindfulness Questionnaire in Meditating and Nonmeditating Samples. *Assessment*, *15*(3), 329–342. https://doi.org/10.1177/1073191107313003

Beaujean, A. A. (2012). *BaylorEdPsych: R Package for Baylor University Education Psychology*. https://cran.r-project.org/package=BaylorEdPsych

Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., Carmody, J., Segal, Z. V., Abbey, S., Speca, M., Velting, D., & Devins, G. (2006). Mindfulness: A Proposed Operational Definition. *Clinical Psychology: Science and Practice*, *11*(3), 230–241. https://doi.org/10.1093/clipsy.bph077

Braeken, M. A. K. A., Jones, A., Otte, R. A., Nyklíček, I., & van den Bergh, B. R. H. (2017). Potential benefits of mindfulness during pregnancy on maternal autonomic nervous system function and infant development. *Psychophysiology*, *54*(2), 279–288. https://doi.org/10.1111/psyp.12782

Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology*, *84*(4), 822–848. https://doi.org/10.1037/0022-3514.84.4.822

Christian, L. M. (2012). Physiological reactivity to psychological stress in human pregnancy: current knowledge and future directions. *Progress in Neurobiology*, *99*(2), 106–116. https://doi.org/10.1016/j.pneurobio.2012.07.003

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A Global Measure of Perceived Stress. *Journal of Health and Social Behavior*, *24*(4), 385. https://doi.org/10.2307/2136404

Cox, J. L., Holden, J. M., & Sagovsky, R. (1987). Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. *The British Journal of Psychiatry: The Journal of Mental Science*, *150*(6), 782–786.

Craici, I., Wagner, S., & Garovic, V. D. (2008). Preeclampsia and future cardiovascular risk: formal risk factor or failed stress test? *Therapeutic Advances in Cardiovascular Disease*, *2*(4), 249–259. https://doi.org/10.1177/1753944708094227

Creswell, J. D., & Lindsay, E. K. (2014). How Does Mindfulness Training Affect Health? A Mindfulness Stress Buffering Account. *Current Directions in Psychological Science*, *23*(6), 401–407. https://doi.org/10.1177/0963721414547415

de Weerth, C., & Buitelaar, J. K. (2005). Physiological stress reactivity in human pregnancy—a review. *Neuroscience & Biobehavioral Reviews*, *29*(2), 295–312. https://doi.org/10.1016/J.NEUBIOREV.2004.10.005

Garg, P., Yadav, K., Jaryal, A. K., Kachhawa, G., Kriplani, A., & Deepak, K. K. (2020). Sequential analysis of heart rate variability, blood pressure variability and baroreflex sensitivity in healthy pregnancy. *Clinical Autonomic Research*, *30*(5), 433–439. https://doi.org/10.1007/S10286-020-00667-4/FIGURES/1

Gotink, R. A., Younge, J. O., Wery, M. F., Utens, E. M. W. J., Michels, M., Rizopoulos, D., van Rossum, L. F. C., Roos-Hesselink, J. W., & Hunink, M. M. G. (2017). Online mindfulness as a promising method to improve exercise capacity in heart disease: 12-month follow-up of a randomized controlled trial. *PLoS ONE*, *12*(5). https://doi.org/10.1371/journal.pone.0175923

Horsley, K. (2021). *Exploring associations between maternal blood pressure, symptoms of depression and anxiety, and gestational age at birth using multivariate and functional data analysis* (dissertation). McGill University Libraries.

Horsley, K., Nguyen, T. V., Ditto, B., & da Costa, D. (2019). The Association Between Pregnancy-Specific Anxiety and Exclusive Breastfeeding Status Early in the Postpartum Period. *Journal of Human Lactation*, *35*(4), 729–736. https://doi.org/10.1177/0890334419838482

Horsley, K., Ramsay, J. O., Ditto, B., & da Costa, D. (2022). Maternal blood pressure trajectories and associations with gestational age at birth: a functional data analytic approach. *Journal of Hypertension*, *40*(2), 213–220. https://doi.org/10.1097/HJH.0000000000002995

Hutcheon, J. A., Lisonkova, S., & Joseph, K. S. (2011). Epidemiology of pre-eclampsia and the other hypertensive disorders of pregnancy. *Best Practice & Research Clinical Obstetrics & Gynaecology*, *25*(4), 391–403. https://doi.org/10.1016/J.BPOBGYN.2011.01.006

Little, B. C., Hayworth, J., Benson, P., Hall, F., Beard, R. W., Dewhurst, J., & Priest, R. G. (1984). Treatment of hypertension in pregnancy by relaxation and biofeedback. *Lancet*, *1*(8382), 865–7.

Lobel, M., Cannella, D. L., Graham, J. E., DeVincent, C., Schneider, J., & Meyer, B. A. (2008). Pregnancy-specific stress, prenatal health behaviors, and birth outcomes. *Health Psychology*, *27*(5), 604–615. https://doi.org/10.1037/a0013242

Loucks, E. B., Britton, W. B., Howe, C. J., Eaton, C. B., & Buka, S. L. (2015). Positive Associations of Dispositional Mindfulness with Cardiovascular Health: the New England Family Study. *International Journal of Behavioral Medicine*, *22*(4), 540–550. https://doi.org/10.1007/s12529-014-9448-9

Luberto, C. M., Park, E. R., & Goodman, J. H. (2018). Postpartum Outcomes and Formal Mindfulness Practice in Mindfulness-Based Cognitive Therapy for Perinatal Women. *Mindfulness*, *9*(3), 850–859. https://doi.org/10.1007/s12671-017-0825-8

Macdonald-Wallis, C., Tilling, K., Fraser, A., Nelson, S. M., & Lawlor, D. A. (2014). Associations of blood pressure change in pregnancy with fetal growth and gestational age at delivery: Findings from a prospective cohort. *Hypertension*, *64*(1), 36–44. https://doi.org/10.1161/HYPERTENSIONAHA.113.02766

MacKillop, J., & Anderson, E. J. (2007). Further Psychometric Validation of the Mindful Attention Awareness Scale (MAAS). *Journal of Psychopathology and Behavioral Assessment*, *29*(4), 289–293. https://doi.org/10.1007/s10862-007-9045-1

Magee, L. A., Pels, A., Helewa, M., Rey, E., von Dadelszen, P., Audibert, F., Bujold, E., Côté, A. M., Douglas, M. J., Eastabrook, G., Firoz, T., Gibson, P., Gruslin, A., Hutcheon, J., Koren, G., Lange, I., Leduc, L., & Logan, A. G. (2014). Diagnosis, Evaluation, and Management of the Hypertensive Disorders of Pregnancy: Executive Summary. *Journal of*

Obstetrics and Gynaecology Canada, *36*(5), 416–438. https://doi.org/10.1016/S1701-2163(15)30588-0

Magnussen, E. B., Vatten, L. J., Lund-Nilsen, T. I., Salvesen, K. Å., Smith, G. D., & Romundstad, P. R. (2007). Prepregnancy cardiovascular risk factors as predictors of pre-eclampsia: population based cohort study. *BMJ*, *335*(7627), 978. https://doi.org/10.1136/BMJ.39366.416817.BE

Mammaro, A., Carrara, S., Cavaliere, A., Ermito, S., Dinatale, A., Pappalardo, E. M., Militello, M., Pedata, R., & Cacciatore, A. (2009). Hypertensive Disorders in Pregnancy. *Journal of Prenatal Medicine*, *3*(1), 1–5. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3279097/pdf/prenatal-03-0001.pdf

McCubbin, J. A., Lawson, E. J., Cox, S., Sherman, J. J., Norton, J. A., & Read, J. A. (1996). Prenatal maternal blood pressure response to stress predicts birth weight and gestational age: A preliminary study. *American Journal of Obstetrics and Gynecology, 175*, 706–712.

Mennitto, S., Ditto, B., & da Costa, D. (2021). The relationship of trait mindfulness to physical and psychological health during pregnancy. *Journal of Psychosomatic Obstetrics and Gynecology*, *42*(4), 313–319. https://doi.org/10.1080/0167482X.2020.1761320

Muthukrishnan, S., Jain, R., Kohli, S., & Batra, S. (2016). Effect of Mindfulness Meditation on Perceived Stress Scores and Autonomic Function Tests of Pregnant Indian Women. *Journal of Clinical and Diagnostic Research*, *10*(4), CC05-8. https://doi.org/10.7860/JCDR/2016/16463.7679

Narendran, S., Nagarathna, R., Narendran, V., Gunasheela, S., & Nagendra, H. R. R. (2005). Efficacy of Yoga on Pregnancy Outcome. *The Journal of Alternative and Complementary Medicine*, *11*(2), 237–244. https://doi.org/10.1089/acm.2005.11.237

Pan, W. L., Chang, C. W., Chen, S. M., & Gau, M. L. (2019). Assessing the effectiveness of mindfulness-based programs on mental health during pregnancy and early motherhood - A randomized control trial. *BMC Pregnancy and Childbirth*, *19*(1), 1–8. https://doi.org/10.1186/S12884-019-2503-4/TABLES/3

Ramsay, J., Hooker, G., & Graves, S. (2009). Functional Data Analysis with R and MATLAB. In *Functional Data Analysis with R and MATLAB*. https://doi.org/10.1007/978-0-387-98185-7

Ramsay, J. O., Wickham, H., Graves, S., & Hooker, G. (2018). *fda: Functional Data Analysis* (2.4.8). https://cran.r-project.org/package=fda

Satyapriya, M., Nagendra, H. R., Nagarathna, R., & Padmalatha, V. (2009). Effect of integrated yoga on stress and heart rate variability in pregnant women. *International Journal of Gynecology & Obstetrics*, *104*(3), 218–222. https://doi.org/10.1016/j.ijgo.2008.11.013

Thompson, M. L., Williams, M. A., & Miller, R. S. (2009). Modelling the association of blood pressure during pregnancy with gestational age and body mass index. *Paediatric and Perinatal Epidemiology*, *23*(3), 254–263. https://doi.org/10.1111/J.1365-3016.2009.01027.X

Tomfohr, L. M., Pung, M. A., Mills, P. J., & Edwards, K. (2015). Trait mindfulness is associated with blood pressure and interleukin-6: exploring interactions among subscales of the Five Facet Mindfulness Questionnaire to better understand relationships between mindfulness

and health. *Journal of Behavioral Medicine*, *38*(1), 28–38. https://doi.org/10.1007/s10865-014-9575-4

Vieten, C., & Astin, J. (2008). Effects of a mindfulness-based intervention during pregnancy on prenatal stress and mood: results of a pilot study. *Archives of Women's Mental Health*, *11*, 67–74. https://doi.org/10.1007/s00737-008-0214-3

Table 2.1

Participant Characteristics

Variable	Value
Maternal age (years/sd)	32.7 (4.56)
Pre-pregnancy Body Mass Index (units/sd)	23.71 (5.01)
Ethnicity (*n*/%)	
White	226 (61.6)
Latin American	25 (6.8)
Chinese	20 (5.4)
Arab	25 (6.8)
Black	18 (4.9)
Other	56 (15.1)
Education (*n*/%)	
High school	31 (8.4)
> High school	339 (91.6)
Marital status (*n*/%)	
Married	280 (75.7)
Co-habiting	68 (18.4)
Single	19 (5.1)
Separated	2 (0.5)
Widowed	1 (0.3)

Employment status (*n*/%)	
Full-time	224 (60.5)
Part-time	33 (8.9)
Student	27 (7.3)
Unemployed	31 (8.4)
Maternity leave	14 (3.8)
Other	40 (10.8)
Missing	1 (0.3)
Income (*n*/%)	
More than $120,000	84 (22.7)
81,000 - $120,000	58 (15.7)
41,000 - $80,000	98 (26.5)
Less than $40,000	72 (19.5)
Did not disclose	6 (1.6)
Parity (*n/%*)	
Primiparous	235 (63.5)
Hypertensive disorders of pregnancy (*n/%)*	21 (5.7)
Gestational hypertension (*n/%)*	11 (2.9)
Preeclampsia (*n/%*)	14 (3.8)
Gestational diabetes (*n/%*)	14 (3.8)

Figure 2.1

Means and Standard Deviations for Systolic and Diastolic Blood Pressure Across Pregnancy

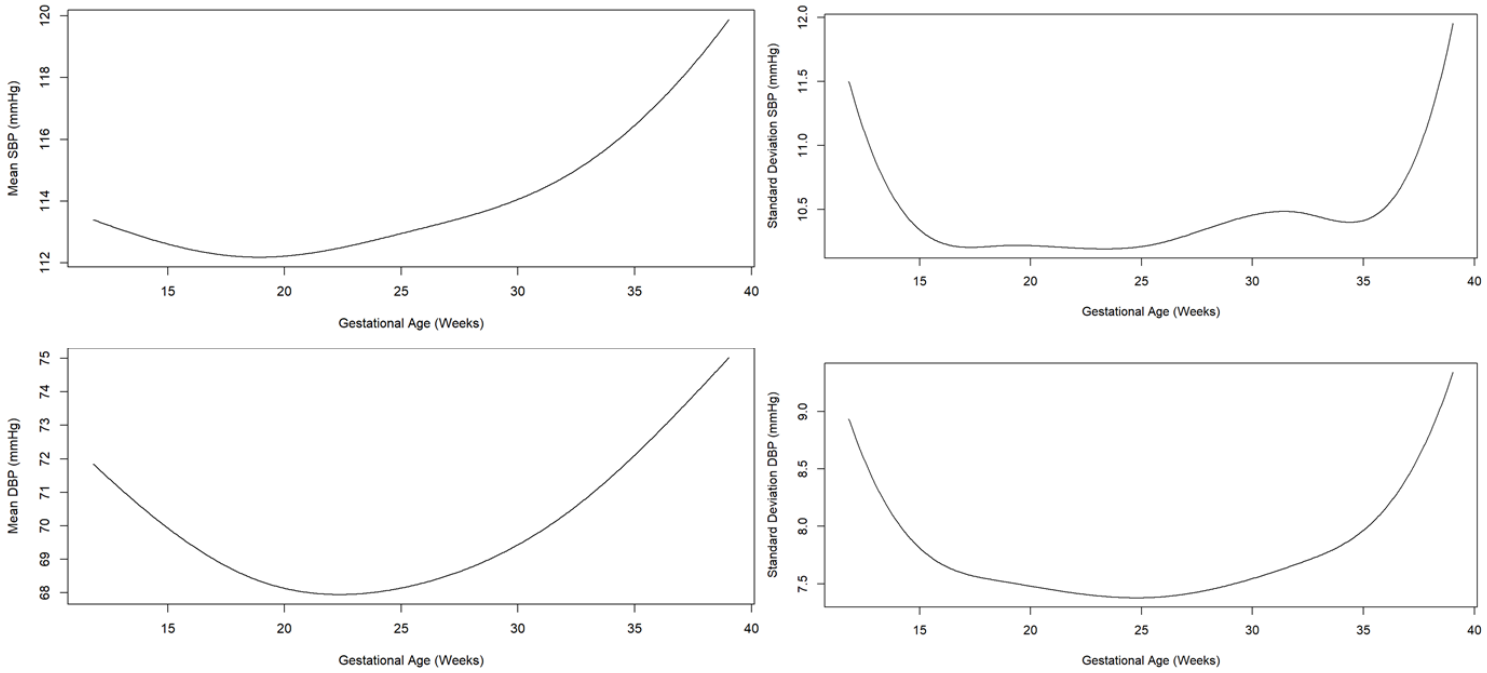


Figure 2.2

Functional F-statistics for Systolic and Diastolic Blood Pressure

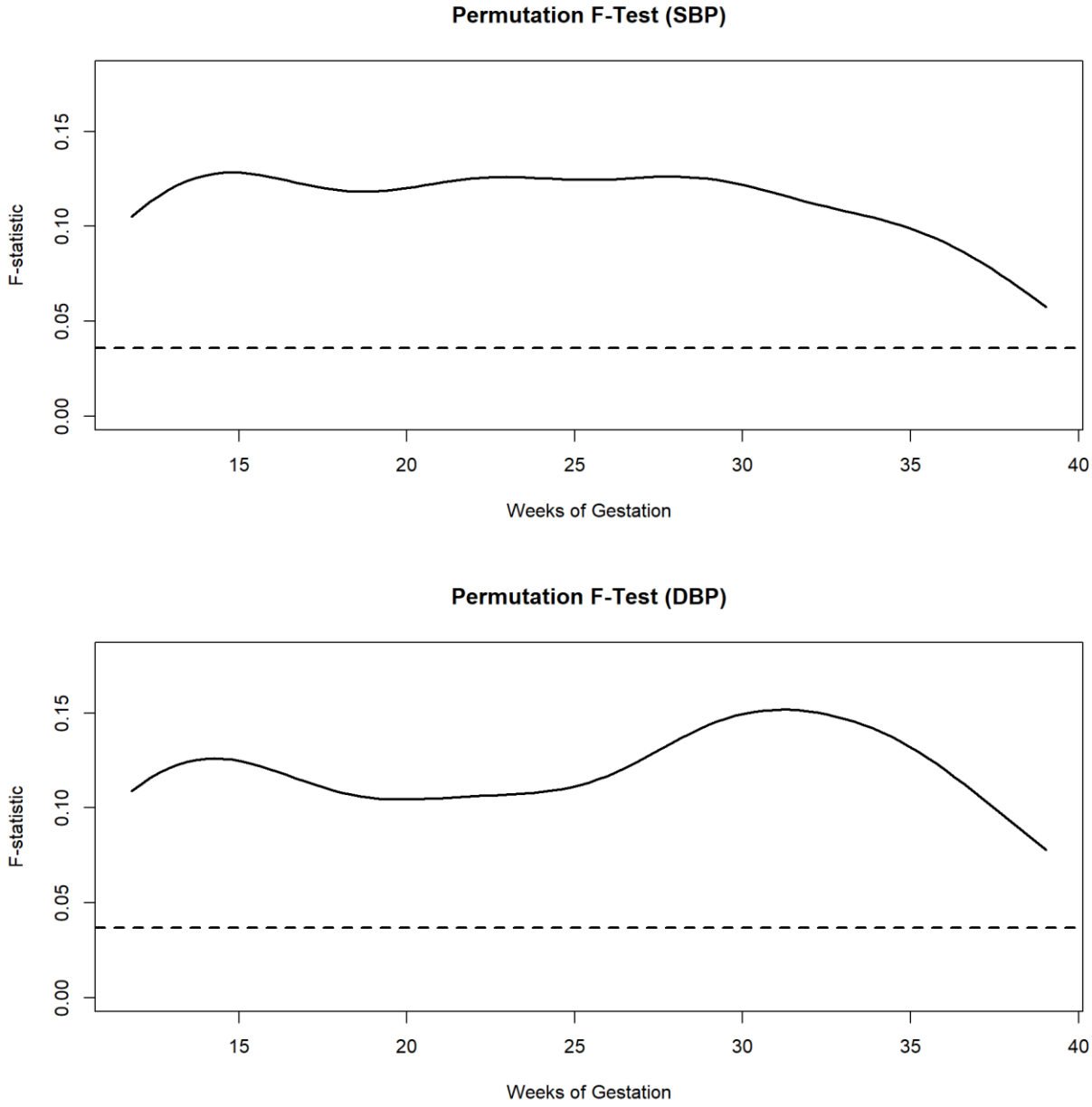


Figure 2.3

Functional Regression Coefficients for Model Predicting Systolic Blood Pressure

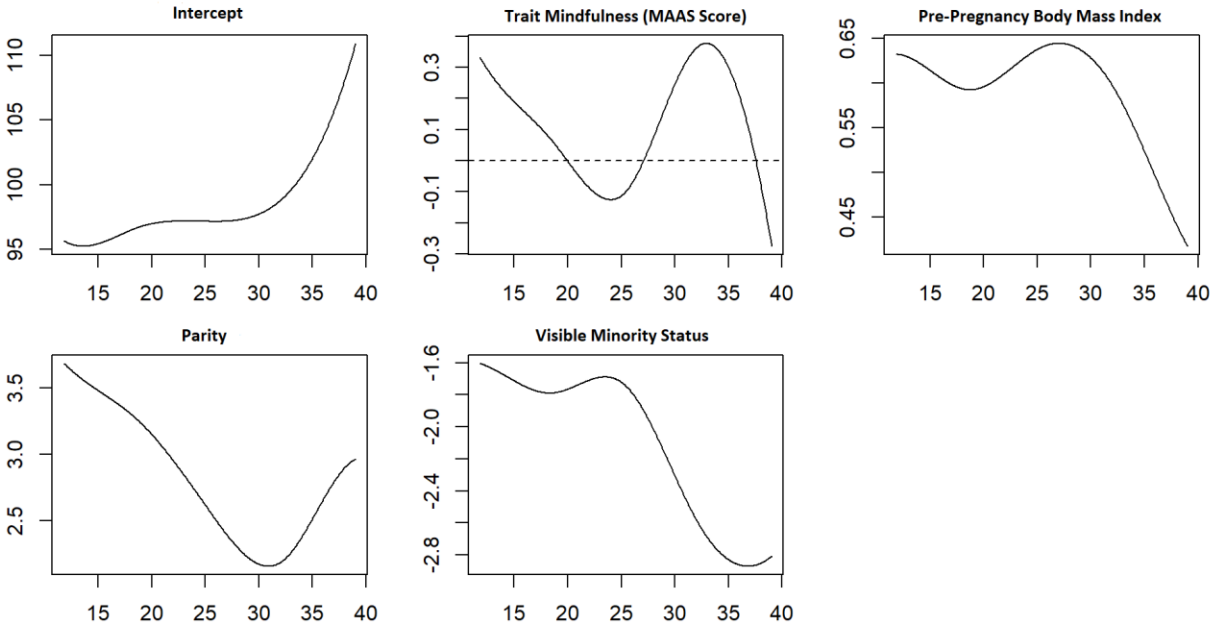
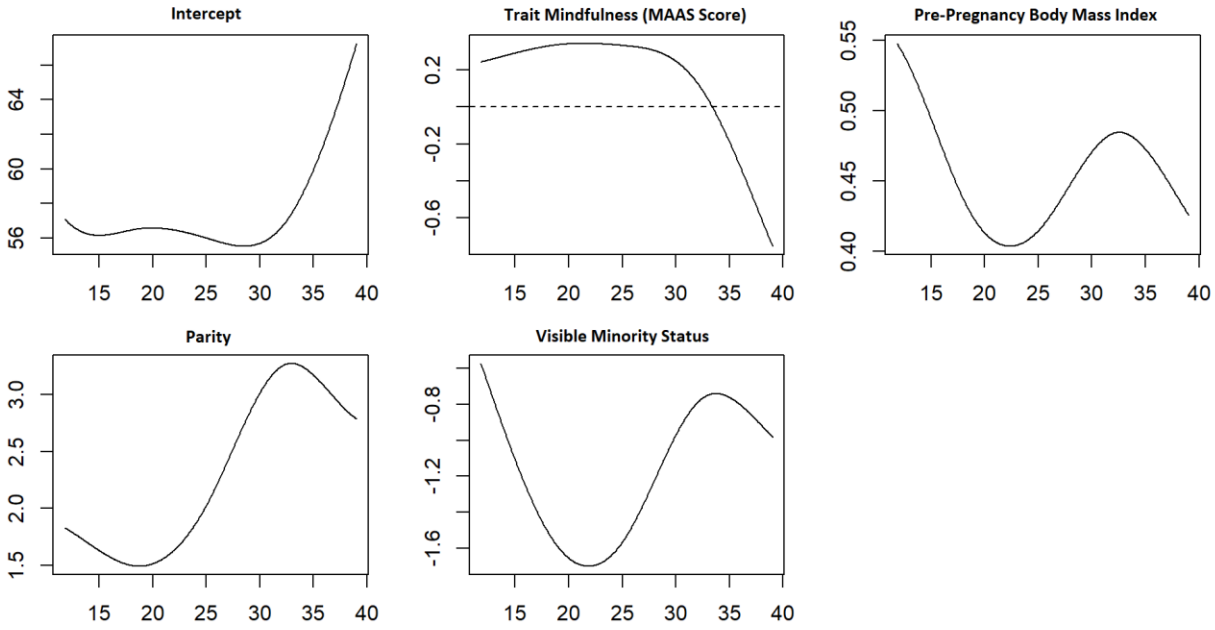


Figure 2.4

Functional Regression Coefficients for Model Predicting Diastolic Blood Pressure



Bridge to Manuscript Three

Studies One and Two examined the longitudinal relationships between trait mindfulness and maternal psychological and cardiovascular outcomes in pregnancy. In Study One, although trait mindfulness measured in early pregnancy significantly predicted subjective, self-report measures of psychological distress throughout gestation, it was found that the characteristic did not significantly predict whether women subsequently received a diagnosis of high blood pressure. The findings from Study Two similarly suggested that trait mindfulness assessed early in pregnancy was not predictive of systolic or diastolic blood pressure trajectories across pregnancy. These results are not in line with other research which has found that mindfulness-based interventions can exert beneficial effects on maternal cardiovascular activity.

It is possible that the effects of mindfulness in pregnancy are important, though they may be more easily observed acutely. Little work has examined the in-the-moment effects of mindfulness meditation on mood and cardiovascular activity in pregnancy. In addition, trait mindfulness has been proposed as a moderator of the effects of interventions, though this question has yet to be examined using a brief, short-term intervention in the gestational period.

Study Three built upon the first two studies by examining the immediate effects of a presumably mindfulness-enhancing body scan meditation on maternal heart rate, heart rate variability (HRV), and mood, with particular attention to the moderating effects of trait mindfulness.

Manuscript Three:

The effects of a body scan meditation on mood, state mindfulness and cardiovascular activity in pregnancy: A virtual laboratory study

*Serena Mennitto, BA[1], and Blaine Ditto, PhD.[1]

From the [1] Department of Psychology, Faculty of Science, McGill University, Montreal, Quebec, Canada

Abstract

Background: Mindfulness-based interventions have been generally shown to be useful as preventative treatments for both psychological and cardiovascular disorders of pregnancy. However, little work has examined the in-the-moment effects of mindfulness meditation on mood and cardiovascular function in pregnancy. In addition, trait mindfulness has been proposed as a moderator of the effects of interventions, though this question has yet to be examined using a short-term intervention in this period.

Methods: 43 pregnant women participated in a within-subjects controlled trial. At baseline, participants completed the Five Facet Mindfulness Questionnaire. In virtual laboratory visits approximately one week apart, participants were asked to follow a guided body scan meditation or to listen to an audiobook. In the pre- and post-intervention periods, participants obtained measures of heart rate and heart rate variability using a cellular phone application that converts the camera to a photoplethysmograph. They also provided ratings of state mindfulness and affect.

Results: State mindfulness increased in both conditions. While the more mindful mothers seemed to benefit more from the two relaxing activities in terms of heart rate variability, the less mindful participants reported a greater decrease in negative affect post-activity. In general, women experienced a greater reduction in heart rate in the meditation condition than the audiobook condition.

Conclusions: These results suggest that a brief, mindfulness-based body scan meditation may have beneficial effects on cardiovascular health and mood, though these effects may be moderated by trait mindfulness. Further research should be conducted to determine the duration

of these effects, particularly in more diverse samples. Also, while there were several interesting associations with mindfulness, causal relationships with variables such as heart rate remain unclear and require further research.

Introduction

Pregnancy and the transition to parenthood is usually experienced as a meaningful part of life. On the other hand, this transition can be a turbulent time, involving varying degrees of stress and reward for parents-to-be (Umberson et al., 2010). Pregnancy has been described as a "stress test for life" (Williams, 2003). There are a number of possible sources of stress for pregnant women that range from short-term practical and medical issues such as having to deal with frequent medical appointments, childcare for current children, juggling work responsibilities, and physical symptoms such as nausea and fatigue, to longer-term concerns about finances, risk for pregnancy complications, the health of the baby and their ability to be a "good" parent. Epidemiological studies have been conducted on the prevalence of psychological distress in this period, focusing mainly on the presence or absence of a diagnosable psychiatric disorder. Though there are significant variations in reported prevalence based on study methodology, in general, it has been found that a large proportion of pregnant women suffer with depression and anxiety. More specifically, approximately one in seven women will report depression in the prenatal and postpartum period, while one in five women will report significant anxiety in these periods (Dunkel Schetter & Tanner, 2012; Leight et al., 2010).

These effects may also have medical consequences. Although the pregnant body adapts to the presence of the new fetus, some women develop physical complications including hypertensive disorders of pregnancy, which have been found to adversely impact maternal health in the short and long term (Tranquilli et al., 2012; Wu et al., 2017). Research strongly suggests that psychological distress and poor maternal mental health during pregnancy can contribute to the development of medical conditions and poor birth outcomes (Dunkel Schetter & Tanner, 2012; Staneva et al., 2015; Zhang et al., 2013).

Recently, mindfulness-based interventions have been studied as possible strategies to mitigate psychological and physical health conditions in pregnancy. Mindfulness can be conceptualized in two main ways. The first is as a state which one can achieve, through a process by which attention is maintained on present-moment experience in a spirit of curiosity and acceptance toward the self (Kabat-Zinn, 2006). Bishop and colleagues (2006) have identified two components of state mindfulness: the "self-regulation of attention", involving sustained attention, the reorientation of attention and the inhibition of elaborative processing, and "orientation to experience", which involves remaining open to gain insight about the subjectivity and transient nature of thoughts (Bishop et al., 2006). Mindfulness-based meditation is one method through which an individual can access a state of mindfulness. The second conceptualization of mindfulness is trait or dispositional mindfulness, which is a person's tendency to experience mindful states in their day-to-day life (Baer et al., 2008). By definition, people high in trait mindfulness have more periods of state mindfulness daily, though the additional benefit this brings is unclear.

Most of the research on mindfulness-based interventions in pregnancy has focused on assessing the efficacy of long-term programs or practice in preventing psychological and physical health conditions. For example, the MindBabyBody program, which consisted of mindful movement practices, meditation, and cognitive exercises, reduced depression and anxiety in high-risk women in a two-month-long trial (Woolhouse, Mercuri, Judd, & Brown, 2014). Similar results have been found in non-clinical, community-based pregnant samples (Beattie et al., 2017; Duncan et al., 2017; Vieten & Astin, 2008) and using online-based meditation interventions (Kubo et al., 2021). In terms of physiological outcomes, Muthukrishnan et al. (2016) found a decreased systolic blood pressure response to a mental arithmetic task, a

decrease in blood pressure response to the cold pressor test, and an increase in resting heart rate variability (HRV) in pregnant women who participated in a meditation group for five weeks. Their results are consistent with those of Satyapriya et al. (2009), who found an increase in high frequency HRV during yoga practice in pregnant participants of a yoga and deep relaxation program. In general, the authors of one recent review conclude that mindfulness-based interventions may increase HRV (Christodoulou et al., 2020).

Still, more research is necessary to better understand the in-the-moment effects of mindfulness-based practices on mood and physical health in pregnancy. Mindfulness-based programs, such as the MindBabyBody program, consist of many types of practice and sometimes include exercises based on other types of therapy, including cognitive therapies (e.g., Vieten & Astin, 2008; Woolhouse et al., 2014). This has made it difficult to isolate the effects of meditation practices on health. As well, dependent measures are often collected only pre- and post-intervention.

In non-pregnant populations, it has been found that participating in a mindfulness-based activity can have an immediate effect on mood and cardiovascular function. For example, a single meditation session improved participants' mood in the immediate aftermath (Johnson et al., 2015). It has also been found that HRV increases during mindfulness-based interventions, though there may be individual differences in HRV trajectory related to characteristics such as coping resources (Krick et al., 2021). In a sample of undergraduate students, it was found that participants experienced a larger increase in respiratory sinus arrhythmia while meditating than while engaging in other presumably relaxing activities such as listening to an audiobook or sitting quietly (Ditto et al., 2006). There may be other cardiovascular effects such as a temporary decrease in blood pressure (Ditto et al., 2006; Steinhubl et al., 2015). On the other hand, results

from a randomized controlled trial in a pregnant population showed that muscle relaxation and guided imagery were associated with a decrease in heart rate (HR) from baseline, but that there was no significant change in blood pressure pre- to post-intervention (Urech et al., 2010). Further research would be required to evaluate the effectiveness of mindfulness-based interventions more specifically in pregnant women. In the later stages of pregnancy, mothers display blunted physiological responses to stress. It has been hypothesized that this blunting effect could extend to responses to mind-body interventions (Christian, 2012).

A secondary question in much of the literature on mindfulness-based interventions is who benefits from these kinds of treatments. Trait mindfulness has been proposed as a potential moderator of the effects of mindfulness-based interventions. This would make sense because these interventions are designed to increase participants' general dispositional mindfulness. The findings relating to this question in non-pregnant samples have been mixed thus far, as some have found that trait mindfulness is a significant moderator of treatment outcomes (Shapiro et al., 2011), while others have not (Greeson et al., 2015). To our knowledge, the potential moderating effect of the trait has not been examined in pregnancy using a brief, mindfulness-based meditation.

The goal of the present study was to determine the effects of a brief, mindfulness-based body scan meditation on maternal mood, state mindfulness and HRV in pregnancy as compared to a passive listening control condition. The secondary aim was to examine the potential moderating effects of trait mindfulness on the effectiveness of the intervention.

Materials and Methods

Procedure

Potential participants were recruited through advertisements posted in North America-based, pregnancy-related Facebook groups. They were asked to email the research team to indicate their interest and were included if they were currently pregnant, older than 18 years of age, could communicate in English, had access to an Apple- or Android-based smartphone, as well as any device that supported the use of Microsoft Teams.

Once they had provided informed consent, they were emailed a link to a secure website where they completed the baseline questionnaires. The use of online self-report measures and testing was intended to reduce participant burden and to maximize study participation during the Covid-19 pandemic, especially given that the prenatal period is generally a challenging period. The completion of baseline assessment occurred on average at 20 weeks gestation (M = 20.5, SD = 9.5).

Once the baseline questionnaires were completed, participants were invited to two virtual visits, approximately one week apart, with a research assistant through Microsoft Teams. They received the intervention and control portions of the study in separate sessions. The structure of each visit was as follows. First, participants completed the pre-test measures through a secure website. Following completion of the psychological measures, participants provided 1.5 minutes of continuous HR using the HeartRate+ Coherence PRO phone application, discussed in more detail below (Softarea srl, 2021). When they were in the intervention condition, participants were then prompted to follow a 13-minute-long body scan meditation, abridged from a meditation designed by Kabat-Zinn (2013). During this meditation, participants were invited to pay attention

to what they experienced in their body at every moment, beginning with a sense of the body as a whole. They were then guided to attend to sensations in particular body parts, beginning with the toes and moving up the body slowly until they reached the top of the head. At regular intervals, participants were prompted to return to the exercise if they found themselves distracted. When in the control condition, participants were asked to listen to a 13-minute-long excerpt of the beginning of *Harry Potter and the Philosopher's Stone* (Rowling, 2004). Once the meditation or audiobook portion was complete, participants provided a second continuous measure of HR and completed the post-test questionnaires.

The meditation and the audiobook recordings were made by the same person in a similar vocal volume and tone. The order of conditions was counterbalanced across participants, such that half the sample received the meditation condition first and vice versa. The excerpt of *Harry Potter* was used as a listening control condition in a previous study examining the effects of mindfulness-based meditation in a non-pregnant population because it can hold the audience's attention but is not one of the more exciting sections of the novel (Ditto et al., 2006).

Ethics approval was granted by the McGill University Research Ethics Board # 21-09-022.

Baseline Self-Report Measures

At the baseline assessment, participants provided demographic information such as their age, ethnicity, education, income, height and weight, and characteristics of their current pregnancy including gestational age and parity. Maternal self-reported height and weight were used to calculate their pre-pregnancy and current body mass index (BMI) in kg/m^2.

The Five-Facet Mindfulness Questionnaire (FFMQ) was used to assess maternal trait mindfulness (Baer et al., 2008). It is a 39-item scale which provides a total score and five subscale scores: Observing, Describing, Acting with awareness, Non-judging of inner experience, and Non-reactivity to inner experience. This scale has previously been validated to assess trait mindfulness during pregnancy (Kantrowitz-Gordon, 2018). The alpha coefficients for the FFMQ subscales have been found to range from .75 to .89 in a large pregnant sample, which represents adequate to good internal consistency (Kantrowitz-Gordon, 2018). Higher scores indicate higher trait mindfulness.

Participants also completed the Prenatal Distress Questionnaire-Revised (PDQR), a 17-item self-report measure of the extent to which they felt bothered, upset or worried about pregnancy-specific stressors, such as child health, parenting and physical symptoms of pregnancy (Lobel et al., 2008). Items are rated on a 3-point Likert scale (0= not at all, 1= somewhat, 2= very much) such that total scores range from 0 to 34. This scale has been associated with health behaviours including eating, exercising and cigarette smoking, as well as birth outcomes such as earlier delivery (Lobel et al., 2008). Previously reported scale reliabilities range from $\alpha = .73$ to .95 (Alderdice et al., 2012).

Maternal depression was assessed using the Edinburgh Postnatal Depression Scale (EPDS; Cox et al., 1987). The scale is composed of 10 items concerning participants' emotional experience in the previous 7 days. The EPDS has been found to have good internal consistency, $\alpha = .87$ (Cox et al., 1987). While originally developed to assess depression during the postpartum period, the EPDS has also been validated for use during pregnancy (Bergink et al., 2011; Kozinszky & Dudas, 2015). In the current study, the final item asking participants about suicidal

ideation was omitted to avoid even the slim possibility of an inadvertent iatrogenic effect of asking about self-harm.

Virtual Visit Self-Report Measures

Before and after the interventions in both conditions, participants completed the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988). The PANAS consists of two, 10-item subscales which measure the relatively uncorrelated and independent constructs of negative and positive affect. Negative affect is a measure of distress which includes unpleasant emotional experiences including fear, guilt, anger and contempt. Lower negative affect scores indicate that a participant feels calm. Positive affect reflects the extent to which the participant feels motivated, concentrated and enthusiastic in the moment. Lower positive affect scores are related to sadness and lethargic mood. It has previously been shown that when participants are instructed to answer the scales based on how they feel in the present moment, both scales are sensitive to fluctuations in mood (Watson et al., 1988).

In addition, participants completed the Toronto Mindfulness Scale (TMS; Lau et al., 2006) before and after the audiobook and meditation interventions as a manipulation check. The TMS is a reliable and valid 13-item scale measuring state mindfulness, defined as an experience cultivated when attention is intentionally focused with a curious and nonjudgmental attitude (Bishop et al., 2006). Higher scores indicate that participants perceived themselves as being in a more mindful state.

Preceding the meditation and control interventions, participants were asked to complete an adapted version of the Credibility/Expectancy Questionnaire (Devilly & Borkovec, 2000). This scale was developed to assess expectancy about interventions and the credibility of treatment rationales in participants of intervention studies. Participants were asked to respond to

11 items, which indicated the extent to which they expected the intervention they were receiving that session would affect their mood and physical health in the immediate aftermath of the intervention. This questionnaire was previously found to have high internal consistency (Devilly & Borkovec, 2000).

Measures of Cardiovascular Function

Photoplethysmography was used to obtain 1.5 minutes of continuous HR data via the HeartRate+ Coherence PRO mobile application immediately preceding and following the interventions (Softarea srl, 2021). Participants were instructed to hold their index finger on their mobile phone camera, which projected a light onto the finger in order to track blood vessel transparency, which varies with blood flow. This method of obtaining HR and HRV measurements has been previously found to be effective and accurate in non-moving participants, though there are some limitations related to potential confounders such as participants' finger pressure, skin tone, and movement, as well as telephone light intensities (Li et al., 2019).

Several dependent measures were calculated off-line using the sequential interbeat intervals provided by the HeartRate+ Coherence PRO application. HRV was evaluated using the Kubios HRV Standard program, version 3.4 (Tarvainen et al., 2014). Estimates of high frequency (0.15–0.4 Hz) HRV and low frequency (0.04–0.15 Hz) HRV in normalized units (nu) were obtained. Normalized units are an estimate of relative power, which divides the absolute power for a specific frequency band by the summed absolute power of both the low frequency and high frequency bands. This method affords the direct comparison of frequency-domain measurements across participants in spite of variation in absolute specific and total power (Kuusela, 2012).

High frequency HRV is considered to be a relatively pure index of parasympathetic system activity (Shaffer & Ginsberg, 2017). On the other hand, low frequency HRV is often used as an index of cardiac sympathetic activity. However, low frequency HRV has been linked to both sympathetic and parasympathetic system activity (Akselrod et al., 1981; Appel et al., 1989; Goldstein et al., 2011). It is important to note that the relationship between the sympathetic and parasympathetic systems is complex, and that increased activity in one system may or may not have an impact on activity in the other (Shaffer & Ginsberg, 2017).

Results

Participant Characteristics

A total of 62 women provided informed consent to participate in the study and completed the baseline questionnaire. 43 completed both the control and mindfulness sessions. There were no statistical differences between those who completed both sessions versus only one session in demographic variables or baseline questionnaire scores. Only those who completed both sessions were included in the following analyses.

Of those who completed both sessions, 27 were able to provide HR data using the HeartRate+ Coherence PRO application. This was mainly due to the inability of some women to effectively use the application. Thus, the sample of women who are included in the analyses of self-report, psychological outcome measures is 43, while the sample of women included in the analyses of cardiovascular outcomes is 27. There were no significant demographic differences between these two subsamples.

Characteristics of the sample retained for analysis are presented in Table 1. More than half of participants identified as White and primiparous. Average maternal age was 32.4 in the

sample used in the analyses of self-report measures (sd = 6.0) and 31.8 in the subsample who provided cardiovascular data (sd = 5.5). Most were married. The mean FFMQ score obtained in the first assessment was 3.2 (sd = 0.4) in both subsamples. These scores are generally comparable to those reported in other samples (Baer et al., 2008; Pan et al., 2019).

Statistical Analyses

Repeated measures general linear models were employed to investigate the potential moderating effects of trait mindfulness on participant responses to the meditation and control interventions. Outcomes included state mindfulness, positive and negative affect, RR interval, and HRV. Baseline FFMQ score was treated as a continuous variable to avoid the loss of information that might occur if participants were partitioned into several groups.

There were no demographic differences between women with higher and lower trait mindfulness. However, higher trait mindfulness was significantly associated with lower EPDS and PDQR scores, indicating that in this sample more mindful pregnant women were generally reporting fewer symptoms of depression ($r = -.59$, $p < .001$) and pregnancy-related distress ($r = -.38$, $p = .003$). As a result, to examine the effects of trait mindfulness more specifically, EPDS and PDQR scores were entered as covariates in the following analyses.

There were no differences in beliefs about credibility/expectancy of benefit between the control and meditation conditions.

State Mindfulness

Despite being described as a mindfulness exercise, the body scan meditation did not specifically increase ratings of state mindfulness. There were no significant effects involving Condition in the Condition x Time x Trait Mindfulness analysis of TMS scores. On the other

hand, there were significant effects of Time, $F(1,39) = 5.369$, $p = .026$, $\eta_p^2 = .121$, and Time x Trait Mindfulness $F(1,39) = 5.122$, $p = .029$, $\eta_p^2 = .116$. In general, these breaks in the women's day, either for meditation or to listen to an audiobook, increased their sense of mindfulness, especially for women with higher trait mindfulness (Figure 1).

Effects on Cardiovascular Activity

The HRV results underscored the somewhat generic effects of the two procedures and their relatively greater impact on more mindful women. Like the analysis of TMS scores, the analysis of HFnu produced significant effects of Time, $F(1,23) = 8.888$, $p = .007$, $\eta_p^2 = .279$, and Time x Trait Mindfulness, $F(1,23) = 6.636$, $p = .017$, $\eta_p^2 = .224$. This indicated that, across conditions, more mindful women generally displayed an increase in high frequency HRV at the end of the sessions compared to less mindful women whose high frequency HRV stayed the same or decreased (Figure 2).

The analysis of LFnu showed a mirror effect with both significant Time, $F(1,23) = 9.151$, $p = .006$, $\eta_p^2 = .285$, and Time x Trait Mindfulness, $F(1,23) = 6.936$, $p = .015$, $\eta_p^2 = .232$, effects. In general, more mindful women displayed a decrease in low frequency HRV at the end of the sessions compared to less mindful women. This interaction is illustrated in Figure 3.

While the results of the analyses described above suggested relatively generic effects of the two presumably relaxing procedures, there was also some evidence of more specific effects of the mindfulness exercise.

In particular, the Condition x Time interaction effect in the analysis of RR interval was significant, $F(1,23) = 4.308$, $p = .049$, $\eta_p^2 = .158$. This was due to a greater slowing of the heart during the mindfulness exercise compared to listening to the audiobook. As can be seen in Figure

4, although the Condition x Time x Trait Mindfulness interaction was not quite significant, $F(1,23) = 3.862$, $p = .062$, this was due primarily to women with higher trait mindfulness. There were no other significant effects in the analysis of RR interval.

Effects on Mood

As far as changes in mood as measured by the PANAS, there were no significant effects in the analysis of Positive Affect. However, the analysis of Negative Affect scores yielded a significant Condition x Time interaction, $F(1,39) = 11.474$, $p = .002$, $\eta_p^2 = .227$, as well as a significant Condition x Time x Trait Mindfulness Interaction, $F(1,39) = 10.486$, $p = .002$, $\eta_p^2 = .212$. Somewhat unexpectedly given the results discussed above, this was due to a greater decrease in negative affect in less mindful women during the meditation condition (Figure 5). However, they decreased to a level equivalent to more mindful women at that point. The interaction was due to the fact that more mindful women began the mindfulness session with lower negative affect, another indication of generally fewer psychological symptoms in more mindful women.

Sub-analyses of Observing Subscale

Given the modest sample size, it was not appropriate to examine the effects of all FFMQ subscales. However, the Observing subscale was the measure most closely related to the mindfulness questionnaire used in the previous studies of this project (the MAAS). This subscale reflects the tendency to observe one's internal experiences, including cognitions, emotions, and sensations, and external environment. As a result, the previous analyses were re-done substituting Observing for the total FFMQ score.

Most notably, the three-way Condition x Time x Observing interaction in the analysis of RR interval was significant, $F(1,23) = 7.667$, $p = .011$, $\eta_p^2 = .250$. This was due to a lengthening of the RR interval and a decrease in HR in more mindful women in the meditation condition. On the other hand, less mindful women experienced a decrease in the RR interval in the meditation condition.

Discussion

The present investigation sought to determine the effects of a brief, mindfulness-based body scan meditation on maternal mood, state mindfulness and HRV in pregnancy as compared to a control condition. The secondary aim was to examine the potential moderating effects of trait mindfulness on the effectiveness of the intervention.

In general, brief periods of relaxation, whether by listening to an audiobook or by practicing a mindfulness exercise, seemed to increase mindfulness and high frequency HRV related to vagal activity temporarily. These findings are not especially surprising, but nevertheless useful and support the value of such an activity. As well, participants with higher FFMQ scores generally displayed greater increases in state mindfulness and high frequency HRV and greater decreases in low frequency HRV regardless of condition. Across all participants, the RR interval lengthened more in the meditation condition than in the audiobook condition. There is also a mild suggestion that practicing an activity more specifically designed to increase mindfulness may have some cardiovascular benefits in women already predisposed to mindfulness. Mothers with higher scores on the Observing subscale displayed a lengthening of the RR interval in the meditation condition, while the opposite was the case for women with lower scores. This is not to suggest that relaxing activities are unhelpful for less mindful participants. In fact, they displayed larger decreases in negative affect.

The results related to the cardiovascular measures are consistent with previous literature examining the short- and longer-term effects of mindfulness practice, though they provide more nuance. Urech et al. (2010) reported a decrease in HR during mindfulness-based practices, including guided imagery and progressive muscle relaxation, as compared to a passive relaxation control condition in a pregnant sample. Others have noted changes in HRV after participation in mindfulness-based programs, though whether trait mindfulness moderated the effects of the treatment was not reported (Muthukrishnan et al., 2016; Satyapriya et al., 2009). Interventions which exert effects on HRV in particular could represent important tools during pregnancy, as it has been shown that there is a general decrease in HRV across all trimesters of pregnancy (Garg et al., 2020; Solanki et al., 2020). In a review of studies comparing HRV in normotensive and hypertensive pregnancies, a decrease in overall HRV was found in hypertensive women (Moors et al., 2020).

On the other hand, the effects of the body scan in the current investigation on cardiovascular function may or may not extend to benefits in terms of mood. Participating in a mindfulness-based meditation activity reduced negative affect in women who are less predisposed to mindfulness to a level that is comparable to women with higher trait mindfulness. This effect could be due to the fact that the more mindful pregnant women in this sample seemed to be experiencing less psychological and emotional distress overall, which is consistent with previous research suggesting that higher FFMQ scores are associated with fewer negative affect symptoms (Carpenter et al., 2019). Johnson et al. (2019) also noted that affect improved in participants after one meditation session, though this effect extended to the sham meditation control condition as well.

However, it is important to caution against causal inferences. The present data are insufficient to determine causality. The two activities increased state mindfulness and high frequency HRV. Though these effects were more pronounced in women with higher trait mindfulness and the activity purported to increase state mindfulness produced a larger decrease in HR, it is important to note that these effects were not necessarily due to changes in state mindfulness. Indeed, in results not reported above, there were no significant correlations between the degree of change in state mindfulness and the degree of change in high frequency HRV or the degree of change in negative affect. In contrast, it is possible that these effects are linked to something else, such as an increased sense of safety and relaxation (e.g., comparable to listening to a bedtime story), that in turn reduced intrusive thinking and increased parasympathetic activity. Relatedly, it is noteworthy that the body scan meditation lowered HR significantly more than the audiobook did, despite the apparent lack of an observable greater effect on state mindfulness. It is possible that other key features of the body scan such as a greater focus on muscle tension or regular breathing were responsible for this. This represents an interesting area for further research.

Previously, it has been suggested that there is little to no association between mindful states during meditation and trait mindfulness (Bergomi et al., 2013). In the current study, it was found that state mindfulness increased in both the meditation and audiobook conditions, though interestingly, there was a moderating effect of trait mindfulness. More mindful women experienced a greater increase in state mindfulness regardless of condition than less mindful participants. In their review of the literature on mindfulness-based therapies, Xia et al. (2019) found that many active control conditions, such as equine therapy and hiking groups, also increase mindfulness over time. It may be useful to expand the definition of what consists of a

mindful activity to activities outside of meditation. Many mindfulness-based programs guide participants in performing everyday activities such as eating or washing dishes in a mindful manner (e.g., Harris & Hayes, 2019; Segal et al., 2013).

Taken together, these results suggest that the brief, body scan meditation may have beneficial, short-term effects on cardiovascular function and mood in pregnancy. Trait mindfulness is an important moderator of the effects of the body scan on these outcomes. Clinically, this information may be useful when healthcare professionals provide recommendations for meditation practice in pregnant women.

The current study focused on the time periods immediately preceding and following the meditation. Thus, the duration of these effects is not possible to determine at this time. Future research could examine the longer-term effects of brief interventions in the days following the practice. There are some other limitations to the current study. It was conducted online to reduce risk and burden to participants during the Covid-19 pandemic, rather than in a controlled, laboratory environment. That being said, cellular phone-based photoplethysmography has been considered as a useful method of assessing HR and HRV in spite of its limitations (Li et al., 2019). In addition, this approach may have more external validity given that, on a day-to-day basis, participants are more likely to meditate in a less controlled environment such as their home or workplace, which may be more distracting. The small sample size was somewhat mitigated by the within-subjects approach. However, it is important to note that the sample primarily consisted of white, highly educated, married women with incomes higher than the mean. This may be due to the fact that women were recruited online and were required to have access to the internet and a smartphone. Future research should be conducted in a more inclusive, diverse sample.

References

Akselrod, S., Gordon, D., Ubel, F. A., Shannon, D. C., Barger, A. C., & Cohen, R. J. (1981). Power Spectrum Analysis of Heart Rate Fluctuation: A Quantitative Probe of Beat-to-Beat Cardiovascular Control. *Science*, *213*(4504), 220–222. https://doi.org/10.1126/SCIENCE.6166045

Alderdice, F., Lynn, F., & Lobel, M. (2012). A review and psychometric evaluation of pregnancy-specific stress measures. *Journal of Psychosomatic Obstetrics & Gynecology*, *33*(2), 62–77. https://doi.org/10.3109/0167482X.2012.673040

Appel, M. L., Berger, R. D., Saul, J. P., Smith, J. M., & Cohen, R. J. (1989). Beat to beat variability in cardiovascular variables: Noise or music? *Journal of the American College of Cardiology*, *14*(5), 1139–1148. https://doi.org/10.1016/0735-1097(89)90408-7

Baer, R. A., Smith, G. T., Lykins, E., Button, D., Krietemeyer, J., Sauer, S., Walsh, E., Duggan, D., & Williams, J. M. G. (2008). Construct Validity of the Five Facet Mindfulness Questionnaire in Meditating and Nonmeditating Samples. *Assessment*, *15*(3), 329–342. https://doi.org/10.1177/1073191107313003

Beattie, J., Hall, H., Biro, M. A., East, C., & Lau, R. (2017). Effects of mindfulness on maternal stress, depressive symptoms and awareness of present moment experience: A pilot randomised trial. *Midwifery*, *50*, 174–183. https://doi.org/10.1016/j.midw.2017.04.006

Bergink, V., Kooistra, L., Lambregtse-van den Berg, M. P., Wijnen, H., Bunevicius, R., van Baar, A., & Pop, V. (2011). Validation of the Edinburgh Depression Scale during pregnancy. *Journal of Psychosomatic Research*, *70*(4), 385–389. https://doi.org/10.1016/j.jpsychores.2010.07.008

Bergomi, C., Tschacher, W., & Kupper, Z. (2013). The Assessment of Mindfulness with Self-Report Measures: Existing Scales and Open Issues. *Mindfulness*, *4*(3), 191–202. https://doi.org/10.1007/S12671-012-0110-9

Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., Carmody, J., Segal, Z. V., Abbey, S., Speca, M., Velting, D., & Devins, G. (2006). Mindfulness: A Proposed Operational Definition. *Clinical Psychology: Science and Practice*, *11*(3), 230–241. https://doi.org/10.1093/clipsy.bph077

Carpenter, J. K., Conroy, K., Gomez, A. F., Curren, L. C., & Hofmann, S. G. (2019). The relationship between trait mindfulness and affective symptoms: A meta-analysis of the Five Facet Mindfulness Questionnaire (FFMQ). *Clinical Psychology Review*, *74*, 101785. https://doi.org/10.1016/j.cpr.2019.101785

Christian, L. M. (2012). Physiological reactivity to psychological stress in human pregnancy: current knowledge and future directions. *Progress in Neurobiology*, *99*(2), 106–116. https://doi.org/10.1016/j.pneurobio.2012.07.003

Christodoulou, G., Salami, N., & Black, D. S. (2020). The Utility of Heart Rate Variability in Mindfulness Research. *Mindfulness*, *11*(3), 554–570. https://doi.org/10.1007/S12671-019-01296-3/TABLES/3

Cox, J. L., Holden, J. M., & Sagovsky, R. (1987). Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. *The British Journal of Psychiatry: The Journal of Mental Science*, *150*(6), 782–786. https://doi.org/10.1192/BJP.150.6.782

Devilly, G. J., & Borkovec, T. D. (2000). Psychometric properties of the credibility/expectancy questionnaire. *Journal of Behavior Therapy and Experimental Psychiatry*, *31*(2), 73–86. https://doi.org/10.1016/S0005-7916(00)00012-4

Ditto, B., Eclache, M., & Goldman, N. (2006). Short-Term Autonomic and Cardiovascular Effects of Mindfulness Body Scan Meditation. *Annals of Behavioral Medicine*, *32*(3), 227–234.

Duncan, L. G., Cohn, M. A., Chao, M. T., Cook, J. G., Riccobono, J., & Bardacke, N. (2017). Benefits of preparing for childbirth with mindfulness training: a randomized controlled trial with active comparison. *BMC Pregnancy and Childbirth*, *17*(1), 140. https://doi.org/10.1186/s12884-017-1319-3

Dunkel Schetter, C., & Tanner, L. (2012). Anxiety, depression and stress in pregnancy: implications for mothers, children, research, and practice. *Current Opinion in Psychiatry*, *25*(2), 141. https://doi.org/10.1097/YCO.0B013E3283503680

Garg, P., Yadav, K., Jaryal, A. K., Kachhawa, G., Kriplani, A., & Deepak, K. K. (2020). Sequential analysis of heart rate variability, blood pressure variability and baroreflex sensitivity in healthy pregnancy. *Clinical Autonomic Research*, *30*(5), 433–439. https://doi.org/10.1007/S10286-020-00667-4/FIGURES/1

Goldstein, D. S., Bentho, O., Park, M. Y., & Sharabi, Y. (2011). Low-frequency power of heart rate variability is not a measure of cardiac sympathetic tone but may be a measure of modulation of cardiac autonomic outflows by baroreflexes. *Experimental Physiology*, *96*(12), 1255–1261. https://doi.org/10.1113/EXPPHYSIOL.2010.056259

Greeson, J. M., Smoski, M. J., Suarez, E. C., Brantley, J. G., Ekblad, A. G., Lynch, T. R., & Wolever, R. Q. (2015). Decreased Symptoms of Depression after Mindfulness-Based Stress Reduction: Potential Moderating Effects of Religiosity, Spirituality, Trait Mindfulness, Sex, and Age. *Journal of Alternative and Complementary Medicine*, *21*(3), 166–174. https://doi.org/10.1089/ACM.2014.0285/ASSET/IMAGES/LARGE/FIGURE1.JPEG

Harris, R., & Hayes, S. C. (2019). *ACT Made Simple: an Easy-To-Read Primer on Acceptance and Commitment Therapy.* New Harbinger Publications.

Johnson, S., Gur, R. M., David, Z., & Currier, E. (2015). One-Session Mindfulness Meditation: A Randomized Controlled Study of Effects on Cognition and Mood. *Mindfulness*, *6*(1), 88–98. https://doi.org/10.1007/S12671-013-0234-6/TABLES/2

Kabat-Zinn, J. (2006). Mindfulness-Based Interventions in Context: Past, Present, and Future. *Clinical Psychology: Science and Practice*, *10*(2), 144–156. https://doi.org/10.1093/clipsy.bpg016

Kabat-Zinn, J. (2013). *Full catastrophe living: using the wisdom of your body and mind to face stress, pain, and illness*. New York, NY: Bantam Books.

Kantrowitz-Gordon, I. (2018). Factor Structure and External Validity of the Five Facet Mindfulness Questionnaire in Pregnancy. *Mindfulness*, *9*(1), 243–257. https://doi.org/10.1007/S12671-017-0768-0

Kozinszky, Z., & Dudas, R. B. (2015). Validation studies of the Edinburgh Postnatal Depression Scale for the antenatal period. *Journal of Affective Disorders*, *176*, 95–105. https://doi.org/10.1016/J.JAD.2015.01.044

Krick, A., Felfe, J., & Klug, K. (2021). Building Resilience: Trajectories of Heart Rate Variability During a Mindfulness-Based Intervention and the Role of Individual and Social Characteristics. *International Journal of Stress Management*, *28*(3), 220–231. https://doi.org/10.1037/STR0000227

Kubo, A., Aghaee, S., Kurtovich, E. M., Nkemere, L., Quesenberry, C. P., McGinnis, M. A. K., & Avalos, L. A. (2021). mHealth Mindfulness Intervention for Women with Moderate-to-Moderately-Severe Antenatal Depressive Symptoms: a Pilot Study Within an Integrated Health Care System. *Mindfulness*, *12*(6), 1387–1397. https://doi.org/10.1007/S12671-021-01606-8

Kuusela, T. (2012). Methodological aspects of heart rate variability analysis. In M. V. Kamath, M. A. Watanabe, & A. R. M. Upton (Eds.), *Heart Rate Variability (HRV) Signal Analysis: Clinical Applications* (pp. 9–42). CRC Press. https://doi.org/10.1201/B12756-4

Lau, M. A., Bishop, S. R., Segal, Z. V., Buis, T., Anderson, N. D., Carlson, L., Shapiro, S., Carmody, J., Abbey, S., & Devins, G. (2006). The Toronto mindfulness scale: Development and validation. *Journal of Clinical Psychology*, *62*(12), 1445–1467. https://doi.org/10.1002/JCLP.20326

Leight, K. L., Fitelson, E. M., Weston, C. A., & Wisner, K. L. (2010). Childbirth and mental disorders. *International Review of Psychiatry*, *22*(5), 453. https://doi.org/10.3109/09540261.2010.514600

Li, K. H. C., White, F. A., Tipoe, T., Liu, T., Wong, M. C. S., Jesuthasan, A., Baranchuk, A., Tse, G., & Yan, B. P. (2019). The current state of mobile phone apps for monitoring heart

rate, heart rate variability, and atrial fibrillation: Narrative review. *Journal of Medical Internet Research, 21*(2), e11606. https://doi.org/10.2196/11606

Lobel, M., Cannella, D. L., Graham, J. E., DeVincent, C., Schneider, J., & Meyer, B. A. (2008). Pregnancy-specific stress, prenatal health behaviors, and birth outcomes. *Health Psychology*, *27*(5), 604–615. https://doi.org/10.1037/a0013242

Moors, S., Staaks, K. J. J., Westerhuis, M. E. M. H., Dekker, L. R. C., Verdurmen, K. M. J., Oei, S. G., & van Laar, J. O. E. H. (2020). Heart rate variability in hypertensive pregnancy disorders: A systematic review. *Pregnancy Hypertension*, *20*, 56–68. https://doi.org/10.1016/J.PREGHY.2020.03.003

Muthukrishnan, S., Jain, R., Kohli, S., & Batra, S. (2016). Effect of Mindfulness Meditation on Perceived Stress Scores and Autonomic Function Tests of Pregnant Indian Women. *Journal of Clinical and Diagnostic Research*, *10*(4), CC05-8. https://doi.org/10.7860/JCDR/2016/16463.7679

Pan, W. L., Chang, C. W., Chen, S. M., & Gau, M. L. (2019). Assessing the effectiveness of mindfulness-based programs on mental health during pregnancy and early motherhood - A randomized control trial. *BMC Pregnancy and Childbirth*, *19*(1), 1–8. https://doi.org/10.1186/S12884-019-2503-4/TABLES/3

Rowling, J. K. (2004). *Harry Potter and the Philosopher's Stone*. Raincoast Books.

Satyapriya, M., Nagendra, H. R., Nagarathna, R., & Padmalatha, V. (2009). Effect of integrated yoga on stress and heart rate variability in pregnant women. *International Journal of Gynecology & Obstetrics*, *104*(3), 218–222. https://doi.org/10.1016/j.ijgo.2008.11.013

Segal, Z. V., Williams, J. M. G., & Teasdale, J. D. (2013). *Mindfulness-based cognitive therapy for depression*. New York, NY: Guilford Press.

Shaffer, F., & Ginsberg, J. P. (2017). An Overview of Heart Rate Variability Metrics and Norms. *Frontiers in Public Health*, *5*, 258. https://doi.org/10.3389/FPUBH.2017.00258/BIBTEX

Shapiro, S. L., Brown, K. W., Thoresen, C., & Plante, T. G. (2011). The moderation of Mindfulness-based stress reduction effects by trait mindfulness: Results from a randomized controlled trial. *Journal of Clinical Psychology*, *67*(3), 267–277. https://doi.org/10.1002/JCLP.20761

SoftArea srl. (2020). *HeartRate + Coherence PRO* (version 3.2.4) [Mobile app]. App Store. https://apps.apple.com/us/app/id763865838?l=it&ls=1

Solanki, J., Desai, F., & Desai, K. (2020). Heart rate variability is reduced in normal pregnancy irrespective of trimester: A cross-sectional study from Gujarat, India. *Journal of Family Medicine and Primary Care*, *9*(2), 626-631. https://doi.org/10.4103/JFMPC.JFMPC_1123_19

Staneva, A. A., Bogossian, F., & Wittkowski, A. (2015). The experience of psychological distress, depression, and anxiety during pregnancy: A meta-synthesis of qualitative research. *Midwifery*, *31*(6), 563–573. https://doi.org/10.1016/j.midw.2015.03.015

Steinhubl, S. R., Wineinger, N. E., Patel, S., Boeldt, D. L., Mackellar, G., Porter, V., Redmond, J. T., Muse, E. D., Nicholson, L., Chopra, D., & Topol, E. J. (2015). Cardiovascular and nervous system changes during meditation. *Frontiers in Human Neuroscience*, *9*, 145. https://doi.org/10.3389/fnhum.2015.00145

Tarvainen, M. P., Niskanen, J. P., Lipponen, J. A., Ranta-aho, P. O., & Karjalainen, P. A. (2014). Kubios HRV – Heart rate variability analysis software. *Computer Methods and Programs in Biomedicine*, *113*(1), 210–220. https://doi.org/10.1016/J.CMPB.2013.07.024

Tranquilli, A. L., Landi, B., Giannubilo, S. R., & Sibai, B. M. (2012). Preeclampsia: No longer solely a pregnancy disease. *Pregnancy Hypertension: An International Journal of Women's Cardiovascular Health*, *2*(4), 350–357. https://doi.org/10.1016/J.PREGHY.2012.05.006

Umberson, D., Pudrovska, T., & Reczek, C. (2010). Parenthood, Childlessness, and Well-Being: A Life Course Perspective. *Journal of Marriage and Family*, *72*(3), 612–629. https://doi.org/10.1111/j.1741-3737.2010.00721.x

Urech, C., Fink, N. S., Hoesli, I., Wilhelm, F. H., Bitzer, J., & Alder, J. (2010). Effects of relaxation on psychobiological wellbeing during pregnancy: A randomized controlled trial. *Psychoneuroendocrinology*, *35*(9), 1348–1355. https://doi.org/10.1016/j.psyneuen.2010.03.008

Vieten, C., & Astin, J. (2008). Effects of a mindfulness-based intervention during pregnancy on prenatal stress and mood: results of a pilot study. *Archives of Women's Mental Health*, *11*, 67–74. https://doi.org/10.1007/s00737-008-0214-3

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and Validation of Brief Measures of Positive and Negative Affect: The PANAS Scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070. https://doi.org/10.1037/0022-3514.54.6.1063

Williams, D. (2003). Pregnancy: a stress test for life. *Current Opinion in Obstetrics & Gynecology*, *15*(6), 465–471. https://doi.org/10.1097/00001703-200312000-00002

Woolhouse, H., Mercuri, K., Judd, F., & Brown, S. J. (2014). Antenatal mindfulness intervention to reduce depression, anxiety and stress: a pilot randomised controlled trial of the MindBabyBody program in an Australian tertiary maternity hospital. *BMC Pregnancy and Childbirth*, *14*(1), 369. https://doi.org/10.1186/s12884-014-0369-z

Wu, P., Haththotuwa, R., Kwok, C. S., Babu, A., Kotronias, R. A., Rushton, C., Zaman, A., Fryer, A. A., Kadam, U., Chew-Graham, C. A., & Mamas, M. A. (2017). Preeclampsia and Future Cardiovascular Health: A Systematic Review and Meta-Analysis. *Circulation. Cardiovascular Quality and Outcomes*, *10*(2). https://doi.org/10.1161/CIRCOUTCOMES.116.003497

Xia, T., Hu, H., Seritan, A. L., & Eisendrath, S. (2019). The Many Roads to Mindfulness: A Review of Nonmindfulness-Based Interventions that Increase Mindfulness. *The Journal of Alternative and Complementary Medicine*, *25*(9), 874–889. https://doi.org/10.1089/acm.2019.0137

Zhang, S., Ding, Z., Liu, H., Chen, Z., Wu, J., Zhang, Y., & Yu, Y. (2013). Association Between Mental Stress and Gestational Hypertension/Preeclampsia. *Obstetrical & Gynecological Survey*, *68*(12), 825–834. https://doi.org/10.1097/OGX.0000000000000009

Table 3.1

Participant Characteristics

Variable	Participants in Analyses of Self-Report Outcomes (n=43)	Participants in Analyses of Physiological Outcomes (n=27)
Maternal age (years/sd)	32.4 (5.0)	31.8 (5.5)
Pre-Pregnancy Body Mass Index (units/sd)	24.7 (4.2)	24.7 (3.5)
Current Body Mass Index (units/sd)	26.7 (4.0)	26.8 (3.4)
Gestational age (weeks/sd)	20.2 (9.3)	21.3 (8.9)
Ethnicity (*n*/%)		
White	27 (62.8)	18 (66.7)
Chinese	4 (9.3)	2 (7.4)
Arab	1 (2.3)	1 (3.7)
Black	7 (16.3)	5 (18.5)
Other	4 (9.3)	1 (3.7)

Education (*n*/%)		
High school	2 (4.7)	1 (3.7)
> High school	41 (95.3)	26 (96.3)
Marital status (*n*/%)		
Married	31 (72.1)	20 (74.1)
Co-habiting	8 (18.6)	4 (14.8)
Single	4 (9.3)	3 (11.1)
Employment status (*n*/%)		
Full-time	29 (67.4)	20 (74.1)
Part-time	5 (11.6)	3 (11.1)
Student	2 (4.7)	1 (3.7)
Medical leave	3 (7.0)	2 (7.4)
Maternity leave	2 (4.7)	1 (3.7)
Other	2 (4.7)	0 (0)
Income (*n*/%)		
More than $120,000	20 (46.5)	15 (55.6)
81,000 - $120,000	7 (16.3)	6 (22.2)
41,000 - $80,000	4 (9.3)	1 (3.7)

Less than $40,000	7 (16.3)	5 (18.5)
Did not disclose	2 (4.7)	0 (0)
Parity (*n*/%)		
Primiparous	28 (65.1)	18 (66.7)
Multiparous	14 (32.6)	9 (33.3)
Did not disclose	1 (2.3)	0 (0)
FFMQ Score	3.2 (0.4)	3.2 (0.4)
EPDS Score	13.2 (3.4)	13.0 (3.2)
PDQR Score	9.3 (3.6)	9.5 (4.0)

Figure 3.1

Pre- and Post-Intervention State Mindfulness Based on Trait Mindfulness

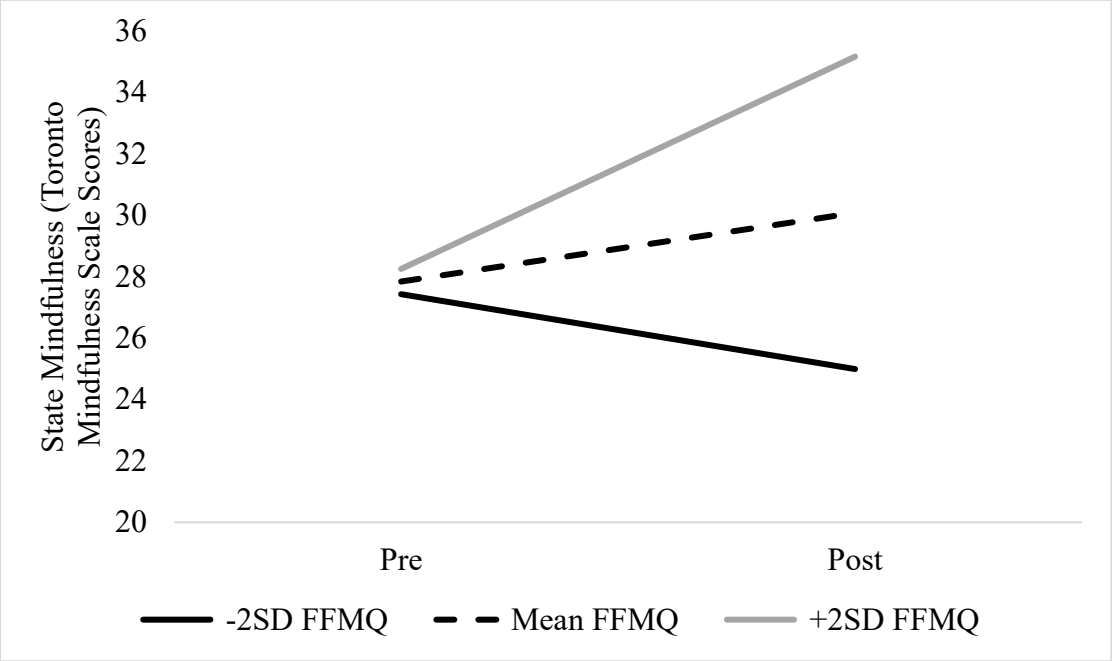


Figure 3.2

Pre- and Post-Intervention High Frequency Heart Rate Variability Based on Trait Mindfulness

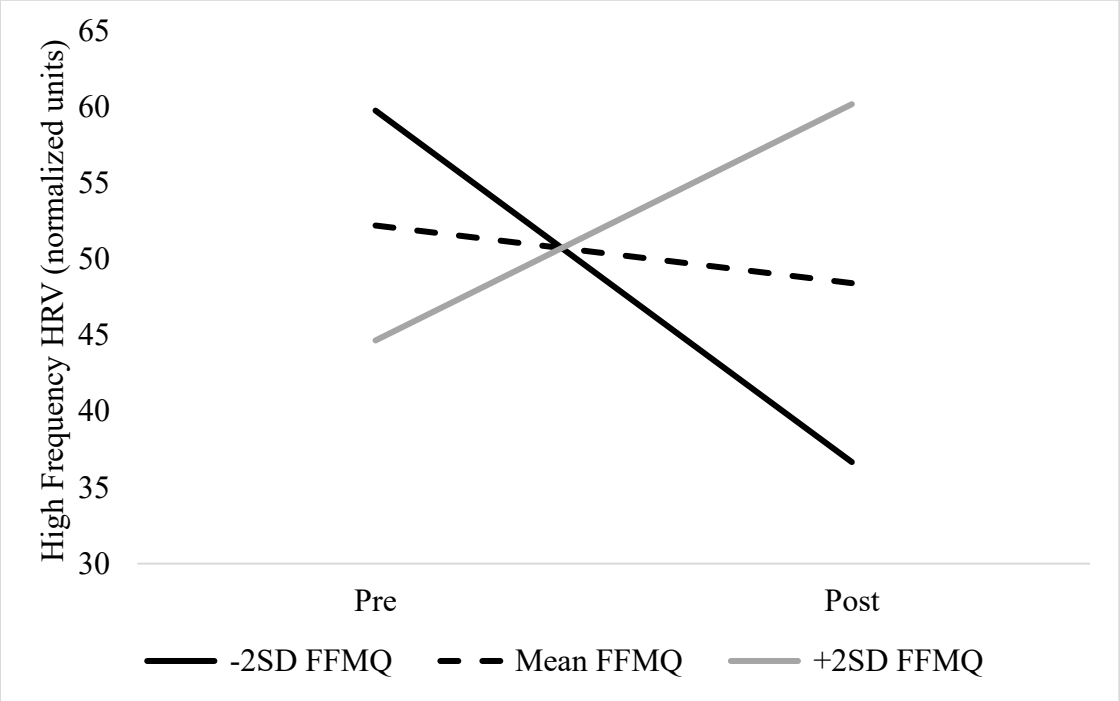


Figure 3.3

Pre- and Post-Intervention Low Frequency Heart Rate Variability Based on Trait Mindfulness

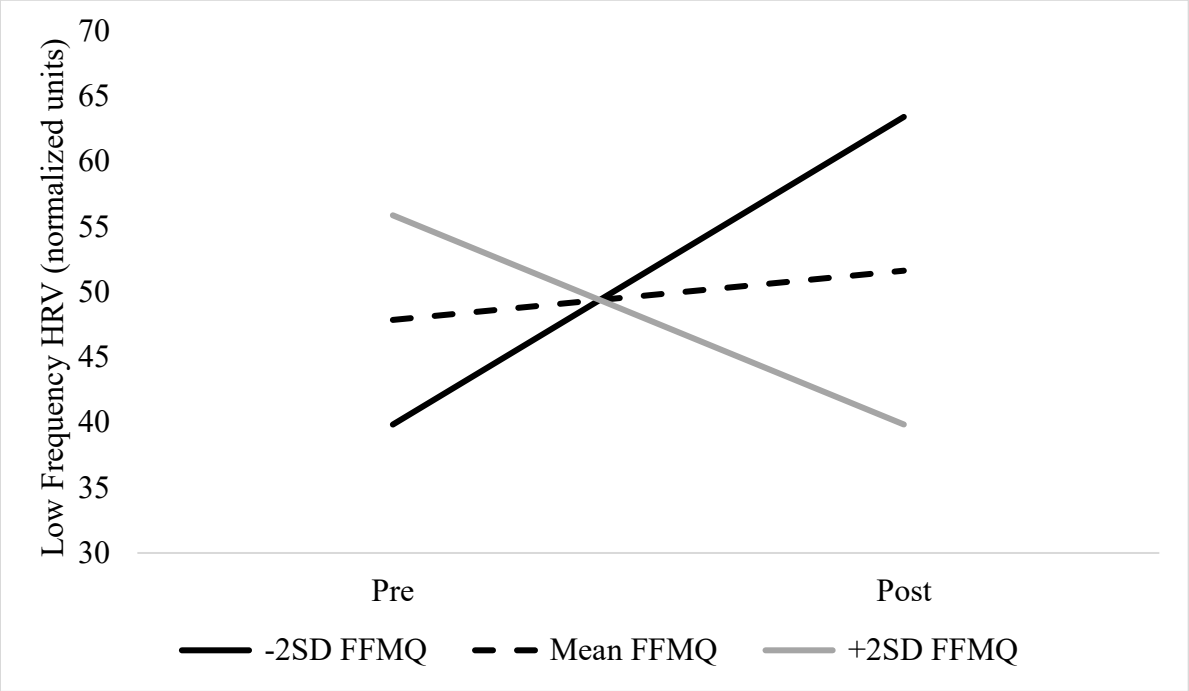


Figure 3.4

RR Interval Based on Trait Mindfulness, Condition and Time

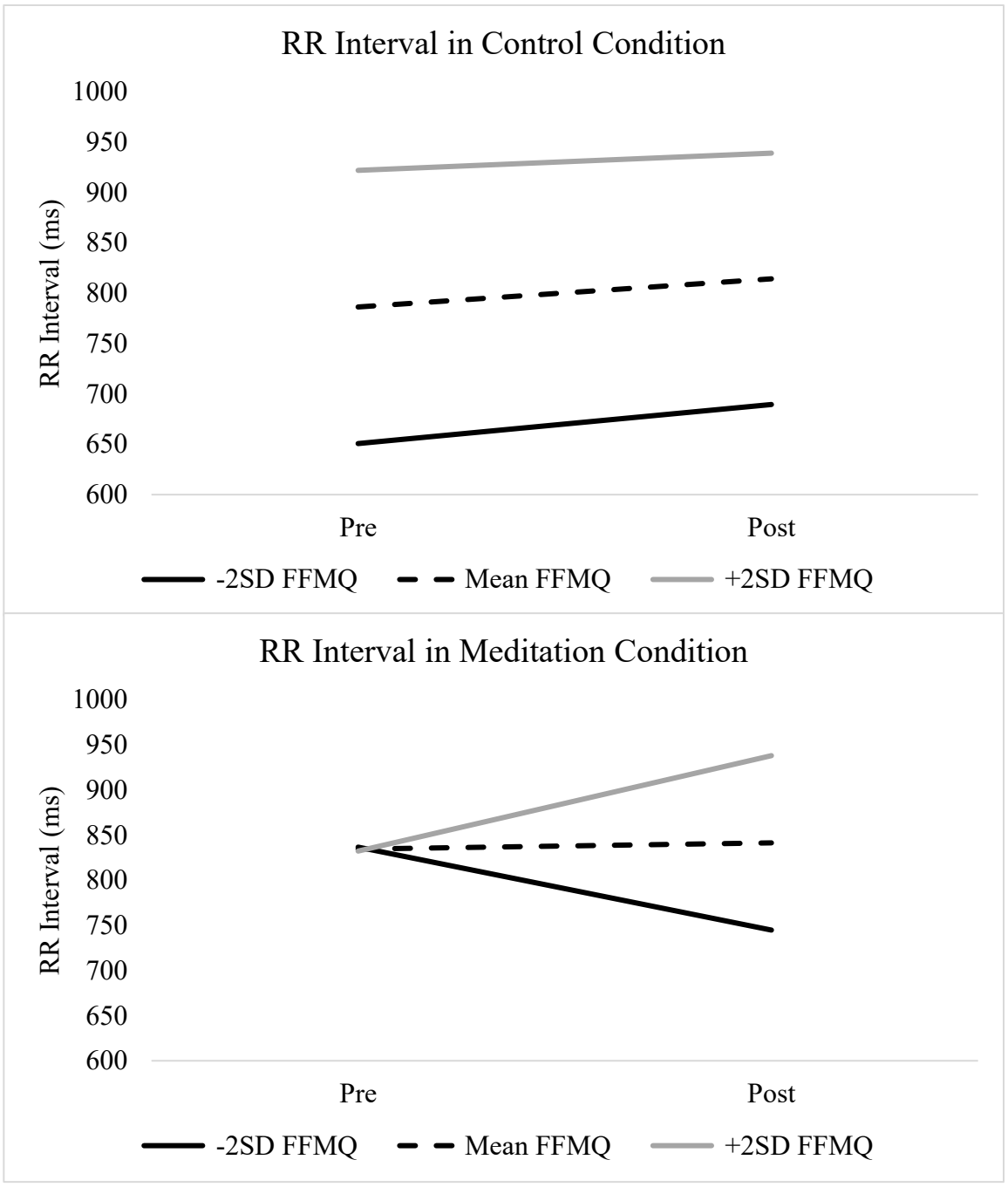
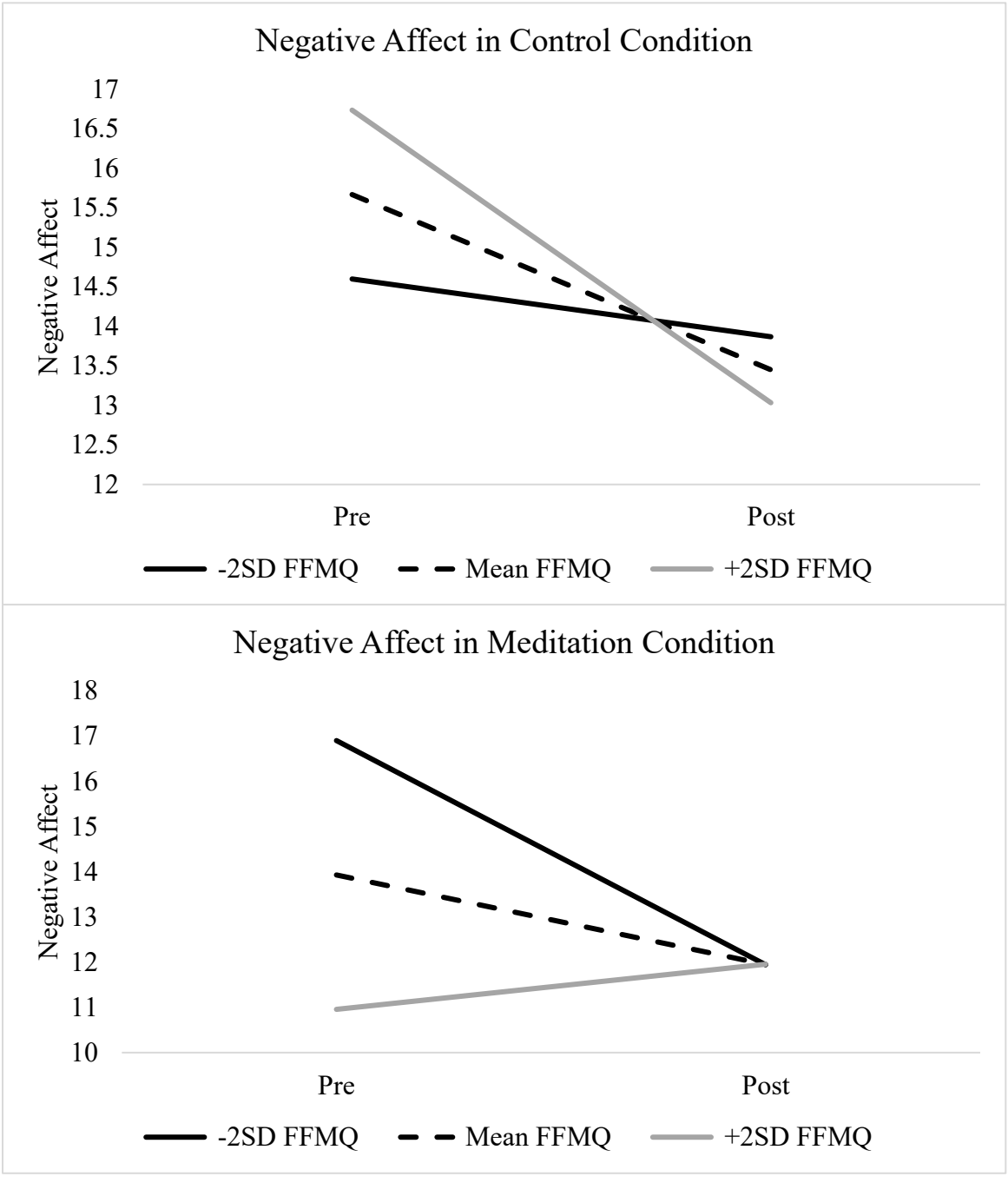


Figure 3.5

Negative Affect Based on Trait Mindfulness, Condition and Time



General Discussion

Pregnancy and the transition to parenthood can be experienced with mixed feelings on the part of the parent-to-be. This transition is often as turbulent as it is meaningful, involving various novel sources of stress for parents. These might include short-term issues such as having to deal with frequent medical appointments, childcare for current children, work responsibilities, and physical symptoms such as pain and fatigue, as well as long-term worries about finances, the potential risk for complications, the health of the fetus and their ability to have a positive impact on their child's development. Previous research suggests that psychological distress and poor maternal mental health during pregnancy can contribute to the development of medical conditions and poor birth outcomes. Recently, mindfulness-based interventions have been studied for their potential role in the prevention or mitigation of psychological and physical health conditions during gestation. However, the associations between trait mindfulness, which these interventions intend to develop, and maternal cardiovascular and mental health remain unclear. In addition, most research on this topic has focused on evaluating long-term, multi-week-long interventions. Thus, the immediate effects of mindfulness-based practices are not well-understood in this population.

The objective of the current dissertation was to examine the associations between mindfulness and maternal psychological and cardiovascular health, both longitudinally and acutely. Results from the present work are of relevance to professionals in the medical, psychiatric and psychological fields involved in the care of pregnant women, as well as to both researchers and clinicians interested in the study of mindfulness more generally.

Summary of findings

In Manuscript One, we investigated the relationships between trait mindfulness and maternal psychological and physical health outcomes throughout gestation. Regression analyses showed that higher scores on the Mindful Attention Awareness Scale (MAAS) in the first or early second trimester predicted lower scores on the Perceived Stress Scale (PSS), Edinburgh Postnatal Depression Scale (EPDS) and Prenatal Distress Questionnaire-revised (PDQR), and less severe physical symptoms across all trimesters. MAAS scores were a stronger predictor of PSS scores earlier in pregnancy than in its late stages. Logistic regression analyses found that trait mindfulness did not predict the presence of physical discomforts, nor the diagnosis of gestational diabetes or hypertension. These results suggest that trait mindfulness is, at the very least, an important predictor of subjective outcomes such as stress, depression, anxiety and the severity of physical discomforts during pregnancy. These findings also imply that interventions earlier in pregnancy may increase the impact of mindfulness on maternal health.

Study Two was designed to address a key limitation in the first study, the use of a binary, self-report outcome measure as an index of maternal blood pressure. In Study Two, the association between trait mindfulness and blood pressure trajectories across pregnancy was examined using functional data analysis, a promising yet underutilized statistical procedure in the study of blood pressure and its potential determinants. Clinical blood pressure observations were obtained from participants in the cohort studied in Manuscript One. Functional regression analyses showed that MAAS scores did not significantly predict systolic nor diastolic blood pressure trajectories across pregnancy. This finding was in line with the findings from Study One.

While Studies One and Two examined the associations between mindfulness and health longitudinally, Study Three concerned the more acute, in-the-moment effects of a body scan meditation on maternal heart rate, heart rate variability (HRV), and mood, with particular attention to the moderating effects of trait mindfulness. Participants attended two virtual laboratory sessions approximately one week apart, where they were asked to follow a guided meditation recording or to listen to an audiobook. Trait mindfulness was assessed with the Five Facet Mindfulness Questionnaire (FFMQ), a more inclusive self-report measure of trait mindfulness. It was found that both the meditation and control conditions increased high frequency HRV related to vagal activity. Trait mindfulness was found to be a significant moderator of response to the practices, such that more mindful women benefitted more from both practices with regards to cardiovascular activity, while less mindful women reported larger reductions in negative affect during both activities. Heart rate was reduced to a greater degree by the meditation than by the audiobook, though this was not significantly moderated by trait mindfulness. These results suggest that mindfulness-based practices may have beneficial, acute effects on maternal mood and cardiovascular activity in pregnancy, though causality cannot be inferred given the study's design.

Strengths and Limitations

This dissertation contributes to our understanding of the associations between mindfulness and maternal psychological and cardiovascular activity in pregnancy. General strengths of the current studies include large sample sizes in Studies One and Two, as well as the use of a within-subjects design to somewhat mitigate the limitations of the smaller sample size in Study Three. The use of both subjective and objective outcome measures was a strength across all manuscripts. Ecological validity was generally strong given the use of objective clinical

outcome measures such as the diagnosis of high blood pressure, clinical blood pressure observations and HRV, though the sources of measurement bias from the patient, observer, device, or recording should also be recognized (Kallioinen et al., 2017; Tolonen et al., 2015). Participant burden was reduced through the completion of online questionnaires in all studies, as well as the virtual laboratory visits in Study Three. The prospective approaches taken in Studies One and Two are a key strength. In Study Three, it is important to note that, while women in both conditions experienced brief benefits in cardiovascular activity and a simultaneous increase in state mindfulness, causality cannot be inferred due to the study's design.

The use of an audiobook control condition was a strength of Study Three, as the lack of control conditions has been a criticism of past studies of the effects of mindfulness-based interventions (Van Dam et al., 2018). This passive control condition was selected due to the fact that it, like the body scan meditation, required participants to pay attention to auditory information, though they were not expected to direct their attention to their own bodies. In future research, it may prove useful to compare mind-body interventions with sham interventions that are not based on principles of mindfulness, but which include common practices in mindfulness-based programs such as deep breathing or yoga sequences. For example, a sham intervention has been previously administered to a sample of non-pregnant undergraduates (Zeidan et al., 2010). This intervention was identical to the mindfulness-based practice, except that the instructor did not provide guided instructions. Rather, participants were reminded that they were engaging in meditation and that they should be taking deep breaths. Participants in this condition did not experience the benefits of the mindfulness-based program, such as decreases in negative mood and fatigue (Zeidan et al., 2010). Approaches such as this could be utilized to more precisely determine the mechanisms underlying the benefits of mindfulness-based approaches.

Diversity

A common criticism in research about both mindfulness and pregnancy is the lack of diversity in study samples. In Studies One and Two, potential participants were recruited at obstetrics clinics affiliated with McGill University that serviced a general population, though they completed measures online and thus required internet access. In Study Three, though our online recruitment strategy and the use of virtual study sessions were useful in reducing participant risk and burden during the height of the Covid-19 pandemic, they also may have impacted the composition of our sample. Potential participants needed access to a technological device such as a mobile smartphone and to the internet, which is not the case for all mothers-to-be. Consequently, the majority of our samples identified themselves as White, married and of higher socioeconomic status, which impacted the generalizability of our results. Further research on the associations between maternal mindfulness and psychological and cardiovascular health in pregnancy should be conducted in more diverse samples.

In addition, somewhat relatedly, the samples analyzed in Studies One, Two and Three were at low risk for the development of hypertensive disorders of pregnancy and pregnancy complications more broadly. It has been hypothesized that the effects of mindfulness are observable mainly in highly stressed populations for which stress can have an influence on the onset or exacerbation of disease (Creswell & Lindsay, 2014). It is important to note that in Studies One and Two, potential participants who had been diagnosed with pre-pregnancy diabetes or with gestational diabetes in the past were excluded from participating. In Study Three, there were no exclusion criteria related to health, though given the nature of the study, it was not possible to obtain information on pregnancy complications and health after participants had completed both laboratory sessions. Potential areas for participant recruitment in the future

may include high-risk obstetrics clinics. Covid-19-related measures restricted access to this little-studied population in recent years.

It is important to mark the existence of another group which has been little studied in pregnancy: the LGBTQ2S+ (lesbian, gay, bisexual, transgender, queer/questioning, two-spirited) community. Though pregnancy requires that someone be biologically female, gender and sexual orientation can vary. In this dissertation, participants are referred to as "women" because gender identity was not assessed. In future work, gender identity and sexual orientation should be considered, especially given that members of the LGBTQ2S+ community are generally more likely to suffer from perinatal depression than are non-members (Ross et al., 2007) and are more likely to experience miscarriages, preterm births and stillbirths than women who identify as heterosexual (Everett et al., 2019). Thus, this population may be at higher risk for the development of disease during pregnancy. It is possible that the associations between mindfulness and health may be more observable in this population or that this group may benefit especially from mindfulness-based practices.

Adverse Events

It has previously been recommended that the incidence of adverse events, any undesirable and harmful effects that result from an intervention, be reported in studies on mindfulness-based interventions (e.g., Van Dam et al., 2018). Adverse events could include the incidence of new symptoms or the exacerbation of a current condition. For example, it is possible that a pregnant mother engaging in a mindfulness-based practice requiring her to pay attention to her body might experience an increase in nausea or pain in the areas she is attending to. In Study Three, no participant reported an adverse effect of the meditation on their physical or emotional well-being in the moment. In general, negative affect decreased during the meditation

practice across participants. This might be in part due to the brevity of the practice (approximately 13 minutes). In two recently studied programs of longer duration, between 83 and 87% of participants reported at least one adverse event, though these were rarely long-lasting (Britton et al., 2021; Aizik-Reebs et al., 2021). Another recent study of a school-based mindfulness program reported that higher dose of the mindfulness program was associated with worse social, emotional and behavioural functioning at follow-up in a sample of adolescents (Montero-Marin et al., 2022). Across all populations, Van Dam et al. (2018) report that twenty published research reports have described the incidence of meditation-related adverse events including psychosis, panic and mania. Binda et al. (2022) write that these types of severe events are potentially due to multiple factors, such as the intensity and length of the mindfulness-based practices, the presence of psychological stressors and participants' psychiatric histories. The authors conclude that experiencing negative emotion should not be considered an adverse event, as this is a normal part of meditation and allows for participants to learn better coping strategies rather than experiential avoidance. Still, it remains possible that more diverse and populations at higher risk for psychological and physical conditions might be more likely to experience adverse events during meditation. In future studies of pregnant samples of this kind, adverse events represent an important topic to consider.

Problems of Definition, Measurement, and Stability in the Study of Mindfulness

In the current dissertation, special care was taken to ensure that the definition of mindfulness and the mindfulness measures used in each manuscript matched the study's design as, in a previous review of the literature, it was suggested that one pay special attention to whether the authors' chosen definition of mindfulness was related to the design of their study (Van Dam et al., 2018). The measures utilized in the three studies presented here were selected

given their previous use in studies of mindfulness in pregnancy in particular. Issues pertaining to the definition and measurement of mindfulness are described in more detail below. The discussion of these issues is warranted, especially given that the change of mindfulness measure from Studies One and Two to Study Three was motivated by them.

Some have questioned whether self-report assessments are a valid method of measuring mindfulness (Grossman, 2011; Bergomi et al., 2013; Van Dam et al., 2018). The first reason for this doubt is the problem of definition. As mentioned in the General Introduction, there is significant heterogeneity in the ways that researchers define mindfulness. In addition, there has been some criticism that mindfulness may not be a distinct construct, but rather simply a measure of "more versus less pathology" and "Relative Sanity or Reasonableness" (Rosch, 2007, p. 262–263). Indeed, mindfulness has been found to be correlated with emotional intelligence, self-compassion, psychological symptoms, thought suppression, emotion regulation, alexithymia, dissociation, absent-mindedness, impulsivity, self-control, neuroticism and self-efficacy (Baer, Smith, Hopkins, Kritemeyer, & Toney, 2006; Fetterman et al., 2010; Sharma & Kumra, 2022). In line with these findings, in Study One, trait mindfulness was a significant predictor of maternal perceived stress, depression and pregnancy-related distress. In Study Three, trait mindfulness was correlated with maternal depression and pregnancy-related distress. It is noteworthy that trait mindfulness was predictive of responses to the meditation and audiobook above and beyond depression and pregnancy-related distress, which were entered as covariates. This suggests that trait mindfulness may encapsulate something beyond the absence of pathology. Also, there exists a large conceptual literature that suggests it is something distinct from pathology and other personality characteristics (e.g., Rau & Williams, 2016).

Additionally, as is the case for all self-report measures of psychological characteristics, measures of mindfulness are subject to bias. For example, Grossman (2011) poses the question of whether participants' responses are colored by the personal meaningfulness of mindfulness to them. To date, the data on this question remains mixed, as some scales have been found to be correlated with social desirability scales, while others have not (Brown & Ryan, 2003; Cardaciotto et al., 2008). In addition, it has been reported that the understanding of the abstract items on mindfulness scales can vary across populations (i.e., experienced versus inexperienced meditators) and that humans are generally poor judges of the extent of their attentional lapses (Bergomi et al., 2013). Additionally, Grossman (2011) writes that a sufficient level of trait mindfulness is necessary to meaningfully complete a mindfulness measure. For example, people must be aware of lapses in attention, the extent and frequency of their rumination, and the content or nature of their thoughts (i.e., self-critical or self-compassionate) in order to provide the most accurate self-assessment. Bergomi et al. (2013) also propose that the process of self-monitoring while completing a mindfulness measure can alter people's answers, given that many of the items are about self-awareness and people are asked to be self-aware when responding. This potentially suggests to participants that they are self-aware simply because they are able to respond.

Though there exist many limitations to the assessment of mindfulness and these undoubtedly have an impact on the quality of research on the topic, Bergomi et al. (2013) do not recommend a complete rejection of the validity of current scales. Rather, they provide guidelines for the refinement of scales and recommend the use of more comprehensive scales. This recommendation is a key reason that a more inclusive measure, the FFMQ, was employed in Manuscript Three, rather than the MAAS utilized in Manuscripts One and Two. It is possible

that the diagnosis of high blood pressure or maternal blood pressure trajectories are related to certain aspects of mindfulness, but not to the attentional component which is captured by the MAAS. For example, the attitude with which one pays attention to their internal and external experiences might have a stronger influence on cardiovascular activity and health than the act of paying attention itself.

Others have offered suggestions of how one might assess mindfulness differently. For instance, Bishop et al. (2006) suggest that behavioural measures could prove useful. Grossman (2011) dismisses this idea, stating that there is little evidence that self-reported mindfulness corresponds to observable behaviour and that many of the facets of mindfulness might be difficult to operationalize. He offers the idea of using qualitative data from interviews with participants to assess mindfulness, though he also notes that this may be time-consuming and not feasible in health-related research settings (Grossman, 2011). One more promising solution is the use of ecological momentary assessment approaches to measuring mindfulness. Moore et al. (2016) compared the performance of self-reported measures of mindfulness using traditional paper-and-pencil forms with ambulatory measurement of state mindfulness via ecological momentary assessment. A sample of older adults completed the Cognitive Affective Mindfulness Scale-Revised (CAMS-R; Feldman et al., 2007) before and after participation in a randomized trial of Mindfulness-Based Stress Reduction or a health education intervention. Additionally, they also completed four items from the CAMS-R with ecological momentary assessment surveys three times per day for approximately 10 days in the pre-treatment and post-treatment phases. It was found that when measuring mindfulness with ecological momentary assessment, there were significant differences between treatment and control groups on mindfulness at the end of the trial, but these differences were not found for the traditional mindfulness measure

(Moore et al., 2016). This could represent a promising area for future research in the assessment of mindfulness, though the use of ecological momentary assessment requires more resources on the part of scientists and participants than traditional methods. As such, self-report measures such as the MAAS and the FFMQ remain the method of assessment of choice at this time, especially to reduce participant burden which is an important consideration.

It is necessary to keep the limitations listed above in mind when evaluating research on mindfulness and the possible inconsistencies in results across studies. That being said, mindfulness has been discussed as a non-culturally bound skill that can be experienced by anyone and it is assumed that anyone has the capacity to report on their mindfulness (Brown & Ryan, 2004; Kabat-Zinn, 2003).

There is one other paradox worthy of note in the assessment of mindfulness. Mindfulness is often studied as a trait, implying that it is considered to be somewhat stable, though, on the other hand, relatively brief interventions of 4-8 weeks are often expected to produce change in one's general tendency to be mindful. Given this, an additional area for further study is the stability of trait mindfulness over time, particularly in the prenatal period. Even if they do not participate in a mindfulness-based programme, this is a time when women may attend more to their bodily sensations than they usually would and are asked on a somewhat regular basis by their medical team to report on these sensations. The acts of tuning into one's body and of verbalizing one's experiences seem remarkably in line with the Observing and Describing facets of the FFMQ. The functional data analytic approach employed in Study Two may prove useful in the study of trajectories of trait mindfulness throughout gestation.

Conclusion

The present dissertation provides further knowledge on the associations between mindfulness and maternal psychological and cardiovascular activity across pregnancy, both longitudinally and acutely. Taken together, the findings from the first two studies suggest that trait mindfulness is significantly related to subjective reports of maternal psychological and physical health, but not to diagnoses of gestational diabetes or hypertension, or to blood pressure trajectories in the prenatal period. The findings from Study Three suggest that mindfulness-based practices might exert some acute benefits in terms of maternal mood and cardiovascular activity, though these effects appear to be moderated by one's general level of mindfulness and may not differ significantly from the effects of a presumably relaxing control condition.

This dissertation also highlights certain gaps in the literature on mindfulness in pregnancy, as well as common limitations in the assessment of mindfulness. Further research in samples at high risk for the development of cardiovascular disease and pregnancy complications is recommended. In addition, gender, sexual orientation, and the risk for adverse events are important future considerations in the study of mindfulness and pregnancy more broadly.

The current work is of importance to professionals in the fields of obstetrics, psychiatry and clinical psychology who are involved in the care of people in the perinatal period. The results from these studies have implications for the health of parents and their children, both in pregnancy and beyond.

References

Aizik-Reebs, A., Shoham, A., & Bernstein, A. (2021). First, do no harm: An intensive experience sampling study of adverse effects to mindfulness training. *Behaviour Research and Therapy*, *145*. https://doi.org/10.1016/J.BRAT.2021.103941

Alsubaie, M., Abbott, R., Dunn, B., Dickens, C., Keil, T. F., Henley, W., & Kuyken, W. (2017). Mechanisms of action in mindfulness-based cognitive therapy (MBCT) and mindfulness-based stress reduction (MBSR) in people with physical and/or psychological conditions: A systematic review. *Clinical psychology review*, *55*, 74–91. https://doi.org/10.1016/j.cpr.2017.04.008

Alder, J., Fink, N., Bitzer, J., Hösli, I., & Holzgreve, W. (2007). Depression and anxiety during pregnancy: A risk factor for obstetric, fetal and neonatal outcome? A critical review of the literature. *The Journal of Maternal-Fetal & Neonatal Medicine*, *20*(3), 189–209. https://doi.org/10.1080/14767050701209560

Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using Self-Report Assessment Methods to Explore Facets of Mindfulness. *Assessment*, *13*(1), 27–45. https://doi.org/10.1177/1073191105283504

Baer, R. A., Smith, G. T., Lykins, E., Button, D., Krietemeyer, J., Sauer, S., Walsh, E., Duggan, D., & Williams, J. M. G. (2008). Construct Validity of the Five Facet Mindfulness Questionnaire in Meditating and Nonmeditating Samples. *Assessment*, *15*(3), 329–342. https://doi.org/10.1177/1073191107313003

Bastani, F., Hidarnia, A., Montgomery, K. S., Aguilar-Vafaei, M. E., & Kazemnejad, A. (2006). Does relaxation education in anxious primigravid Iranian women influence adverse

pregnancy outcomes?: a randomized controlled trial. *The Journal of Perinatal & Neonatal Nursing*, *20*(2), 138–46.

Beattie, J., Hall, H., Biro, M. A., East, C., & Lau, R. (2017). Effects of mindfulness on maternal stress, depressive symptoms and awareness of present moment experience: A pilot randomised trial. *Midwifery*, *50*, 174–183.

Beddoe, A. E., Paul Yang, C.-P., Kennedy, H. P., Weiss, S. J., & Lee, K. A. (2009). The Effects of Mindfulness-Based Yoga During Pregnancy on Maternal Psychological and Physical Distress. *Journal of Obstetric, Gynecologic & Neonatal Nursing*, *38*(3), 310–319. https://doi.org/10.1111/j.1552-6909.2009.01023.x

Bergomi, C., Tschacher, W., & Kupper, Z. (2013). The Assessment of Mindfulness with Self-Report Measures: Existing Scales and Open Issues. *Mindfulness*, *4*(3), 191–202. https://doi.org/10.1007/s12671-012-0110-9

Berle, J. Ø., Mykletun, A., Daltveit, A. K., Rasmussen, S., Holsten, F., & Dahl, A. A. (2005). Neonatal outcomes in offspring of women with anxiety and depression during pregnancy. *Archives of Women's Mental Health*, *8*(3), 181–189. https://doi.org/10.1007/s00737-005-0090-z

Binda, D. D., Greco, C. M., & Morone, N. E. (2022). What are adverse events in mindfulness meditation? *Global Advances in Health and Medicine*, *11*. https://doi.org/10.1177/2164957X221096640

Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., Carmody, J., Segal, Z. v., Abbey, S., Speca, M., Velting, D., & Devins, G. (2006). Mindfulness: A Proposed

Operational Definition. *Clinical Psychology: Science and Practice*, *11*(3), 230–241. https://doi.org/10.1093/clipsy.bph077

Braeken, M. A. K. A., Jones, A., Otte, R. A., Nyklíček, I., & Van den Bergh, B. R. H. (2017). Potential benefits of mindfulness during pregnancy on maternal autonomic nervous system function and infant development. *Psychophysiology*, *54*(2), 279–288. https://doi.org/10.1111/psyp.12782

Britton, W. B., Lindahl, J. R., Cooper, D. J., Canby, N. K., & Palitsky, R. (2021). Defining and Measuring Meditation-Related Adverse Effects in Mindfulness-Based Programs. *Clinical Psychological Science*, *9*(6), 1185–1204. https://doi.org/10.1177/2167702621996340

Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology*, *84*(4), 822–848. https://doi.org/10.1037/0022-3514.84.4.822

Brown, K. W., & Ryan, R. M. (2004). Perils and promises in defining and measuring mindfulness: observations from experience. *Clinical Psychology: Science and Practice, 11*, 242–248.

Byrne, J., Hauck, Y., Fisher, C., Bayes, S., & Schutze, R. (2014). Effectiveness of a Mindfulness-Based Childbirth Education Pilot Study on Maternal Self-Efficacy and Fear of Childbirth. *Journal of Midwifery & Women's Health*, *59*(2), 192–197. https://doi.org/10.1111/jmwh.12075

Campbell, T. S., Labelle, L. E., Bacon, S. L., Faris, P., & Carlson, L. E. (2012). Impact of mindfulness-based stress reduction (mbsr) on attention, rumination and resting blood

pressure in women with cancer: a waitlist-controlled study. *Journal of Behavioral Medicine*, *35*(3), 262–271. https://doi.org/10.1007/s10865-011-9357-1

Cardaciotto, L., Herbert, J. D., Forman, E. M., Moitra, E., & Farrow, V. (2008). The assessment of present-moment awareness and acceptance: the Philadelphia Mindfulness Scale. *Assessment*, *15*(2), 204–223. https://doi.org/10.1177/1073191107311467

Cebolla, A., Campos, D., Galiana, L., Oliver, A., Tomás, J. M., Feliu-Soler, A., … Baños, R. M. (2017). Exploring relations among mindfulness facets and various meditation practices: Do they work in different ways? *Consciousness and Cognition*. https://doi.org/10.1016/j.concog.2017.01.012

Chadwick, P., Hember, M., Symes, J., Peters, E., Kuipers, E., & Dagnan, D. (2008). Responding mindfully to unpleasant thoughts and images: Reliability and validity of the Southampton mindfulness questionnaire (SMQ). *British Journal of Clinical Psychology*, *47*(4), 451–455. https://doi.org/10.1348/014466508X314891

Christian, L. M. (2012). Physiological reactivity to psychological stress in human pregnancy: current knowledge and future directions. *Progress in Neurobiology*, *99*(2), 106–16. https://doi.org/10.1016/j.pneurobio.2012.07.003

Craici, I., Wagner, S., & Garovic, V. D. (2008). Preeclampsia and future cardiovascular risk: formal risk factor or failed stress test? *Therapeutic Advances in Cardiovascular Disease*, *2*(4), 249–59. https://doi.org/10.1177/1753944708094227

Creswell, J. D., & Lindsay, E. K. (2014). How Does Mindfulness Training Affect Health? A Mindfulness Stress Buffering Account. *Current Directions in Psychological Science*, *23*(6), 401–407. https://doi.org/10.1177/0963721414547415

de Weerth, C., & Buitelaar, J. K. (2005). Physiological stress reactivity in human pregnancy—a review. *Neuroscience & Biobehavioral Reviews*, *29*(2), 295–312. https://doi.org/10.1016/J.NEUBIOREV.2004.10.005

Dimidjian, S., Goodman, S. H., Felder, J. N., Gallop, R., Brown, A. P., & Beck, A. (2016). Staying well during pregnancy and the postpartum: A pilot randomized trial of mindfulness-based cognitive therapy for the prevention of depressive relapse/recurrence. *Journal of Consulting and Clinical Psychology*, *84*(2), 134–45. https://doi.org/10.1037/ccp0000068

Ditto, B., Eclache, M., & Goldman, N. (2006). Short-Term Autonomic and Cardiovascular Effects of Mindfulness Body Scan Meditation. *Annals of Behavioral Medicine*, *32*(3), 227–234.

Duncan, L. G., Cohn, M. A., Chao, M. T., Cook, J. G., Riccobono, J., & Bardacke, N. (2017). Benefits of preparing for childbirth with mindfulness training: a randomized controlled trial with active comparison. *BMC Pregnancy and Childbirth*, *17*(1), 140. https://doi.org/10.1186/s12884-017-1319-3

Dunn, C., Hanieh, E., Roberts, R., & Powrie, R. (2012). Mindful pregnancy and childbirth: effects of a mindfulness-based intervention on women's psychological distress and well-being in the perinatal period. *Archives of Women's Mental Health*, *15*(2), 139–143. https://doi.org/10.1007/s00737-012-0264-4

Everett, B. G., Kominiarek, M. A., Mollborn, S., Adkins, D. E., & Hughes, T. L. (2019). Sexual Orientation Disparities in Pregnancy and Infant Outcomes. *Maternal and Child Health Journal*, *23*(1), 72–81. https://doi.org/10.1007/s10995-018-2595-x

Felder, J. N., Segal, Z., Beck, A., Sherwood, N. E., Goodman, S. H., Boggs, J., … Dimidjian, S. (2017). An Open Trial of Web-Based Mindfulness-Based Cognitive Therapy for Perinatal Women at Risk for Depressive Relapse. *Cognitive and Behavioral Practice*, *24*(1), 26–37. https://doi.org/10.1016/J.CBPRA.2016.02.002

Feldman, G., Hayes, A., Kumar, S., Greeson, J., & Laurenceau, J. P. (2007). Mindfulness and emotion regulation: The development and initial validation of the Cognitive and Affective Mindfulness Scale Revised (CAMS-R). *Journal of Psychopathology and Behavioral Assessment, 29*(3), 177-190.

Fetterman, A. K., Robinson, M. D., Ode, S., & Gordon, K. H. (2010). Neuroticism as a risk factor for behavioral dysregulation: a mindfulness-mediation perspective. *Journal of Social and Clinical Psychology*, *29*(3), 301–321.

Fisher, C., Hauck, Y., Bayes, S., & Byrne, J. (2012). Participant experiences of mindfulness-based childbirth education: a qualitative study. *BMC Pregnancy and Childbirth*, *12*(1), 126. https://doi.org/10.1186/1471-2393-12-126

Garg, P., Yadav, K., Jaryal, A. K., Kachhawa, G., Kriplani, A., & Deepak, K. K. (2020). Sequential analysis of heart rate variability, blood pressure variability and baroreflex sensitivity in healthy pregnancy. *Clinical Autonomic Research*, *30*(5), 433–439. https://doi.org/10.1007/S10286-020-00667-4/FIGURES/1

Goodman, J. H., Guarino, A., Chenausky, K., Klein, L., Prager, J., Petersen, R., … Freeman, M. (2014). CALM Pregnancy: results of a pilot study of mindfulness-based cognitive therapy for perinatal anxiety. *Archives of Women's Mental Health*, *17*(5), 373–387. https://doi.org/10.1007/s00737-013-0402-7

Greeson, J. M., Smoski, M. J., Suarez, E. C., Brantley, J. G., Ekblad, A. G., Lynch, T. R., & Wolever, R. Q. (2015). Decreased Symptoms of Depression after Mindfulness-Based Stress Reduction: Potential Moderating Effects of Religiosity, Spirituality, Trait Mindfulness, Sex, and Age. *Journal of Alternative and Complementary Medicine*, *21*(3), 166–174. https://doi.org/10.1089/ACM.2014.0285/ASSET/IMAGES/LARGE/FIGURE1.JPEG

Grossman, P. (2011). Defining Mindfulness by How Poorly I Think I Pay Attention During Everyday Awareness and Other Intractable Problems for Psychology's (Re)Invention of Mindfulness: Comment on Brown et al. (2011). *Psychological Assessment*, *23*(4), 1034–1040. https://doi.org/10.1037/a0022713

Grossman, P., Niemann, L., Schmidt, S., & Walach, H. (2004). Mindfulness-based stress reduction and health benefits. *Journal of Psychosomatic Research*, *57*(1), 35–43. https://doi.org/10.1016/S0022-3999(03)00573-7

Guardino, C. M., Dunkel Schetter, C., Bower, J. E., Lu, M. C., & Smalley, S. L. (2014). Randomised controlled pilot trial of mindfulness training for stress reduction during pregnancy. *Psychology & Health*, *29*(3), 334–49. https://doi.org/10.1080/08870446.2013.852670

Harris, Russ., & Hayes, S. C. (2019). *ACT Made Simple: an Easy-To-Read Primer on Acceptance and Commitment Therapy.* New Harbinger Publications.

Hawley, L. L., Schwartz, D., Bieling, P. J., Irving, J., Corcoran, K., Farb, N. A. S., Anderson, A. K., & Segal, Z. V. (2014). Mindfulness practice, rumination and clinical outcome in mindfulness-based treatment. *Cognitive Therapy and Research*, *38*(1), 1–9. https://doi.org/10.1007/s10608-013-9586-4

Hoffman, S., & Hatch, M. C. (2000). Depressive symptomatology during pregnancy: Evidence for an association with decreased fetal growth in pregnancies of lower social class women. *Health Psychology*, *19*(6), 535–543. https://doi.org/10.1037/0278-6133.19.6.535

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: past, present, and future. *Clinical Psychology: Science and Practice, 10*, 144–156.

Kabat-Zinn, J. (1982). An outpatient program in behavioral medicine for chronic pain patients based on the practice of mindfulness meditation: theoretical considerations and preliminary results. *General Hospital Psychiatry*, *4*(1), 33–47.

Kabat-Zinn, J. (2013). *Full catastrophe living : using the wisdom of your body and mind to face stress, pain, and illness*. New York, NY: Bantam Books.

Kabat-Zinn, J. (2006). Mindfulness-Based Interventions in Context: Past, Present, and Future. *Clinical Psychology: Science and Practice*, *10*(2), 144–156.

Kabat-Zinn, J. (2009). Forward. In F. Dinonna (Ed.), Clinical handbook of mindfulness (pp. xxv–xxxiii). New York, NY: Springer

Kallioinen, N., Hill, A., Horswill, M. S., Ward, H. E., & Watson, M. O. (2017). Sources of inaccuracy in the measurement of adult patients' resting blood pressure in clinical settings: A systematic review. *Journal of Hypertension, 35*(3), 421-441. https://doi.org/10.1097/HJH.0000000000001197

Lau, M. A., Bishop, S. R., Segal, Z. v., Buis, T., Anderson, N. D., Carlson, L., Shapiro, S., Carmody, J., Abbey, S., & Devins, G. (2006). The toronto mindfulness scale: Development and validation. *Journal of Clinical Psychology*, *62*(12), 1445–1467. https://doi.org/10.1002/JCLP.20326

Little, B. C., Hayworth, J., Benson, P., Hall, F., Beard, R. W., Dewhurst, J., & Priest, R. G. (1984). Treatment of hypertension in pregnancy by relaxation and biofeedback. *Lancet*, *1*(8382), 865–7.

Maina, G., Saracco, P., Giolito, M. R., Danelon, D., Bogetto, F., & Todros, T. (2008). Impact of maternal psychological distress on fetal weight, prematurity and intrauterine growth retardation. *Journal of affective disorders*, *111*(2-3), 214–220. https://doi.org/10.1016/j.jad.2008.02.017

Mammaro, A., Carrara, S., Cavaliere, A., Ermito, S., Dinatale, A., Pappalardo, E. M., … Cacciatore, A. (2009). Hypertensive Disorders in Pregnancy. *Journal of Prenatal Medicine*, *3*(1), 1–5.

Matvienko-Sikar, K., & Dockray, S. (2017). Effects of a novel positive psychological intervention on prenatal stress and well-being: A pilot randomised controlled trial. *Women and Birth: Journal of the Australian College of Midwives*, *30*(2), e111–e118. https://doi.org/10.1016/j.wombi.2016.10.003

McCubbin, J. A., Lawson, E. J., Cox, S., Sherman, J. J., Norton, J. A., & Read, J. A. (1996). Prenatal maternal blood pressure response to stress predicts birth weight and gestational age: A preliminary study. *American Journal of Obstetrics and Gynecology, 175*(3 PART I), 706–712.

Montero-Marin, J., Ahmed, S., Allwood, M., Ball, S., Crane, C., De Wilde, K., Hinze, V., Jones, B., Lord, L., Nuthall, E., Raja, A., Taylor, L., Tudor, K., Blakemore, S.-J., Byford, S., Dalgleish, T., Ford, T., Greenberg, M. T., Ukoumunne, O. C., … MYRIAD Team. (2022). School-based mindfulness training in early adolescence: what works, for whom and how in

the myriad trial? *Evidence-Based Mental Health*, *25*(3), 117-124. https://doi.org/10.1136/ebmental-2022-300439

Moore, R. C., Depp, C. A., Wetherell, J. L., & Lenze, E. J. (2016). Ecological momentary assessment versus standard assessment instruments for measuring mindfulness, depressed mood, and anxiety among older adults. *Journal of Psychiatric Research*, *75*, 116–123. https://doi.org/10.1016/j.jpsychires.2016.01.011

Moors, S., Staaks, K. J. J., Westerhuis, M. E. M. H., Dekker, L. R. C., Verdurmen, K. M. J., Oei, S. G., & van Laar, J. O. E. H. (2020). Heart rate variability in hypertensive pregnancy disorders: A systematic review. *Pregnancy Hypertension*, *20*, 56–68. https://doi.org/10.1016/J.PREGHY.2020.03.003

Muthukrishnan, S., Jain, R., Kohli, S., & Batra, S. (2016). Effect of Mindfulness Meditation on Perceived Stress Scores and Autonomic Function Tests of Pregnant Indian Women. *Journal of clinical and diagnostic research*, *10*(4), CC05-8. https://doi.org/10.7860/JCDR/2016/16463.7679

Muzik, M., Hamilton, S. E., Lisa Rosenblum, K., Waxler, E., & Hadi, Z. (2012). Mindfulness yoga during pregnancy for psychiatrically at-risk women: Preliminary results from a pilot feasibility study. *Complementary Therapies in Clinical Practice*, *18*(4), 235–240. https://doi.org/10.1016/j.ctcp.2012.06.006

Narendran, S., Nagarathna, R., Narendran, V., Gunasheela, S., & Nagendra, H. R. R. (2005). Efficacy of Yoga on Pregnancy Outcome. *The Journal of Alternative and Complementary Medicine*, *11*(2), 237–244. https://doi.org/10.1089/acm.2005.11.237

Nierop, A., Bratsikas, A., Zimmermann, R., & Ehlert, U. (2006). Are stress-induced cortisol changes during pregnancy associated with postpartum depressive symptoms? *Psychosomatic Medicine*, *68*(6), 931–937. https://doi.org/10.1097/01.psy.0000244385.93141.3b

Nijjar, P. S., Puppala, V. K., Dickinson, O., Duval, S., Duprez, D., Kreitzer, M. J., & Benditt, D. G. (2014). Modulation of the autonomic nervous system assessed through heart rate variability by a mindfulness based stress reduction program. *International Journal of Cardiology*, *177*(2), 557–559. https://doi.org/10.1016/j.ijcard.2014.08.116

Nyklíček, I., Mommersteeg, P. M. C., Van Beugen, S., Ramakers, C., & Van Boxtel, G. J. (2013). Mindfulness-based stress reduction and physiological activity during acute stress: A randomized controlled trial. *Health Psychology*, *32*(10), 1110–1113. https://doi.org/10.1037/a0032200

Nyklíček, I., Truijens, S. E. M., Spek, V., & Pop, V. J. M. (2018). Mindfulness skills during pregnancy: Prospective associations with mother's mood and neonatal birth weight. *Journal of Psychosomatic Research*, *107*, 14–19. https://doi.org/10.1016/j.jpsychores.2018.01.012

Orr, S. T., James, S. A., & Blackmore Prince, C. (2002). Maternal Prenatal Depressive Symptoms and Spontaneous Preterm Births among African-American Women in Baltimore, Maryland. *American Journal of Epidemiology*, *156*(9), 797–802. https://doi.org/10.1093/aje/kwf131

Pepping, C. A., O'Donovan, A., & Davis, P. J. (2013). The positive effects of mindfulness on self-esteem. *The Journal of Positive Psychology*, *8*(5), 376–386. https://doi.org/10.1080/17439760.2013.807353

Perez-Blasco, J., Viguer, P., & Rodrigo, M. F. (2013). Effects of a mindfulness-based intervention on psychological distress, well-being, and maternal self-efficacy in breast-feeding mothers: results of a pilot study. *Archives of Women's Mental Health*, *16*(3), 227–236. https://doi.org/10.1007/s00737-013-0337-z

Qiu, C., Williams, M. A., Calderon-Margalit, R., Cripe, S. M., & Sorensen, T. K. (2009). Preeclampsia Risk in Relation to Maternal Mood and Anxiety Disorders Diagnosed Before or During Early Pregnancy. *American Journal of Hypertension*, *22*(4), 397–402. https://doi.org/10.1038/ajh.2008.366

Rau, H. K., & Williams, P. G. (2016). Dispositional mindfulness: a critical review of construct validation research. *Personality and Individual Differences*, *93*, 32–43. https://doi.org/10.1016/j.paid.2015.09.035

Rosch, E. (2007). More than mindfulness: when you have a tiger by the tail, let it eat you. *Psychological Inquiry, 18*, 258–264.

Ross, L. E., Steele, L., Goldfinger, C., & Strike, C. (2007). Perinatal depressive symptomatology among lesbian and bisexual women. *Archives of Women's Mental Health, 10,* 53-59.

Satyapriya, M., Nagendra, H. R., Nagarathna, R., & Padmalatha, V. (2009). Effect of integrated yoga on stress and heart rate variability in pregnant women. *International Journal of Gynecology & Obstetrics*, *104*(3), 218–222. https://doi.org/10.1016/j.ijgo.2008.11.013

Schmidt, S., Gmeiner, S., Schultz, C., Löwer, M., Kuhn, K., Naranjo, J. R., Brenneisen, C., & Hinterberger, T. (2015). Mindfulness-based stress reduction (mbsr) as treatment for chronic back pain - an observational study with assessment of thalamocortical

dysrhythmia. *Forschende Komplementarmedizin*, *22*(5), 298–303. https://doi.org/10.1159/000440687

Segal, Z. V., Williams, J. M. G., & Teasdale, J. D. (2013). *Mindfulness-based cognitive therapy for depression* (2nd ed.). New York: Guilford Press.

Sharma, P. K., & Kumra, R. (2022). Relationship between mindfulness, depression, anxiety and stress: Mediating role of self-efficacy. *Personality and Individual Differences*, *186*. https://doi.org/10.1016/J.PAID.2021.111363

Siegling, A. B., & Petrides, K. V. (2014). Measures of trait mindfulness: Convergent validity, shared dimensionality, and linkages to the five-factor model. *Frontiers in psychology*, *5*, 1164. https://doi.org/10.3389/fpsyg.2014.01164

Staneva, A., Bogossian, F., Pritchard, M., & Wittkowski, A. (2015). The effects of maternal depression, anxiety, and perceived stress during pregnancy on preterm birth: A systematic review. *Women and Birth*, *28*(3), 179-193.

Steinhubl, S. R., Wineinger, N. E., Patel, S., Boeldt, D. L., Mackellar, G., Porter, V., … Topol, E. J. (2015). Cardiovascular and nervous system changes during meditation. *Frontiers in Human Neuroscience*, *9*, 145. https://doi.org/10.3389/fnhum.2015.00145

Teasdale, J. D., Segal, Z. V., Williams, J. M. G., Ridgeway, V. A., Soulsby, J. M., & Lau, M. A. (2000). Prevention of relapse/recurrence in major depression by mindfulness-based cognitive therapy. *Journal of Consulting and Clinical Psychology*, *68*(4), 615–623. https://doi.org/10.1037/0022-006X.68.4.615

Tolonen, H., Koponen, P., Naska, A., Männistö, S., Broda, G., Palosaari, T., & Kuulasmaa, K. (2015). Challenges in standardization of blood pressure measurement at the population level. *BMC Medical Research Methodology*, *15*(1), 1–11. https://doi.org/10.1186/s12874-015-0020-3

Townshend, K., Caltabiano, N., Powrie, R., & O'Grady, H. (2018). A preliminary study investigating the effectiveness of the caring for body and mind in pregnancy (CBMP) in reducing perinatal depression, anxiety and stress. *Journal of Child and Family Studies, 27*(5), 1556-1566. doi:10.1007/s10826-017-0978-z

Umberson, D., Pudrovska, T., & Reczek, C. (2010). Parenthood, Childlessness, and Well-Being: A Life Course Perspective. *Journal of Marriage and Family*, *72*(3), 612–629. https://doi.org/10.1111/j.1741-3737.2010.00721.x

Urech, C., Fink, N. S., Hoesli, I., Wilhelm, F. H., Bitzer, J., & Alder, J. (2010). Effects of relaxation on psychobiological wellbeing during pregnancy: A randomized controlled trial. *Psychoneuroendocrinology*, *35*(9), 1348–1355.

Van Dam, N. T., van Vugt, M. K., Vago, D. R., Schmalzl, L., Saron, C. D., Olendzki, A., Meissner, T., Lazar, S. W., Kerr, C. E., Gorchov, J., Fox, K. C. R., Field, B. A., Britton, W. B., Brefczynski-Lewis, J. A., & Meyer, D. E. (2018). Mind the Hype: A Critical Evaluation and Prescriptive Agenda for Research on Mindfulness and Meditation. *Perspectives on Psychological Science, 13*(1), 36–61. https://doi-org.proxy3.library.mcgill.ca/10.1177/1745691617709589

van der Velden, A. M., Kuyken, W., Wattar, U., Crane, C., Pallesen, K. J., Dahlgaard, J., … Piet, J. (2015). A systematic review of mechanisms of change in mindfulness-based cognitive

therapy in the treatment of recurrent major depressive disorder. *Clinical Psychology Review*, *37*, 26–39. https://doi.org/10.1016/j.cpr.2015.02.001

Vieten, C., & Astin, J. (2008). Effects of a mindfulness-based intervention during pregnancy on prenatal stress and mood: results of a pilot study. *Archives of Women's Mental Health*, *11*(1), 67–74. https://doi.org/10.1007/s00737-008-0214-3

Walach, H., Buchheld, N., Buttenmüller, V., Kleinknecht, N., & Schmidt, S. (2006). Measuring mindfulness—the Freiburg Mindfulness Inventory (FMI). *Personality and Individual Differences*, *40*(8), 1543–1555. https://doi.org/10.1016/J.PAID.2005.11.025

Williams, D. (2003). Pregnancy: a stress test for life. *Current Opinion in Obstetrics & Gynecology*, *15*(6), 465–471. https://doi.org/10.1097/00001703-200312000-00002

Woisetschläger, C., Waldenhofer, U., Bur, A., Herkner, H., Kiss, H., Binder, M., Laggner, A. N., & Hirschl, M. M. (2000). Increased blood pressure response to the cold pressor test in pregnant women developing pre-eclampsia. *Journal of Hypertension*, *18*(4), 399–403. https://doi.org/10.1097/00004872-200018040-00007

Woolhouse, H., Mercuri, K., Judd, F., & Brown, S. J. (2014). Antenatal mindfulness intervention to reduce depression, anxiety and stress: a pilot randomised controlled trial of the MindBabyBody program in an Australian tertiary maternity hospital. *BMC Pregnancy and Childbirth*, *14*(1), 369. https://doi.org/10.1186/s12884-014-0369-z

Wu, P., Haththotuwa, R., Kwok, C. S., Babu, A., Kotronias, R. A., Rushton, C., Zaman, A., Fryer, A. A., Kadam, U., Chew-Graham, C. A., & Mamas, M. A. (2017). Preeclampsia and Future Cardiovascular Health: A Systematic Review and Meta-Analysis. *Circulation.*

Cardiovascular Quality and Outcomes, *10*(2). https://doi.org/10.1161/CIRCOUTCOMES.116.003497

Zeidan, F., Johnson, S. K., Gordon, N. S., & Goolkasian, P. (2010). Effects of brief and sham mindfulness meditation on mood and cardiovascular variables. *Journal of Alternative and Complementary Medicine (New York, N.Y.)*, *16*(8), 867–873. https://doi.org/10.1089/acm.2009.0321

Zhang, H., & Emory, E. K. (2015). A Mindfulness-Based Intervention for Pregnant African-American Women. *Mindfulness*, *6*(3), 663–674. https://doi.org/10.1007/s12671-014-0304-4

Zhang, S., Ding, Z., Liu, H., Chen, Z., Wu, J., Zhang, Y., & Yu, Y. (2013). Association Between Mental Stress and Gestational Hypertension/Preeclampsia. *Obstetrical & Gynecological Survey*, *68*(12), 825–834. https://doi.org/10.1097/OGX.0000000000000009