

Original Research

Investigating Associations between Maternal Mindfulness, Mental Health, Interoception and Mother-Infant Relationship during Pregnancy and Post-Partum in a Non-Clinical Community Sample

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Abstract

Pregnancy and the postpartum period are times of significant transition for women, with changes in maternal physical and mental health. The relationship between a mother and her infant has been recognised as laying the foundation for later child development. There is considerable evidence that this early relationship is influenced by a woman's wellbeing during pregnancy and in the early post-partum period. Mindfulness has been found to have positive health outcomes, primarily in reducing maternal stress, anxiety, and depression. However, there remains a need for considering the influence of mindfulness on the mother-infant relationship during pregnancy and the first trimester post-partum. Given the limited research on interoception in pregnancy, this maternal variable was included to acknowledge the importance of embodiment in maternal mindfulness, mental health, and mother-infant relationship. Its relevance was assessed through the associations with all the other measures. This study was the first to explore associations between maternal mindfulness, mental health (depression, anxiety, and stress), interoception, and mother-infant relationship during pregnancy and post-partum across three time points in a non-clinical community sample. This can provide possible avenues for assessment and support strategies by pre and perinatal



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healthcare practitioners. Women were assessed at 20+ weeks gestation (110), approximately 36-week gestation (72) and 10-12 weeks postpartum (67). Their age ranged from 18 to 47 ($M = 33.22$). The majority were from Australia and the rest from New Zealand, UK, USA, and Canada. They were from middle to upper class socioeconomic background and from high school/equivalent to doctoral degree educational level, with the majority holding a bachelor's degree. The maternal variables were assessed with self-report questionnaires. Changes in the maternal variables during pregnancy and postpartum across three timepoints were analysed using ANOVA. Correlations were investigated using Pearson correlational analyses. Maternal depression and anxiety significantly decreased from pregnancy to postpartum with $p = 0.035$ for the difference in depressive scores (EPDS) and $p = 0.012$ for the difference in anxiety scores (DASS-21 subscale). Mother-infant relationship during pregnancy increased from the second to the third trimester of gestation, with $p = 0.004$ for the difference in maternal-foetal attachment scores. Significant correlations were found between all maternal variables across the three timepoints. Mindfulness and interoception positively correlated with mother-infant relationship during pregnancy and postpartum and negatively correlated with maternal depression, anxiety, and stress. A power analysis was conducted using G*Power calculation by Tabachnick & Fidell. The sample size required to estimate a medium effect was 100 participants, with power set at 0.95 and an alpha at 0.05. The current sample size ($N = 110$) satisfied this to get meaningful results. The decrease in depression and anxiety post childbirth may confirm untested speculation in the literature that pregnancy, childbirth, and the transition to motherhood may not necessarily represent a risk factor for mental health but enrichment of identity and mitigation of mild/moderate depression in a non-clinical sample. Maternal mindfulness, mental health, and interoception may have an important impact on the quality of mother-infant relationship during pregnancy and post-partum, with potential consequences on infant development and wellbeing. The findings of this study have significant implication for prenatal support programs aiming to reduce the risk for postnatal psychological disorders and mother-infant relationship difficulties by promoting mother-infant relationship and maternal embodiment through interoception and wellbeing during pregnancy. Pre and perinatal practitioners and therapists working in a range of healthcare and clinical settings may support pregnant women through mindfulness relationship-based programs to promote mindfulness, interoception, and their relationship with their developing infant in utero and post-partum, thus impacting infant healthy development. Future research with larger sample sizes is needed to increase the statistical power to detect smaller effect sizes. Furthermore, the use of objective or observational measures should be considered for future studies to represent a stronger study design.

Keywords

Maternal mindfulness; maternal interoception; maternal mental health; maternal depression; maternal anxiety; maternal stress; mother-infant relationship; prenatal healthcare

1. Introduction

The perinatal period, including pregnancy and childbirth, can pose challenges in maternal mental health as many women undergo significant psychological, physiological, and role changes in their transition to motherhood [1]. Postpartum depression can be a serious condition, usually occurs 4-6 weeks after delivery, and has been estimated at around 17% [2]. Antenatal depression has an incidence of up to 20.7% worldwide [3]. Untreated depression and anxiety symptoms could have several short and long-term consequences on pregnancy (e.g., spontaneous abortion, lower immunity, delivery with intervention, caesarean section, preterm birth, lower birthweight), children (lower immunity, reduced cognitive development, behavioral and emotional difficulties) and mother-infant relationship [4-7].

The estimated cost of the lifetime adverse consequences on children development and health of perinatal depression, anxiety, and psychosis is £23b each year in the UK [8] and of perinatal depression and anxiety is £3.9b in Australia [9], with other countries facing similar challenges. It has been suggested that treating perinatal mental health problems effectively by promoting health-enhancement programs during pregnancy could save many of the serious long-term human and economic costs [8, 10, 11]. Therefore, reducing maternal distress during pregnancy and mitigating the risk for post-partum mental health disorders is a vital public health priority.

Studies investigating maternal mental health, mother-infant relationship and child outcomes are important, since the first years of life, including the prenatal period, lay the foundations for the development of healthy attachment relationships and developmental outcomes [12-15]. These studies can inform prenatal and perinatal practitioners in the assessment of mental health issues during pregnancy and in the perinatal period and the development of support strategies [1, 16-18]. Furthermore, research is needed to understand the influence of maternal interoception on maternal mental health and mother-infant relationship during pregnancy and post-partum, which could inform assessment and support programs and help reduce the risk of postpartum psychological disorders and mother-infant relationship difficulties.

Mind-body therapeutic approaches during pregnancy, such as mindfulness-based healthcare practices, have revealed positive outcomes, primarily in reducing parental stress, anxiety and depression [19]. There remains a need for considering the influence of mindfulness on the mother-infant relationship during pregnancy and the first three months in a non-clinical group of pregnant women. The current study is the first to explore changes in depression, anxiety, stress, mindfulness, interoception, and mother-infant relationship and associations among them during pregnancy and postpartum in one single sample and across three time points, as this is a critical time for infant development and health foundations. Another aspect making this study unique is the consideration of maternal embodiment, referred to as interoception, which is an essential aspect of maternal mental health and attuned mother-infant relationship. Its relevance to the study will be assessed through the associations with the other maternal variables. These findings will also have clinical implications for at-risk women and implementation of timely and appropriate support strategies.

The following sections will explore some of the central concepts used in this paper, including maternal mental health, in particular depression, anxiety, and stress, mindfulness, interoception, and mother-infant relationship during pregnancy and in the first trimester postpartum period. Specifically, the mother-infant relationship during pregnancy is referred to maternal-foetus

attachment and the mother-infant relationship postpartum is referred to mother-infant emotional availability.

1.1 Maternal Mental Health

Perinatal and infant mental health refers to the emotional and psychological wellbeing of mothers, their infants, partners, and families, from conception through pregnancy and the first three years postpartum [20]. These first 1001 days can be a time of high risk for the onset or relapse of mental health problems, with potential consequences for maternal caregiving ability and thus the development of the infant in the womb and post-birth. Maternal stress, anxiety, and depression during pregnancy and post-partum are reported to have short and long-term consequences for women's health, impact on mother-infant/child interactions, and increase the risk of emotional, cognitive, behavioural and social problems in children [5, 21-23]. Evidence has increasingly linked maternal mental health during pregnancy with child neurodevelopment outcomes, highlighting the need for improved understanding of antenatal factors that influence maternal mental health [4, 6, 14]. Research found associations between high levels of anxiety during pregnancy and poor quality of maternal bonding at 18 months postpartum [16] and between maternal anxiety and insecure attachment in young babies, as anxiety may hinder maternal sensitivity [24].

Evidence shows mental health problems can affect the quality of caregiving that the infant receives and thus the formation of the prenatal maternal-infant relationship prior and post-partum [25], particularly emotional availability postpartum [26]. Depressed mothers tend to find it hard to engage with their infants, interpret their body cues and attune with them [27]. The formation of a bonding relationship between a mother and her baby has been recognized as laying the foundation for later child development [26].

Mental health disorders during pregnancy may also impact maternal interoception [25], which has been associated to her capacity to respond to the infant's bodily cues, which is a requirement to meet the infant's needs [28, 29]. It follows that identifying interoceptive disorders may help in the early detection of mental health disorders during pregnancy and to mitigate the risk of postpartum depression or anxiety as well as mother-infant relationship difficulties. Therefore, strategic programs supporting maternal mental health and interoception during pregnancy are of utmost importance. While there is considerable evidence of the effects of prenatal programs promoting mindfulness, such as mindfulness-based therapies, in reducing parental stress, anxiety, and depression [19, 30] and improving prenatal attachment [31] and child development outcomes [32], there is a need for studies investigating the associations among all these maternal variables in one single group and during pregnancy and in the first postpartum trimester. The current study sought to address this gap. These findings would inform pilot programs for pregnant women which could positively influence their mental health and at the same time the relationship with their infant postpartum, with potential benefits for infant development and wellbeing. While links between maternal psychological problems in the postpartum period and difficulties in mother-infant relationship have been well documented [5, 33], there is less research investigating the relationship between psychological problems during pregnancy and mother-infant relationship in the first postpartum trimester.

Effective antenatal screening could both identify women with mental health problems during pregnancy and be used as a marker for those at risk for postpartum distress [34]. A deeper

understanding of the prenatal factors, such as mindfulness and interoception, that may mitigate the risks of postnatal depression, could fulfil the need for maternal health services to provide support strategies during pregnancy enabling mothers to cope with the challenges of the transition to childbirth and parenting. This would potentially minimise the risk of mental health and mother-baby relationship issues postpartum.

1.2 Mother-Infant Relationship during Pregnancy

The attachment relationship developed between a mother and her infant begins prenatally, during a period of transitions and sometimes of psychological vulnerability, and extended into the postnatal relationship, plays an important role in fostering more optimal infant development [35, 36]. Rubin [37] first conceived the immediate bond between mother and her neonate as an extension of mother-foetus experiences. Research has found associations between postnatal maternal-infant attachment and antenatal attachment, implying that feelings and affections manifested after the infant is born develop during pregnancy [38]. However, studies investigating the relationship between antenatal and postnatal maternal-infant relationship, in particular emotional availability, less than three months postpartum are needed.

The importance of maternal mental health in the formation of this relationship during pregnancy and postpartum has long been recognised [5, 39], highlighting the importance of supporting this relationship when it experiences difficulties. Depression during pregnancy was found to be negatively related to low maternal-foetal attachment (MFA) [39], suggesting that the links between postpartum depression and difficulties in mother-to-infant attachment may be mediated by antenatal factors. A low sense of attachment between an expectant mother and her unborn infant has been found to be associated with developmental delays, such as difficult infant temperament and uncontrolled crying [40]. This suggests that the quality of prenatal attachment is essential for development. Although prenatal bonding has received less research attention than postpartum bonding, studies suggest that mental health difficulties may undermine mother's ability to form a bonding relationship with her unborn baby [25, 41, 42]. This evidence provides a foundation for looking more attentively at assessing and improving maternal wellbeing and maternal-infant relationship during pregnancy, to give children a head-start before they are born. Furthermore, it informs future support strategies, such as mindfulness practices, to support earliest human connections and promote infant development [17, 18, 43].

1.3 Mindfulness

Pregnant women go through a significant transition into the perinatal period, where preconceived ideas and identity may be challenged. Mindful parenting provides the psychological flexibility required to adapt to the challenges of the perinatal period. Mindfulness-based programs are a relatively new approach to the prevention and treatment of mental health problems. Mindfulness is a quality of human consciousness that can be independently assessed. It is popularly defined by Jon Kabat Zin [44] as "the awareness that arises from paying attention on purpose, in the present moment, and non-judgementally, to the unfolding of experience moment by moment" (p.145). This compassionate awareness also reduces one's automatic, habitual reactions to what is happening and allows for more space between the trigger and the response [45]. Mindfulness involves techniques that help cope with worry by helping an individual attend to the present rather

than the past and the future [46]. For pregnant women and new mothers facing the challenges and stress of a significant period of transition, such skills may be of particular importance.

Parents' distress curtails parents' emotional availability towards their babies and relationship with them, which is supportive of baby's health and development [26]. By practicing present-moment awareness of both their child and their own thoughts and emotions without judgement and accepting them for what they "are", the parents may develop protective psychological strategies [47, 48]. Support programs during pregnancy promoting mindfulness, such as mindfulness-based therapies, have shown positive outcomes, primarily in reducing parental stress, anxiety, and depression [19, 30]. Antenatal maternal mindfulness has been associated with better self-regulation and lower levels of negative affect in 10-month-old infants [49]. Associations between maternal mindfulness and response to infant stress with reduced reactivity have been identified [50]. Researchers found that higher levels of mindfulness were associated with less depressive symptoms and better quality of prenatal attachment [31]. Therefore, mindfulness can be considered a protective factor for two generations, fostering attunement between parent and infant, positive attachment and child development and behaviour outcomes [32, 51].

These findings indicate that maternal mindfulness during pregnancy and postpartum may positively influence early infant development. However, research on how mindfulness changes from pregnancy to the first postpartum trimester and on the effects of maternal mindfulness during pregnancy on mother-infant relationship postpartum and infant outcomes is still in its infancy. Both maternal mental issues and mother-baby relationship difficulties post-partum could be addressed in the future by support strategies that target mindfulness during pregnancy. These findings highlight the importance of prenatal programs promoting mindfulness not only for parents at risk for depression or poor bonding but also for both generations [17, 18, 32]. Programs focused on both enhancing maternal mindfulness and wellbeing, and mothers' connection with their infants from before birth, like the Prenatal Mindfulness Relationship-Based (PMRB) program designed and piloted by Antonella Sansone in her PhD, can lead to positive postnatal outcomes of these variables [17, 18].

1.4 Interoception

Interoception, or interoceptive awareness, has been defined as, "...the process by which the nervous system senses, interprets, and integrates signals originating from within the body, providing a moment-by-moment mapping of the body's internal landscape across conscious and unconscious levels" ([52], p. 501). Interoception could play a key role in maternal sensitive behaviour suggesting that the mother's ability to perceive her own internal bodily signals might support responsiveness to her infant's bodily cues [28]. Since maternal sensitivity or ability to understand and interpret her infant's cues are involved in maternal emotional availability, interoception could play a prominent role in it.

Despite the growing interest in interoception for its significant relevance in the study of mind-body approaches and human health [52-54], little research has examined the influence of interoception on mother-infant relationship during pregnancy and postpartum. Mothers' capacity to interocept and interpret has been associated with her capacity to respond to the infant's bodily cues, which is a requirement to meet the infant's developmental needs [29]. If pregnant mothers suffer from stress, depression and/or anxiety, this has been found to impact upon their

interoceptive abilities [25], and thus their capacity to respond to their infant's need, affecting the future co-regulating processes within the mother-infant relationship [28, 29]. Based on this evidence, it may be necessary to investigate whether interoception can be an effective predictor tool for early detection of mental health disorders during pregnancy and postpartum as well as mother-infant relationship difficulties. Prenatal programs promoting interoception can enhance both maternal mental health and mother-infant relationship during pregnancy and post-partum.

1.5 Emotional Availability

Emotional availability is the ability to share an emotional connection within a dyad or caregiving-child relationship and has been referred to as “the connective tissue” in relationships [55]. Emotional availability has been considered a good postnatal indicator of a well-functioning mother-infant relationship [56]. Findings indicate the importance of emotional availability in the postpartum period and early parenthood as well as the need to support emotional availability in parenthood [57]. Good emotional availability [56, 58] in the first year of life indicates well-attuned preverbal interactions between infant and parent; that is, a well-functioning parent-infant relationship [57]. These parental abilities and preverbal communications are key factors in parent-infant relationship and are essential contributors to infant development [59]. Findings indicate a significant effect of early pregnancy depressive symptoms on maternal emotional availability [27]. Mothers with depressive symptoms have been found to less likely verbally engage and attune with their infants and interpret their body cues, and more likely to manifest irritable behaviour with them [60]. Therefore, maternal mental health issues are reported to have an impact on maternal-infant emotional availability, which highlights the need for support during this crucial time for infant's development of a healthy relationship with the caregiver. Gaining an improved understanding of the associations between post-partum emotional availability and maternal mental health, mindfulness, interoception, and mother-infant relationship during pregnancy and postpartum may highlight support strategies to promote better mother-infant relationship, potentially leading to more positive outcomes for children.

1.6 Current Study

Given the significant transitional time that the prenatal and postnatal period represents for a woman, with changes in maternal mental health from pregnancy to the post-partum period, this study was designed to examine changes in maternal mindfulness, interoception, and mother-infant relationship during pregnancy, referred to as maternal-foetal attachment, and in the first post-partum trimester. In addition, associations between these maternal variables during pregnancy and 10-12 weeks post-partum, including mother-infant relationship post-partum, referred to as maternal emotional availability, were investigated.

2. Method

2.1 Design

The study used a prospective longitudinal design with a quantitative methodology.

2.2 Participants

Women were eligible to participate in the study if they were: (a) aged 18 or older; (b) 20+ weeks gestation (c) had sufficient English and intellectual proficiency to understand and complete the questionnaires; (d) did not receive antenatal care from specialized clinics, irrespective of parity and ethnicity; (e) from any of the following Anglo-Saxon countries: Australia, New Zealand, UK, USA, and Canada. Of those who gave the consent to participate in the study, 110 completed the first survey at 20+ weeks gestation (Timepoint 1-T1), 72 completed the second survey at approximately 36-week gestation (Timepoint 2-T2) and 67 completed the third survey at 10-12 weeks post-partum (Timepoint 3-T3).

Participants' age ranged from 18 to 47 years ($M = 33.22$; $SD = 5.536$). At T2 (Approx 36-week gestation) 79 participants (91.14%) completed the survey. At T3 (10-12 weeks postpartum) 67 participants (87.01%) completed this stage of the study. The majority of participants were Australian (43.64%), 20% British, 17.27 North American, 2.73% and the rest from different nationalities who had lived in any of the Anglo-Saxon countries.

The majority of women were married or in a relationship, from middle to upper class socioeconomic backgrounds (based on the IRSAD) and from high school/equivalent to doctoral degree educational level, with the majority holding a bachelor's degree. Nearly half of the women were in full-time employment, a quarter in part-time employment, three in casual employment, 12 self-employed, 12 were unemployed and four students. Most pregnancies had been planned (76.36%), and 23.64% were unplanned. Almost all the pregnancies were wanted (98.18%). Of 110 participants, 23.64% underwent fertility/infertility treatments and 84.55% did not have any pregnancy complication by the time of enrolment. All the pregnant women had experienced a Covid-19 lockdown of the duration from less than a week to less than a year, 36.36% more than one month and 13.64% between one month and one year. Table 1 displays further demographic characteristics of the sample at T1.

Table 1 Demographic Profile of Participants (N = 110).

Individual-Level Variables	<i>n</i>	% (2 dp)
Age		
<20	1	0.91
20–24	3	2.73
25–29	23	20.91
30–34	40	36.36
35–39	27	24.55
40–44	13	11.82
45–49	3	2.73
Nationality		
Australian	48	43.64
British	22	20.00
North American	19	17.27
Canadian	3	2.73
New Zealander	1	0.91
Hispanic	1	0.91

Indian	1	0.91
Italian	1	0.91
Mexican	1	0.91
Romanian	1	0.91
Other	12	10.91
Marital Status		
Married	66	60.00
In a Relationship/De Facto	39	35.45
Single	5	4.55
N of People in Household		
One	1	0.91
Two	45	40.91
Three	40	36.36
>Four	24	21.82
Highest Level of Education		
High School Certificate/Equivalent	13	11.82
Vocational/Technical College	14	12.73
Bachelor's Degree	37	33.64
Master's Degree	26	23.64
Doctoral Degree	9	8.18
Other	11	10.00
Primary Area of Employment		
Full-Time	50	45.5
Part-Time	29	26.4
Self-Employed	12	10.9
Unemployed	12	10.9
Student	4	3.6
Casual	3	2.7
Hours Per Week		
<10	2	66.67
10–20	1	33.33
Household Total Annual Income		
0–40,000	14	12.73
40,001–60,000	15	13.64
60,001–80,000	15	13.64
80,001–100,000	16	14.55
100,001+	49	44.55
Level of Carer Responsibility		
Primary Carer	56	50.91
Equal Responsibility	46	41.82
Secondary Carer	5	4.55
Other	3	2.73
Pregnancy Planned		
Yes	84	76.36

No	26	23.64
Pregnancy Wanted		
Yes	108	98.18
Ambivalent	2	1.82
Undergone Fertility Treatment		
Yes	26	23.64
No	84	76.36
Current Number of Children		
One	86	78.18
>One	24	21.82
Current Pregnancy Complications		
No	93	84.55
Yes*	17	15.45
Covid Lockdown Experience		
Yes	110	100.00
Covid Lockdown Length		
<1 Week	26	23.64
1 Week–1 Month	29	26.36
>1 Month	40	36.36
1 Month–1 Year	15	13.64

Note. N = total number of participants, n = number of participants in the corresponding category, % = percentage of N in the corresponding category; * Percentages not included as participants may have experienced multiple pregnancy complications.

2.3 Procedure

Pregnant women were invited through advertisements posted in pregnancy groups on social media (e.g., Facebook groups, Twitters) and word of mouth (using the snowball sampling technique) to participate in an online correlational study, including the completion of a self-report questionnaire package consisting of empirically established measures at three timepoints via an electronic link (Qualtrics). The advertisements were also distributed among prenatal organisations, the professional and personal networks of the researcher and supervisor, antenatal clinics, and general practitioner clinics after obtaining gatekeeper approval via an invitation letter sent to the director by the PhD candidate. The use of virtual social networking sites can expand the geographical scope and increase the sample size and its representativeness [61].

The package consisted of a socio-demographic questionnaire and five questionnaires for the first survey at 20+ weeks gestation. Participants received requests for the completion of the same questionnaires at approximately 36 weeks' gestation via email. Participants would then be invited via email to complete a post-birth questionnaire package with the same questionnaires, excluding the Maternal-Foetal Attachment Scale (MFAS) and including the Emotional Availability Self-Report (EA-SR) at 10-12 weeks postpartum follow-up. If no response was received after three email communication attempts, follow-up was aborted. Each email showed gratitude for the participants commitment. The quality of relationship between researcher and participants is a key factor for retention [62]. To encourage recruitment and retention of participants, incentives were offered.

Participants were offered a free link to a digital sleep enhancing product for completing all the surveys. It was made clear in the advertisement that there was no obligation to take part, and each online survey would take approximately 30 minutes. The Participant Information Sheet (PIS) informed the women that the study aimed to examine infant and mother relationships and wellbeing and was provided at each of the three surveys. They PIS made it clear that participants could cease participating in the research at any time. It explained that should participants experience any physical or emotional discomfort related to the research, they were encouraged to seek individual professional support from their general practitioner or other health professional. Contact numbers were displayed on the PIS. They were also given the opportunity to contact the student researcher via email and ask questions. Enabling participants to contact the investigators at any time of the day has shown benefits in retention [62].

The Participant Consent Form (PCF) was also provided at each stage of data collection and consent was sought at each time point after the participants had confirmed that they had read the information about the study. Participants were also invited to include their email address after consenting to participate so that to receive an invitation to participate in next survey. Data collection took place from February 10 to June 14, 2022. Figure 1 displays the time points (T1, T2, and T3).

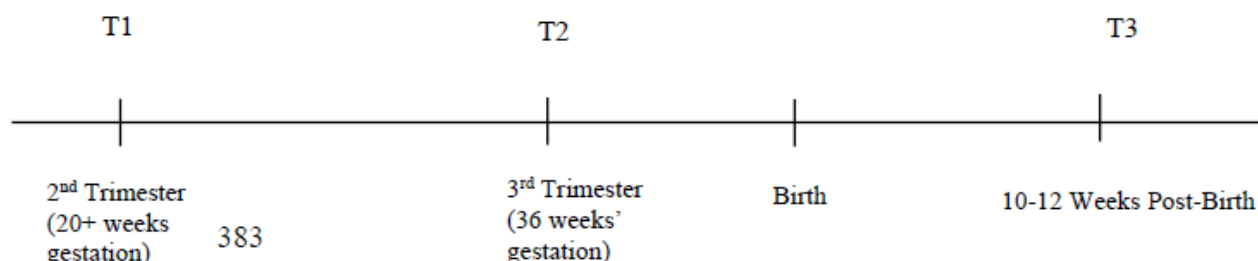


Figure 1 Time Points – T1, T2, T3.

2.4 Measures

The outcome measures were divided into three categories: measures for mental health, measures for mother-infant relationship and measures for maternal personal development. The self-report questionnaire package is described below.

2.4.1 Socio-Demographic and Birth/Post Birth Questionnaires

Socio-demographic information (e.g., relationship status, number of children, and household income level) was collected from participants at baseline before the first survey at 20+ weeks gestation. Information surrounding type of birth, gestation length, birth weight, breastfeeding/feeding, pregnancy complications (e.g., pregnancy-induced hypertension, gestational diabetes, preterm labour) was collected at follow-up before the third survey at 10-12 weeks post-partum.

2.4.2 Maternal Mental Health Measures

Three different outcomes assessed mental health: depression, anxiety, and stress.

The Edinburgh Postnatal Depression Scale (EPDS; [63]). It is one of the most widely used self-report screening tools designed to detect depressive symptoms, particularly during the perinatal period, although it has also been widely used during pregnancy [64]. Pregnant women are required to select the statement which reflects how they have felt in the past 7 days, such as, “I have looked forward with enjoyment to things”, As much as I always could; Rather less than I used to; Definitely less than I used to; Hardly at all. The scale consists of 10 Likert-type items scored from 0 to 3 on a 4-point Likert scale and scores are summed to get an overall score, with some items reversed scored [65], with a maximum score of 30. A higher EPDS score represents an increased risk of depressive symptoms. The scale has shown adequate internal consistency, test-retest reliability, and validity, in previous studies [65, 66].

The Cronbach's alpha for the sum scale in the sample was 0.872 at T1, 0.877 at T2, and 0.895 at T3. A value of 0.7 or higher is generally acceptable for Cronbach's alpha, with higher values indicating better internal consistency and reliability.

The Depression Anxiety Stress Scale-21 (DASS-21; [67]). The self-report DASS-21 was used to assess symptoms of depression, anxiety, and stress over the past week. DASS-21 contains seven items for each of the three subscales (total of 21 items), and items are rated on a four-point Likert scale ranging from 0 = never to 3 = almost always, with higher scores being indicative of higher levels of depression, anxiety, or stress. DASS-21 has adequate reliability and validity, as evidenced in a number of outcomes studies [67, 68]. The DASS-21 has also been considered useful to evaluate psychological distress in the prenatal and perinatal period, as it showed adequate reliability and validity [69].

Cronbach's alpha for the sum scale in the sample was 0.912 at T1, 0.923 at T2, and 0.934 at T3.

2.4.3 Maternal-Infant Relationship Measures

Two different measures assessed mother-infant relationship during pregnancy and post-birth: the Maternal-Foetal Attachment Scale (MFAS; [70]) and the Emotional Availability Self-Report (EA-SR; [57]).

The Maternal-Foetal Attachment Scale (MFAS; [70]). The 24-item MFAS provided an assessment of pregnant women's engagement with behaviors indicative of an emotional connection and interaction with their unborn baby, such as talking to the baby and massaging the stomach where the baby is [70]. The MFAS comprises five subscales: role taking, differentiation of self from the foetus, interaction with the foetus, attributing characteristics to the foetus, and giving of self. Each item is scored on a 5-point Likert-type scale with options ranging from 1 (strongly agree/definitely yes) to 5 (strongly agree/definitely no). The total scale score ranges from 24 to 120, with higher scores indicating more favorable maternal-foetal attachment. The MFAS is a frequently and internationally used instrument in prenatal studies [71]. The MFAS has been found to have good reliability [66, 70].

The Cronbach's alpha for the sum scale in the sample was 0.795 at T1 and 0.812 at T2.

The Emotional Availability Self-Report (EA-SR; [56]). The 36-item self-report was used to assess maternal emotional availability, a measure that is considered a good indicator of a favourable mother-infant relationship during the first year of a child's life [57]. The EA-SR comprises five

subscales: Capacity to Involve the Parent, Mutual Attunement, Affect Quality, Intrusiveness, and Hostility. Each scale is rated on a 5-point Likert scale: (0) Not agree at all, (1) Rather not agree, (2) Neutral (3) Rather agree (4) Totally agree. Two scales, Intrusiveness and Hostility, refer to the parent contribution to the relationship as perceived by the parent. One scale, Capacity to Involve the Parent, refers to the child's contribution to the relationship as perceived by the parent. Two other scales, Mutual Attunement and Affect Quality, refer to both parent and child's contribution to the relationship. An example of the included items is, "I do understand my child, when he or she cries" (Mutual Attunement). The EA-SR is a psychometrically sound measure, with good reliability and convergent validity [57].

The Cronbach's alpha for the sum scale in the sample was 0.845 at T3.

2.4.4 Maternal Personal Development Outcome Measures

Two different outcomes assessed maternal personal development during pregnancy and post-birth: the Five Facets Mindfulness Questionnaire (FFMQ; [72, 73]) exploring the level of maternal mindfulness and the Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAYA-2; [74]), measuring maternal interoception (or interoceptive awareness).

The Five Facets Mindfulness Questionnaire (FFMQ) [72]. The FFMQ contains 39 items, scored on a Likert-scale of 1 (Never or very rarely true) to 5 (Very often or always true), with higher scores indicating greater mindfulness. These items capture five facets of mindfulness: observing, describing, acting with awareness, nonjudgment of inner experience, and nonreactivity to inner experience. An example question from the Acting with Awareness subscale is "It seems I am 'running on automatic' without much awareness of what I am doing". The measure, widely used in diverse populations, has shown high levels of internal consistency and convergency and discriminant validity when used in nonclinical samples [73]. The FFMQ has showed good reliability and validity in a number of outcome studies of pregnant women [16, 75].

The Cronbach's alpha for the sum scale in the sample was 0.930 at T1, 0.930 at T2, and 0.937 at T3.

The Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAYA; [74]). The new version 37-item MAIA-2 consists of eight scales corresponding to its 8-factor structure. These are labelled Noticing, Not-distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trust. The two items were added to improve internal consistency and make it a valid measure of interoception [74]. MAYA has been widely used in research and clinical contexts and is the mostly widely used self-report measure of interoceptive bodily awareness. Despite the growing interest in interoception for its significant relevance in the study of mind-body approaches and human health [52, 53], little research has examined the psychometric properties of interoception in pregnant populations. A pilot study found significant correlations between interoceptive awareness and anxiety [25], showing good validity of this instrument.

The Cronbach's alpha for the sum scale in the sample was 0.938 at T1, 0.933 at T2, and 0.938 at T3.

2.5 Statistical Analysis

Statistical data analysis was performed using Statistical Package or Social Sciences (SPSS) version 28 (IMB Corp, 2021). An alpha coefficient of 0.05 (* $p < 0.05$) was used to assess the significance. Four one-way repeated measures ANOVAs were conducted over three time periods. T1 consisted of 110 participants, T2 consisted of 72 participants and T3 consisted of 67 participants. Following, three follow up ANOVAs were run to investigate the changes in the dependent variable subscales on the FFMQ, DASS-21 and MAIA-2 across the three timepoints. Lastly a final ANOVA was run on the T1 and T2 scores on the MFAS to determine any changes across time.

To best assess for the correlations across the dependent variables total scores, a Pearson's correlation analysis was run across all measures (FFMQ, EPDS, DASS-21, MAIA-2, MFAS, EA-SR). Additionally, to best understand the relationship between these measures, multiple correlational analyses were run to compare the total scores and subscales of the measures.

Prior to conducting the analyses, the data was visually screened for any missing variables, or data entry errors, which was corrected. For those who completed the entire package, no missing data was present. Other aspects such as confounding factors were not handled via control (in hierarchical regression) where possible in this study. There was no missing information to be handed as appropriate in the circumstances such as mean replacement. Participants who did not complete a survey were excluded from the study. At T1, 61.45% (N = 110) of participants who consented to participate in the study and completed only some questionnaires (N = 179) completed Survey 1. At T2, 91.14% (N = 72) of participants who consented to participate in Survey 2 (N = 79), completed all the questionnaires. At T3, 87.01% (N = 69) of participants who consented to participate in Survey 3 (N = 77) completed all the questionnaires. Although the sample at T1 had minimum number to detect smaller effect sizes, the relatively small size at T2 and T3 affected the level of analysis and generalizability of findings [76]. Future research with larger sample sizes is needed to increase the statistical power to detect smaller effect size.

2.6 Ethics Statement

The study was approved by Bond University Human Research Ethics Committee (BUHREC) in 2021 (Project number AS03523) prior to commencement and all participants consented to participate.

3. Results

Information about birth, gestation length, birth weight, breastfeeding/feeding, pregnancy complications was collected at follow-up before the third survey at 10-12 weeks post-partum.

Table 2 displays some birth and post-birth outcomes of the participants reported before completion of the self-report questionnaire package at T3.

Table 2 Birth and Post-Birth Information (N = 67).

Individual-Level Variables	69	% (2 dp)
Birth Experience Satisfaction		
Very Satisfied	36	53.73
Somewhat Satisfied	10	14.93

Neutral	6	8.96
Somewhat Dissatisfied	10	14.93
Very Dissatisfied	5	7.46
Complications During Pregnancy		
Yes	17	25.37
No	50	74.63
Type of Delivery		
Unassisted Vaginal*	39	58.21
Assisted Vaginal	5	7.46
Planned Caesarean	5	7.46
Unplanned Caesarean	18	26.87
Experience of Labour		
Yes	58	86.57
Beginnings of Labour		
Spontaneous	39	67.24
Induced	18	31.03
Result of Fall	1	1.72
No	9	13.43
Complications During Labour and Delivery		
Yes**	35	52.24
No	32	47.76
Labour Pain Management Strategies		
Yes	54	80.60
No	11	16.42
No Response	2	2.99
Birth Attendance		
Partner	61	91.04
Midwife	3	4.48
Doula	2	2.99
Other Support Person	1	1.49
Baby's Weight		
>2500 grams	1	1.49
2500–3000 grams	13	19.40
3001–3500 grams	19	28.36
3501–4000 grams	24	35.82
4001–4500 grams	7	10.45
4501–5000 grams	3	4.48
Weeks of Gestation at Birth		
<35 Weeks	2	2.99
35–37 Weeks	6	8.96
38–40 week	38	56.72
41–42 Weeks	21	31.34
Baby Gender		
Girl	41	61.19

Boy	26	38.81
Skin-To-Skin Contact 2 Hours Post-Birth		
Yes	62	92.54
No	5	7.46
Intent to Breastfeed Prior to Birth		
Yes	66	98.51
Unsure	1	1.49
Attempt to Breastfeed Post Birth		
Yes	66	98.51
Breastfeeding Satisfaction		
Very Satisfied	33	50.00
Somewhat Satisfied	22	33.33
Neutral	6	9.09
Somewhat Dissatisfied	3	4.55
Very Dissatisfied	3	4.55
No	1	1.49
Period After Birth to Breastfeed		
<1 Hour	44	65.67
1–6 Hours	16	23.88
6–12 Hours	1	1.49
12–24 Hours	4	5.97
>24 Hours	2	2.99
Circumstances Delaying First Breastfeed		
Yes **	23	34.33
Baby in Special Care Nursery	4	17.39
Baby in NICU	4	17.39
Mother in Surgery/Recovery	3	13.04
Difficulty Latching	2	8.70
Other	9	39.13
No	25	37.31
No Response	19	28.36
Concern Regarding Baby Crying		
Not Concerned	34	50.75
Somewhat Concerned	12	17.91
Neutral	15	22.39
Concerned	5	7.46
Very Concerned	1	1.49
Concern Regarding Baby Sleeping		
Not Concerned	41	61.19
Somewhat Concerned	7	10.45
Neutral	14	20.90
Concerned	5	7.46

Note. N = total number of participants, n = number of participants in the corresponding category, % = percentage of N in the corresponding category; * Percentages not included as participants may have experienced multiple pregnancy complications.

3.1 Primary ANOVA Results

Four within-subjects ANOVAs were run to explore the change in mindfulness, depression, anxiety, stress, interoceptive awareness during pregnancy and post-partum across T1, T2, and T3, and in mother-infant relationship (maternal-foetal attachment) from T1 to T2 during pregnancy. Using Wilk's λ , univariate analysis on FFMQ did not indicate a significant change in mindfulness scores $F(2, 66) = 0.021, p = 0.980$, partial $\eta^2 = 0.001$. Univariate analysis on EPDS indicated a significant difference in depressive scores $F(2, 66) = 3.535, p = 0.035$, partial $\eta^2 = 0.098$. Univariate analysis on DASS-21 did not indicate a significant difference in depressive, anxiety, and stress scores $F(2, 66) = 1.516, p = 0.227$, partial $\eta^2 = 0.045$. Univariate analysis on MAIA-2 did not indicate a significant difference in interoceptive awareness scores $F(2, 66) = 0.362, p = 0.698$, partial $\eta^2 = 0.011$. Lastly, univariate analysis on MFAS indicated a significant difference in maternal-foetal attachment scores $F(2, 66) = 0.868, p = 0.004$, partial $\eta^2 = 0.111$. Results suggest that participants' mindfulness, interoception, and depression, anxiety, and stress symptoms as measured with DASS-21 did not change over time but remained stable, whereas depression symptoms as measured with the EPDS improved over time. Results also revealed that maternal-foetal attachment scores improved from 20+ weeks to 36 weeks' gestation.

An individual analysis was performed on participants' mean scores of maternal emotional availability as the measure can only be used in the postnatal period. Therefore, a comparison between the MFAS and EA-SR could not be performed. The individual results of EA-SR indicated that participants reported mean score of maternal emotional availability post-partum close to the Non-Depressed Sample mean score. Specifically, the mean scores of the subscales Mutual Attunement, Child Involvement, and Affect Quality were all higher than those of a depressed sample and close to the mean scores of a non-depressed sample. Intrusiveness mean score was lower than in a depressed sample and non-depressed sample. However, level of hostility was higher than in a depressed sample and non-depressed sample.

Referring to the DASS-21 score range at T1, of 110 participants, 71 fell within the normal range for depression, 12 mild, 21 moderate, 3 severe, and 3 extremely severe; 59 participants fell within the normal range for anxiety, 27 mild, 5 moderate, 11 severe, 8 extremely severe; 68 fell within the normal range for stress, 13 mild, 19 moderate, 9 severe, 1 extremely severe. Referring to the EPDS score range, 50 participants fell in Category 1 (presence of some ordinary depressive symptoms), 28 fell in Category 2 (presence of symptoms of distress that may be discomforting and repeating the EPDS in 2-week time is advised), and 3 participants fell in Category 3 (likelihood of high depression is high and referral to a psychiatrist/psychologist may be necessary). Table 3 displays the participants' normal to extremely severe range of depression, anxiety, and stress at T1 of DASS-21 and score range of EPDS. Table 4 displays the means and standard deviations across Time 1 (N = 110), Time 2 (N = 72) and Time 3 (N = 67). The results in Table 3 demonstrate that mean maternal depressive symptoms significantly decreased from T1 and T2 in pregnancy to postpartum T3. The mean maternal-foetal attachment increased from T1 to T2. Figure 2 displays total mean score on

FFMQ, EPDS, DASS-21 and MAIA-2 Across T1, T2 and T3. Table 5 displays EA-SR mean scores comparing to sample mean to depressed and non-depressed Clinical Sample Means.

Table 3 Participants' normal to extremely severe range of depression, anxiety, and stress at T1 (DASS-21); Participants normal to severe range of depression (EPDS).

DASS-21: Participants' Score Range
Depression Levels
- Normal: 71 participants
- Mild: 12 participants
- Moderate: 21 participants
- Severe: 3 participants
- Extremely severe: 3 participants
Anxiety Levels
- Normal: 59 participants
- Mild: 27 participants
- Moderate: 5 participants
- Severe: 11 participants
- Extremely severe: 8 participants
Stress Levels
- Normal: 68 participants
- Mild: 13 participants
- Moderate: 19 participants
- Severe: 9 participants
- Extremely severe: 1 participant
EPDS: Participants' Score Range (see Appendix for category description)
Depression Levels
- Category 1: 50 participants
- Category 2: 28 participants
- Category 3: 32 participants

Table 4 Means and Standard Deviations Across Time 1 (N = 110), Time 2 (N = 72) and Time 3 (N = 67).

Scale	Time 1 M (SD)	Time 2 M (SD)	Time 3 M (SD)
FFMQ	127.02 (18.89)	127.07 (19.59)	126.96 (19.89)
EPDS	20.28 (5.06)	19.12 (5.03)	17.67 (5.36)
DASS-21	36.41 (9.37)	36.25 (10.41)	33.94 (10.40)
MAIA-2	114.26 (22.22)	114.49 (20.95)	111.90 (22.55)
MFAS	91.80 (10.40)	95.93 (10.49)	-

Note. FFMQ = Five Facet Mindfulness Questionnaire; EPDS = Edinburgh Postnatal Depression Scale; DASS-21 = Depression Anxiety Stress Scale-21 Short Form; MAIA-2 = The Multidimensional Assessment of Interoceptive Awareness, Version 2; MFAS = The Maternal-Foetal Attachment Scale.

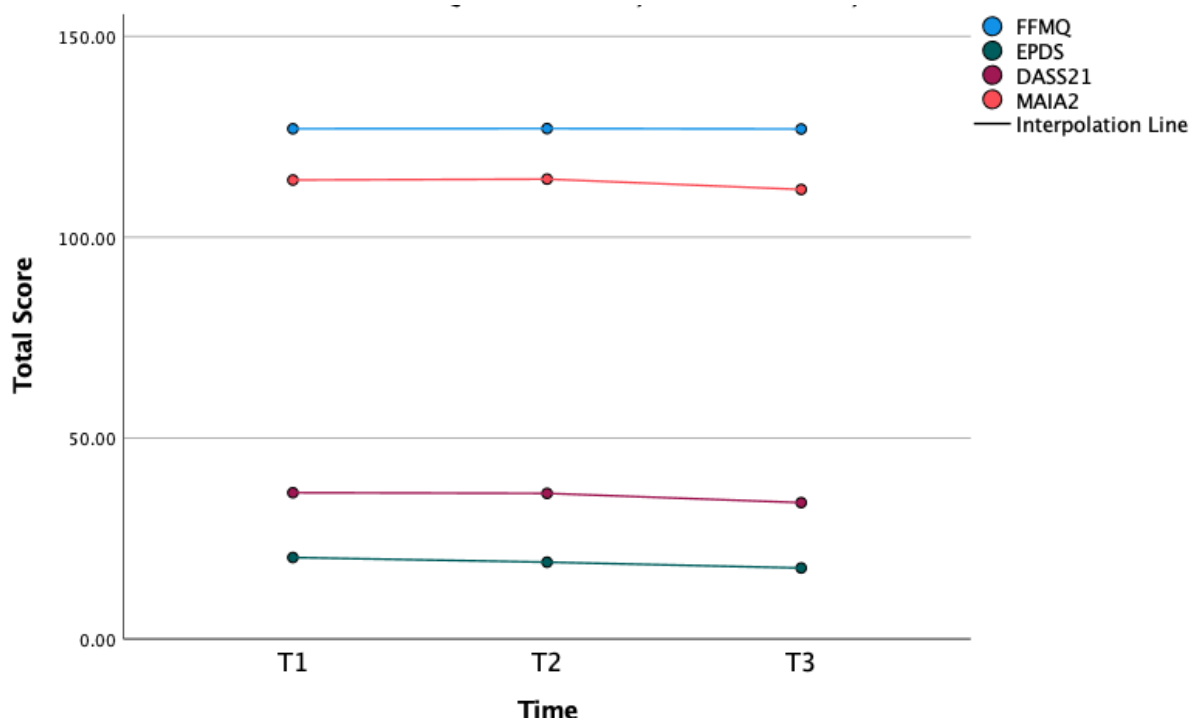


Figure 2 Total Mean Score on FFMQ, EPDS, DASS-21 and MAIA-2 across T1, T2 and T3.

Table 5 EA-SR mean scores comparing to sample Mean to Depressed and Non-Depressed Clinical Sample Means.

Subscale	Study M	Depressed Sample M	Non-Depressed Sample M
Mutual Attunement	38.67	31.52	40.41
Child Involvement	39.25	32.36	35.85
Affect Quality	22.55	21.32	23.86
Intrusiveness	19.01	22.32	21.06
Hostility	10.82	4.98	5.06

Compared to data extracted from Nicole Vliegen, Patrick Luyten & Zeynep Biringen [57]. A Multimethod Perspective on Emotional Availability in the Postpartum Period, Parenting: Science and Practice, 9:3-4, 228-243, DOI: 10.1080/15295190902844514.

3.2 Subscale Analyses and Results

Furthermore, preliminary analyses on the subscales of the FFMQ, DASS-21 and MAIA-2 were also conducted. The only subscale that indicated a significant difference was Anxiety in DASS-21. Using Wilk's λ , univariate analysis on the subscales on the DASS-21 did not indicate a significant difference in depression scores $F(2, 66) = 1.798, p = 0.174$, partial $\eta^2 = 0.052$. Univariate analysis on the anxiety subscale scores indicated a significant difference $F(2, 66) = 4.753, p = 0.012$, partial $\eta^2 = 0.128$. Lastly, univariate analysis on the stress subscale did not demonstrate a significant change across time $F(2, 66) = 0.053, p = 0.948$, partial $\eta^2 = 0.002$. Table 6 demonstrate that mean maternal anxiety symptoms significantly decreased from T1 and T2 in pregnancy to T3 post-partum.

Table 6 Mean score in DASS-21 Anxiety subscale.

DASS-21 Anxiety Subscale	M (SD)
Time 1	11.18 (3.33)
Time 2	11.16 (3.51)
Time 3	9.79 (3.31)

Associations between Scales: maternal mindfulness (MFAS), depression (EPDS & DASS-21), anxiety, and stress (DASS-21), interoception (MAIA-2), and maternal- foetal attachment (MFAS) across T1, T2 and T3, and emotional availability (EA-SR) at T3.

Significant negative associations were found between FFMQ at T1 and EPDS and DASS-21 at T1, T2, and DASS at T3, which means that lower levels of maternal mindfulness in the second trimester of pregnancy were associated with significantly poorer quality of maternal mental health across the time points. Higher levels of maternal mindfulness at T1 were associated with significantly higher interoception at T1 and T2 and maternal-foetal attachment (MFAS) at T1. Quality of maternal mental health, thus lower scores in depression, anxiety, and stress (measured with the EPDS and DASS-21) at T2 were significantly associated with higher levels of the same maternal variables at T1 and higher levels of maternal-foetal attachment at T2. Significant negative associations were found between interoception at T2 and depression, anxiety, and stress (EPDS and DASS-21) at T1, which means that pregnant women with higher scores of depression, anxiety, and stress at T1 were significantly poorer on interoceptive awareness at T2. Interoception at T2 was significantly positively associated with mindfulness and maternal-foetal attachment at T2 and negatively associated with depression, anxiety, and stress (EPDS and DASS-21) at T2. These associations were revealed also at T3, demonstrating that they remained stable over time. Mothers with higher scores in mindfulness revealed significantly better scores in mental health (lower scores on EPDS and DASS-2) at T3. Higher levels of maternal emotional availability (EA-SP) at T3 were positively associated with higher mindfulness at T3 and inversely associations with depression (EPDS) at T3. Taken together, these results indicate that lower mindfulness and interoception and poorer mental health at T1 and T2 may be associated with poorer maternal-infant relationship during pregnancy at T1 and T2 (as referred to maternal-foetal attachment) and post-partum at T3 (as referred to emotional availability). Table 7 displays associations between maternal mindfulness, depression, anxiety, and stress, interoception, and maternal-foetal attachment across T1, T2, and T3 and emotional availability at T3.

Table 7 Pearson Correlation Coefficient for Focal Variables Across T1 (N = 110), T2 (N = 72) and T3 (N = 67).

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. T1 FFMQ	-														
2. T1 EPDS	-0.625**	-													
3. T1 DASS-21	-0.641**	0.725**	-												
4. T1 MFAS	0.251**	0.056	-0.124	-											
5. T1 MAIA-2	0.686**	-0.434**	-0.485**	0.272**	-										
6. T2 FFMQ	0.387**	-0.228	-0.404*	0.024	0.233	-									
7. T2 EPDS	-0.276*	0.110	0.242*	-0.015	-0.175	-0.661**	-								
8. T2 DASS-21	-0.316**	0.224	0.313**	0.051	-0.178	-0.700**	0.825**	-							
9. T2 MFAS	-0.044	-0.010	-0.080	-0.024	-0.003	0.220	-0.041	-0.039	-						
10. T2 MAIA-2	0.393**	-0.258*	-0.375**	0.082	0.217	0.660**	-0.524**	-0.503**	0.271*	-					
11. T3 FFMQ	0.165	-0.211	-0.237	0.015	0.199	0.112	-0.084	-0.095	-0.065	0.089	-				
12. T3 EPDS	-0.114	0.129	0.164	0.000	-0.091	-0.106	0.048	0.048	0.019	-0.117	-0.562**	-			
13. T3 DASS-21	-0.265*	0.206	0.292*	-0.010	-0.256*	-0.180	0.181	0.133	0.059	-0.243*	-0.715**	-0.846**	-		
14. T3 EAS-R	0.041	-0.110	-0.184	0.022	0.100	0.200	-0.045	-0.060	-0.061	0.116	0.480**	-0.483**	-0.574	-	
15. T3 MAIA-2	0.001	-0.082	-0.126	-0.095	0.047	0.072	-0.081	-0.056	-0.096	-0.005	0.710**	-0.429**	-0.487**	0.398**	-

Note. FFMQ = Five Facet Mindfulness Questionnaire; EPDS = Edinburgh Postnatal Depression Scale; DASS-21 = Depression Anxiety Stress Scale-21 Short Form; MFAS = The Maternal-Foetal Attachment Scale; MAIA-2 = The Multidimensional Assessment of Interoceptive Awareness, Version 2.

* $p < 0.05$; ** $p < 0.001$.

3.3 Associations between Subscales

Analyses were conducted to ascertain associations between maternal variables subscales across T1, T2, and T3 (For correlation tables see:

<https://accounts.osf.io/login?service=https://osf.io/5shc3/>).

3.3.1 Associations between MFAS Overall Scores and MAIA-2 Subscale Scores

Higher levels of maternal-foetal attachment at T1 were significantly associated with all the MAIA subscales: higher levels of attention regulation, emotional awareness, self-regulation, and body listening at T1 and higher levels of noticing, attention regulation, emotional awareness and body listening at T2.

3.3.2 Associations between MFAS Overall Scores and FFMQ Subscale Scores

Significant associations were found between maternal-foetal attachment and the mindfulness facet “observing” and “describing” at T1 and “observing” at T2.

3.3.3 Associations between MFAS Overall Scores and DASS-21 Subscale Scores

Higher levels of maternal-foetal attachment were significantly associated with lower levels of depression at T1. However, this correlation was not revealed at T2.

3.3.4 Associations between FFMQ Subscales and MAIA-2 Subscales

All the mindfulness facets were significantly associated with all the subscales of MAYA-2 at T1, T2. And T3. Tables displayed in the link provided indicate significant correlations between the subscales of FFMQ and MAIA-2 at T1, T2, and T3.

3.3.5 Associations between MAIA-2 Subscales Scores and DASS-21 Subscales

Several significant correlations were found between the scores of MAIA-2 subscales and the scores of DASS-21 subscales. Depression was significantly negatively associated with not-worrying at T1, T2, and T3, self-regulation at T1, T2 and T3, trust at T1, T2, and T3, not-distracting at T1, T2, and T3, attention regulation at T1 and T2, emotional awareness at T2 and T3. Anxiety at T1 was associated with significantly more-worrying at T2, and T3, more distracting at T1 and T3, less attention regulation at T1, less self-regulation at T1, less trust at T1, T2, and T3. Anxiety at T2 was associated with significantly more distracting at T2, less attention regulation at T2, less self-regulation at T1 and T2, and less trust at T2. Anxiety at T3 was significantly associated with more worrying at T1 and T3, less attention regulation at T1, less self-regulation at T1 and T3, and less trust at T1 and T3. Stress at T1, T2 and T3 was significantly associated with more worrying at T1, at T1 and T2 with less attention regulation, at T1 with less self-regulation, at T1 and T3 with less trust at T1 and T2, and at T1 and T2 with more distracting at T1. Stress at T2 was significantly associated with less attention regulation at T1, less self-regulation at T1, and trust at T1.

3.3.6 Associations between MAIA-2 Subscales Scores and EA-SR Subscales Scores

Significant positive associations were found between the subscales of MAIA-2 Not Distracting, Not Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, and Trust and EA-SR subscales Mutual Attachment at T3, and between MAIA-2 subscales Not Worrying and Trust and EA-SR subscales Child Involvement and Affect Quality at T3. Not Worrying, Attention Regulation and Trust at T3 were inversely associated with EA-SR subscales Hostility. Attention Regulation at T2 was inversely associated with Intrusiveness at T3 and Not Worrying at T2 negatively associated with Hostility at T3.

3.3.7 Associations between FFMQ Subscales Scores and DASS-21 Subscale Scores

Significant negative associations were found between mindfulness facets and DASS-21 subscales, revealing that mindfulness was inversely associated with depression, anxiety, and stress in most of its facets. Specifically, the ability to observe at T2 was inversely associated with depression at T2 and anxiety at T1. No associations were found between the same facet at T1 and T3 and any of the DASS-21 subscales. The ability to describe inner experience at T1 was negatively associated with depression, anxiety, and stress at T1, T2, and T3. Acting with awareness at T1 inversely associated with depression, anxiety, and stress at T1, and with depression at T2. Negative associations were found between the same facet at T2 and depression, anxiety, and stress at T2, and the same facet at T3 and depression, anxiety, and stress at T3 and anxiety at T2. Acting with awareness at T2 negatively associated with depression at T1 and anxiety and stress at T2. Acting with awareness at T3 inversely associated with depression at T3. A negative association was found between nonjudgement of inner experience at T1 and depression, anxiety, and stress at T1 and depression and stress at T2. The same facet at T2 was negatively associated with depression, anxiety, and stress at T1 and T2, and at T3 with depression, anxiety, and stress at T3 and stress at T1. The subscale non reacting at T1 was negatively associated with depression, anxiety, and stress at T1, at T2 with depression and anxiety at T1 and T2, and stress at T1. Non reacting at T3 was negatively associated with depression, anxiety, and stress at T3.

3.3.8 Associations between FFMQ Subscales Scores and EA-SR Subscale Scores

A significant positive association was found between the mindfulness facet “ability to describe inner experience” at T1 and affect quality of emotional availability at T3. Observing, ability to describe inner experience, and non-reacting at T2 were negatively associated with intrusiveness at T3. Ability to describe inner experience, acting with awareness, non-judging, and non-reacting at T3 were positively associated with mutual attachment and non-judging and non-reacting at T3 were positively associated with affect quality. Non-judging at T3 was inversely associated with intrusiveness and non-reacting with hostility at T3.

3.3.9 Associations between DASS-21 Subscale Scores and EA-SR Subscale Scores

Higher levels of depression, anxiety, and stress were associated with lower levels in the subscales of EA-SR mutual attachment and affect quality, which means that mothers with poorer mental health had poorer mutual attachment and affect quality at T3. Depression and stress were significantly associated with intrusiveness and hostility and anxiety with hostility.

4. Discussion

The current study was conducted to ascertain whether associations exist between maternal mindfulness, mental health, specifically depression, anxiety, and stress, interoception (or interoceptive awareness), and maternal-infant relationship at 20 weeks (T1) and 36 weeks (T2) of pregnancy and 10-12 weeks postpartum (T3), and between these variables and maternal emotional availability at T3. Exploring this important area could improve our understanding of mother-infant relationship during pregnancy and post-partum, which has implications on infant development and wellbeing.

Maternal mindfulness, mental health, and interoception may have an important impact on maternal emotional availability and the quality of mother-infant relationship during pregnancy and post-partum, with consequences on infant attachment and development [17, 25, 49, 50, 60]. This study provides the first evidence of links between these maternal variables across two time points during pregnancy and one time point during the first post-partum trimester. This study is also the first to examine the protective function of maternal mindfulness, interoception, and mother-infant relationship during pregnancy, referred to by the Maternal-Foetal Attachment Scale (MFAS; [70]) as maternal-foetal attachment, for maternal mental health and mother-infant relationship postpartum.

4.1 Key Findings and Theoretical Implications

Results suggest that participants' mindfulness, interoception, and depression, anxiety, and stress symptoms as measured with DASS-21 did not change over time but remained stable, whereas depression symptoms as measured with the EPDS significantly decreased from T1 and T2 to T3. This result was unexpected, as not in line with findings that depression is more prevalent postpartum than during pregnancy [16, 60, 77, 78]. It provides further information that reviews the widely established construct considering childbirth as a risk factor for the development of postnatal depression and anxiety in a non-clinical population [16, 33]. This widely recognised increase in depressive symptoms postpartum has been attributed to stress, sleep deprivation, hormonal and physiological changes, poor social support, and the transition to motherhood implying changes in the sense of identity [79]. These findings have indicated the need for maternal health services to support mothers during this critical period, which can increase vulnerability to mental health issues [8, 10, 11] and suicide, considered the leading cause of maternal death in the first year postpartum [80]. However, the increase of maternal depression from pregnancy to postpartum has been found to be typically less pronounced in non-clinical samples [81]. There may be a need for future research with a clinically depressed population during pregnancy.

The decrease in maternal depression postpartum may confirm untested speculation in the literature that pregnancy and the transition to motherhood are a time of significant change for women that may result not necessarily in mental health disorders but enrichment of identity and mitigation of mild or moderate depression [82]. These findings have theoretical implications for Blatt's [83] dialectic model of personality development and relatedness, which considers that personality styles may be subject to transformation during significant transitional periods [84]. According to this theory, the period of transition to parenthood is a period of vulnerability. The results of this study are also of relevance to Positive Psychology, which focuses on human strengths,

meanings and positive experiences [85]. Other studies have encouraged further research in this area to fully understand the role of the birth experience for psychological well-being [82].

Overall, DASS-21 did not report significant changes in maternal depression, anxiety, and stress across the three time points, although there was a decrease at T3, but not significant. In contrast, by T3 the Anxiety subscale of DASS-21 did show mothers' significant lower scores from T1 and T2 to T3. This is consistent with findings of anxiety during pregnancy being more prevalent during pregnancy than postpartum, due to the hormonal changes brought by pregnancy, worries about the developing infant and unknown childbirth experience [1, 86].

The high rate of participants falling into moderate (28 out of 110) and high depression (32) levels reported by the EPDS and of those falling into mild (27), moderate (5), severe (11), and extremely severe (8) anxiety levels reported by the DASS-21 altogether at T1 was expected, as studies have found an increase in depression and anxiety consequent to Covid-19 lockdowns and pandemic [87]. A global survey revealed a substantial increase of maternal depression during the COVID-19 pandemic from 15% before the outbreak to 41% [87]. In addition, the study also found that the number of women reporting moderate to high anxiety symptoms rose from 29% prior to the pandemic to 72%. Presumably, pregnant mothers may have experienced fear of contagion and its consequences on the developing infant and of the potential effects of the vaccination. Childbirth might have brought a relief of these concerns and represented a positive life event after long months of pandemic, which may explain the decrease of depression (EPDS) and anxiety (DASS-21 subscale) post-partum. Further research is needed to analyse the correlations between the length of lockdowns experienced by the participants from different countries, and outcomes of mental health, birth and baby's patterns of crying and sleeping, which is data collected in the first survey during pregnancy and last survey post-partum.

Maternal-foetal attachment was found to significantly increase from the second (T1) to the third trimester (T2) of gestation, which was expected, as this change may be related to the increasing perception of the developing baby with the progress of pregnancy. This result may be also linked to the nonsignificant changes in depression, anxiety, and stress from T1 to T2, suggesting that mother-infant antenatal relationship appears to be a protective factor for maternal mental health during pregnancy [17, 18, 38, 39, 88]. This is consistent with significant negative associations between maternal-foetal attachment at T1 and T2 and maternal mental health variables revealed by the current study. Better quality of maternal mental health, thus lower scores in depression, anxiety, and stress (measured with the EPDS and DASS) at T2 were associated with higher levels of maternal-foetal attachment at T2.

Maternal depression, anxiety, and stress are reported to affect mother-infant relationship during pregnancy [25, 39, 88] and mother's sensitivity and responsiveness to her infant [28, 60], which are aspects of maternal emotional availability, and impact the attachment relationship [89]. Maternal depression was also inversely associated with maternal emotional availability at T3. This is in line with findings indicating that maternal depression may hinder emotional availability, including her capacity to interpret the infant's signals and attune with them, and thus have adverse consequences for infant development [27, 59].

Overall, mindfulness remained stable from T1 and T2 to T3, which is in line with a study investigating change in maternal mindfulness from 30 weeks' gestation to 18 months' postpartum [16] and other studies reporting that mindfulness appears to be stable over time [90, 91]. This may suggest that mindfulness corresponds to an essential set of maternal abilities needed for her

caregiving behaviour beginning from pregnancy. In fact, mindfulness appears to be a protective factor linked to secure attachment and positive child outcomes [47, 51, 92]. Significant positive associations were found between maternal mindfulness and interoceptive awareness and maternal-foetal attachment, which confirms the important protective influence of mindfulness and interoception on the prenatal relationship. Like mindfulness, interoception also revealed to be stable over time and be positively associated with mindfulness in every mutual subscale.

Interoception may play a key role in maternal sensitivity, suggesting that the mother's ability to perceive her own internal bodily processes and signals might support responsiveness to her infant's bodily cues [28]. Since maternal sensitivity or ability to understand and interpret her infant's cues are involved in maternal emotional availability, interoception could play a very important role in it. Interoception may also have a key role in maternal mental health. Stress, depression and/or anxiety during pregnancy has been found to impact upon maternal interoceptive abilities [25], and thus the capacity to respond to her infant's need, with effects on the future co-regulating processes within the mother-infant relationship [28, 29].

Focusing on parental body sensations and bodily states as well as reflective functioning might provide a new perspective of caregiving behaviour recognizing interoception as an important contributor to supporting parental ability to understand and thus respond to the infant's body signals and emotional states [28]. This view is in line with the theoretical framework introduced in this paper, which suggests that early emotional and cognitive mother-infant processes are rooted in bodily systems. This new perspective suggests that early mother-infant relational processes from pregnancy, including her reflectivity, are embodied, and that interoception may play a prominent role in the mother's perception of self and others, including her infant. Interoception may broaden mothers' repertoire of body sensations and experiences, allowing them to have a better understanding of their child's experience [93]. This re-fined interoceptive sensitivity could allow for greater richness of emotional experiences and better mental health, which in turn might support better understanding of infants' emotions [94]. Furthermore, maternal interoception might give rise to body sensations and subjective feelings which modulate mother-infant early interactions and have co-regulating physiological effects [95].

In line with these findings, interoceptive awareness at T2 was significantly negatively associated with depression, anxiety, and stress (EPDS and DASS-21) at T2 and significantly positively associated with mindfulness and maternal-foetal attachment at T2. These associations were revealed also at T3. Mothers with lower scores in interoception and mindfulness were significantly poorer on mental health (higher scores on EPDS and DASS-2) at T3. As there is little research in this area on the influence of interoception on maternal mental health and mother-infant relationship during pregnancy and post-partum, these findings are of interest.

Overall, significant positive associations were found between maternal emotional availability (EA-SP) at T3 and mindfulness at T3 and negative associations between maternal emotional availability and depression (EPDS) were revealed at T3. Regarding associations between subscales, the mindfulness facet "ability to describe inner experience" at T1 was positively associated with affect quality of emotional availability at T3. The facets observing, ability to describe inner experience, and non-reacting at T2 were inversely associated with intrusiveness subscale of emotional availability at T3. Ability to describe inner experience, acting with awareness, non-judging and non-reacting at T3 were positively associated with mutual attachment and non-judging and non-reacting at T3 were positively associated with affect quality. Non-judging at T3 was negatively

associated with intrusiveness and non-reacting with hostility. This is also of interest as more research in this area is needed.

Contrary to expectations, in another study maternal mindfulness during pregnancy was not significantly associated with maternal bonding, although maternal ability to act with awareness revealed positive associations with all three Maternal Postnatal Attachment Scale subscales at 18 months' postpartum [16]. Thus, the mother's ability to be in the present moment when interacting with her child positively influences the attachment relationship. The current study is the first to look at correlations between maternal variables and maternal response to her infant in the first postpartum trimester. Maternal affect quality appeared to be influenced by maternal ability to describe inner experience at T1 and non-judging and non-reacting at T3. Maternal ability to observe, describe inner experience and non-react at T2 displayed a positive association with absence of intrusiveness toward the infant at 10-12 weeks' postpartum (T3). Mutual attachment appears to be influenced by maternal ability to describe inner experience, act with awareness, not to judge and not to react at T3 and affect quality was associated with the mindfulness facets non-judging and non-reacting at T3. Maternal ability to stay calm and non-react presented a positive association with absence of hostility at T3.

These results have important implications for mindfulness-based programs during pregnancy, as they may impact not only on mother-infant relationship early in the postpartum period, but also on long-term attachment relationships beyond the first 12 months' postpartum [48, 51, 92]. The finding that maternal mindfulness and interoceptive awareness positively correlated with mother-infant relationship further confirms the important protective influence of mindfulness and interoception on the prenatal attachment relationship. It has also implications for the directions and focus of mindfulness-based programs on maternal interoceptive awareness as well the mother-infant relationship during pregnancy [17, 18].

The findings that maternal mindfulness was negatively associated with depression, anxiety, and stress across the three timepoints and positively associated with prenatal attachment, that these relationships were maintained across pregnancy and the first post-partum trimester, are in line with evidence that mindfulness can be an antidote to depression, anxiety and stress and prenatal relationship difficulties [19, 30, 31]. The multiple significant positive correlations revealed across the three time points between mindfulness and all the other maternal variables investigated in the current study confirm that mindfulness remains stable over time and may be a protective factor for maternal mental health and healthy mother-infant relationship. Mindfulness facets also correlated with many of the subscales of each maternal variable.

4.2 Practical and Clinical Implications

These findings have significant implications for prenatal support programs aiming to reduce the risk for postnatal psychological disorders and mother-infant relationship difficulties by promoting mother-infant relationship and maternal wellbeing during pregnancy [17, 18]. This can be of utmost importance for parents at risk of depression and other mental disorders or poor prenatal relationship. The significant implication may extend to prenatal clinical intervention, where severe depression, anxiety, and stress can have serious adverse effects on the earliest prenatal relationship and development, with postpartum consequences. Prenatal support programs promoting maternal reflective functioning and mother-infant relationship prior to birth may provide protective

strategies preparing the becoming mother to a greater understanding of her infant's nonverbal signals and mental states [17, 18].

Based on previous research on interoception and findings of the current study, assessing interoception can help in the early detection of mental health disorders such as depression, anxiety, and stress during pregnancy and postpartum as well as mother-infant relationship difficulties. This study's results about interoception have significant implications for prenatal support programs aiming to reduce the risk of interoception disorders and its effects on both mental health and mother-infant relationship. Parental level of interoception during early interactions with their infant can also have clinical implications, in that it could help identify mental health problems. Because of the widely recognized associations between dysregulation in interoception and postnatal depression, anxiety, and high stress [25, 52], enhancing maternal body and baby awareness during pregnancy through an appropriate program, such as the PMRB program [17, 18], might reduce depressive symptoms and improve mother-infant relationship during pregnancy and postpartum.

A qualitative study has suggested that supporting mother's awareness of her own emotions and body sensations improves the quality of her caregiving and ability to regulate emotions in the postnatal period [96]. Although the sample studied did not comprise mothers with postpartum depression, findings suggest that when mothers are supported and encouraged to "tune in" to their bodily states and use this awareness while interacting with their infants, both their mental wellbeing and ability to understand and respond to the infant's body cues also improve [17, 18, 28]. Therefore, awareness of body sensations might be a key factor in emotional regulation, emotional availability, and depressive symptom reduction and should be promoted in prenatal programs.

Recent evidence has revealed that mindfulness-based programs for the treatment of physical and mental health conditions can lead to improved interoceptive awareness and emotion regulation via modification of interoception neural pathways and vagus nerve through sustained focused on breath sensations during meditation [97]. These findings are consistent with those of a study examining the benefits of mindfulness-based childbirth preparation training (Mind in Labor) in the second half of pregnancy, just before childbirth, and within six weeks after childbirth on primiparas with fear and anxiety about childbirth [98]. The pregnant women who received the Mind in Labor education showed reduced postpartum depressive symptoms and increased interoceptive scores compared to pregnant women who received standard treatment. Another study found that antenatal dispositional mindfulness was significantly associated with higher levels of interoception and mother-infant relationship and lower levels of depression and anxiety postpartum (Sansone et al., under review for publication). The intervention study of the same project showed the benefits of the prenatal mindfulness relationship based (PMRB) program on the same maternal variables investigated in the correlational study [17, 18]. There is a need for larger studies exploring these relationships to inform antenatal support programs and help mitigate the risk of postnatal maternal psychological disorders and mother-infant relationship difficulties and their consequences on infant development and mental health.

The decrease of depression and anxiety after childbirth revealed by the current study has important implications for pre and perinatal healthcare providers, as it provides an opportunity to review the construct of birth as a risk factor for maternal mental health and mother-infant relationship in a non-clinical population. Pre and perinatal healthcare services could expand the focus of mindfulness-based programs on maternal mental health, including a focus on the prenatal

relationship as a source of empowerment, which can potentially mitigate the risk of postnatal psychological disorders and bonding difficulties.

Pregnancy is a window of opportunity for parents and their infants, a potentially transformative and empowering time in a woman's life when she is open to receiving new information and developing a new repertoire of skills to cope with pregnancy, birth, and parenting challenges. It follows that childbirth and parenting preparation classes can benefit from incorporating some training in mindfulness as well as cultivation of interoceptive awareness fostering embodiment, and the embodied prenatal relationship, thus providing becoming parents the opportunity to learn important abilities. Future research should focus on expanding alternative mind-body health enhancement approaches that are readily available to pregnant women, so that to reduce the global perinatal mental health pandemic.

This study adds to the growing interest in interoception for its significant relevance in the study of mind-body approaches and human health, especially in the pre and perinatal period. Little research has previously examined the influence of interoception (an indication of embodiment) in mother-infant relationship during pregnancy and postpartum. Identification of low levels of mindfulness, interoception, and mother-infant relationship during pregnancy may be of utmost importance to long-term wellbeing. The finding that maternal mindfulness, interoception and mental health during pregnancy correlate with maternal emotional availability post-partum has implications for mindfulness relationship-based programs with at-risk women. Such programs need to be conducted during pregnancy and the early postpartum period to empower mothers' resources and thus reduce the risk of mother-infant relationship difficulties, which impact on future attachment formation [99]. Support strategies should focus on maternal ability to relate to the unborn and newborn infant mindfully, while at the same time also enhancing maternal mental health.

4.3 Limitation and Implications for Future Research

The longitudinal design of this study has a number of strengths, including the collection of data at three time points, which allows us to predict the relationship between maternal mindfulness, interoception, and mother-infant relationship at two time points during pregnancy and post-partum, and between these maternal variables and emotional availability post-partum. In this study, the snow sampling technique was used to recruit participants through the social network platforms over a 3-stage process. This technique is a popular tool to assist researchers in accessing geographically diverse large populations [61]. Identifying and recruiting members of a pregnancy group via snowball sampling is not inferior to other methods especially considering that getting to this targeted population may not be easy to achieve [61].

Nevertheless, there are several limitations to consider. Although the sample at T1 had more than the minimum number (110) to detect smaller effects sizes, the study was limited by the relatively small sample sizes at T2 (72) and at T3 (67), which effected the level of analyses and generalizability of findings [76]. Future research with larger sample sizes is needed to increase the statistical power to detect smaller effect sizes. Furthermore, considering the burden for neo mothers to complete the third full battery of five questionnaires only 10-12 weeks post-partum and the higher drop of participants in the post-partum that has been revealed by other studies (e.g., [100]), the retention of participants in the current study was relatively high.

As recruitment included other countries out of Australia – UK, Republic of Ireland, USA, Canada, and New Zealand to reduce the cultural differences – the sample is not representative of one specific population. Unfortunately, the sample size in each group appears too small (and too reliant on convenience sampling) to conduct cross-national comparisons. Larger scale study and attention to the national and cultural context of motherhood and mother-infant relationships, especially given the cross-national nature of the sample would address this major limitation. Furthermore, the sample's socio-economic status was medium-high, with more than 60% of participants highly educated, 45.5% in full employment and 26.4% in part-time and 10.9% self-employed. The variable 'length of lockdown' experienced by participants from different countries, which has been documented to have impacted mental health, was not analysed in this study. Yet, it may have influenced the results. Since it was collected, a future study may analyse this data.

A further limitation was the collection of data using self-report questionnaires. The use of objective or observational measures would have represented a stronger study design and should be considered for future studies. Furthermore, no data related to the other partner or infant temperament was examined in this study, although evidence reveals that factors related to both infant [101] and the other partner [102, 103] may influence mother-infant relationship. However, data related to the mother's concern about her infant's crying, feeding, and sleeping patterns were collected in the current study via a birth/post-birth questionnaire and can be used for future studies since their examination was not within the scope of the PhD thesis including the current study. Other biases such as social desirability and selection biases also warrant consideration, as participation was voluntary. Further research replicating the findings of this project and examining different communities and clinical populations is needed.

To be noted is that while the other maternal measures could be repeatedly administered prenatally and postnatally in both studies, a comparison between mother-infant relationship during pregnancy and post-partum could not be performed, since they were assessed with different questionnaires. Therefore, two different analyses had to be performed and emotional availability was assessed individually through each EA-SR subscales, referring their mean scores to clinical and non-clinical sample means. This highlights the need to develop a single measure to assess mother-infant relationship during pregnancy and post-partum, which would be consistent with data indicating a continuum in human development from pregnancy to the postnatal period.

5. Conclusions

Despite some methodological limitations, these findings have significant implications for our understanding of pregnancy, childbirth, and motherhood, as the emphasis shifts from pregnancy, childbirth, and motherhood as a transitional time of vulnerability for mental health to an opportunity for positive transformation and healing. The significant decrease of maternal depression and anxiety (as in subscale) post-partum and increase of prenatal relationship revealed by the current study may indicate this shift of paradigm. Findings regarding mindfulness stability over time and its positive associations with mother-infant relationship during pregnancy and post-partum, in particular maternal emotional availability, confirm that maternal mindfulness and prenatal relationship may both be a protective factor for healthy mother-infant relationship and attachment. This has important implications for health-enhancement programs, which need to include mindfulness and cultivation of the prenatal relationship.

The study is the first to reveal significant correlations between maternal mindfulness, mental health, interoception, and mother-infant relationship during pregnancy and post-partum across three time points and the importance of maternal embodiment in all the other maternal variables investigated. While further research is needed to support these results, the findings suggest the importance to assess as well as support these maternal variables during pregnancy, to support maternal embodiment, the embodied mother-infant relationship, and developing attachment during early motherhood. These correlations between maternal variables may promote a holistic understanding among prenatal and perinatal practitioners, including therapists, of maternal characteristics and set of abilities corresponding to mindfulness and required by motherhood. This evidence sheds light on the potential value for perinatal educators and clinicians to expand their focus on mental health, to include consideration of maternal mindfulness, interoception, and mother-infant relationship prior to birth to support later mother-infant relationship and secure attachment. In doing so, early assessment and mindfulness- relationship-based programs in the prenatal period, like the Prenatal Mindfulness Relationship Based (PMRB) program [17, 18], can enhance maternal embodiment and resources, and the earliest relationship and thus prepare pregnant women for early motherhood, with potential benefits for infant development and mental health.

Appendix: EPDS Score Range Category Description

0-9: Scores in this range may indicate the presence of some symptoms of distress that may be short-lived and less likely to interfere with day-to-day ability to function at home or at work. However, if these symptoms have persisted more than a week or two further enquire is warranted.

10-12: Scores within this range indicate presence of symptoms of distress that may be discomforting. Repeat the EPDS in 2-week time and continue monitoring progress regularly. If the scores increase to above 12 assess further and consider referral as needed.

13+: Scores above 12 require further assessment and appropriate management as the likelihood of depression is high. Referral to a psychiatrist/psychologist may be necessary.

Author Contributions

The first author, Dr Antonella Sansone, conceived and designed the PhD study, Prof Peta Stapleton was the Principle Supervisor, Prof Alan Patching the Associate Supervisor, and Zoe Lawrence assisted in the statistical analysis.

Competing Interests

The authors have declared that no competing interests exist.

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