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Exercise Frequency and Maternal Mental Health: Parallel Process Modelling Across the Perinatal Period in an Australian Pregnancy Cohort

Short Title: Exercise and Perinatal Depression
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Abstract

Objective: Since the potential mental health benefits of exercise during pregnancy remain unclear, this study examined longitudinally the bidirectional relationship between exercise and maternal mental health symptoms during the perinatal period, and included adjustment for both depression and antidepressant treatment.

Methods: Data were collected across pregnancy (first and third trimesters) and the postpartum (six and 12 months) for 258 women drawn from an Australian pregnancy cohort, the Mercy Pregnancy and Emotional Wellbeing Study (MPEWS). The women were assessed for depression using the EPDS, anxiety using the STAI and a clinical diagnostic interview (SCID-IV), and self-reported use of antidepressants. Exercise was measured using self-reported weekly frequency of 30-minute bouts of moderate to vigorous exercise, and data were analyzed using parallel process growth curve modelling.

Results: On average, women’s weekly exercise frequency declined during pregnancy, returning to first trimester levels by 12 months postpartum. Women with depression and taking antidepressants reported lower first trimester exercise compared to control women. However, where non-medicated depressed women remained lower and continued to decline to 12 months, women taking antidepressants reported increasing levels of exercise during the perinatal period. Notably, a steeper decline in exercise frequency during the perinatal period was associated with a faster rate of increase in depressive and anxiety symptoms.

Conclusions: This study is the first to examine the longitudinal interaction between exercise and mental health symptoms across the perinatal period. These preliminary findings demonstrate potential benefits for depressive and anxious symptoms when maintaining levels of early-pregnancy exercise throughout pregnancy and the postpartum.

Keywords: Anxiety, Depression, Exercise, Pregnancy, Antidepressants
The need to develop interventions to improve mental health in pregnancy is increasingly being recognized and can only be enhanced by drawing on evidence from well-designed cohort studies. Poor mental health has been associated with increased risk of pregnancy complications resulting in poorer outcomes for both mother and infant (1-3). For example, outcomes such as pregnancy-induced hypertension (PIH), preterm birth (<37 weeks), and low infant birth weight (<2500g) have all been demonstrated as more prevalent in women with antepartum depression (4, 5). It is likely that such relationships are mediated by mechanisms such as glucose regulation, changes in vasculature and placental function, maternal stress regulation and the inflammatory response (5-7). In the long-term, offspring exposed to chronic maternal stress and inflammation during pregnancy may be more likely to develop psychological disorders (8-11). During pregnancy, there is evidence of the preventative and protective benefits for pregnant women who maintain and even increase physical activity (12, 13).

Randomized control trials (RCTs) in adults with mental disorders have demonstrated exercise has some efficacy as an intervention for depressive symptoms, anxiety and quality of life (14). The mechanisms through which exercise is associated with improved physical and psychological health is most likely the regulation of stress hormones, such as cortisol, via the hypothalamus-pituitary-adrenal (HPA) axis (15) and subsequent anti-inflammatory protection against a chronic low-grade inflammatory response (16). There is good evidence to support the safety of exercising during pregnancy and the positive effects that exercising yields for maternal and infant outcomes, and fetal development (17-23).

The strength of this empirical support has culminated in clinical guidelines from the American College of Obstetricians and Gynecologists (12) and the Royal Australian and New Zealand College of Obstetricians and Gynaecologists (13) recommending health care professionals to encourage modified exercise routines during pregnancy following careful
assessment of medical and obstetric complications (24). These guidelines specify the need for appropriate duration, intensities, and activities for pregnant women following the careful assessment of absolute and relative contraindications, such as pregnancy-induced hypertension and fetal growth-restrictions. However, these guidelines only briefly acknowledge the benefits of exercising for general psychological wellbeing for pregnancy women.

Several observational studies to date have examined natural patterns of physical activity during the perinatal period. A recent study plotted trajectories of exercise for pregnant women during only the antepartum period (25). On average, physical activity increased in the first trimester, plateauing during the third trimester and sharply declining late in the third trimester. Women who self-identified as inactive engaged in less physical activity at the beginning of pregnancy and became more sedentary further into the pregnancy. Another study demonstrated that physical activity rebounds by three months postpartum, returning to levels in the first trimester (26). These studies of general populations did not explore the associations between exercise and mental health during pregnancy.

The few studies that have documented the associations between exercise and mental health across the perinatal period (27, 28) have used small samples of healthy women (29). Using a sample of 43 women, Goodwin et al. demonstrated that women who self-reported any exercise during pregnancy were less likely to score in the clinical range of the General Health Questionnaire compared to women who self-reported no exercise during pregnancy. Poudevigne and O’Connor compared the changes in associations between physical activity and mood in a group of 12 pregnant women to a matched group of 12 non-pregnant women for seven months. They found that similar to non-pregnant women during the same period, above-average energy expenditure by healthy pregnant women was associated with mood stability during pregnancy. However, while there appears to be some association between
exercise and mental health in pregnancy, a meta-analysis examining clinical trials of exercise in pregnancy identified low-to-moderate quality trials and concluded that there is only limited evidence that exercise is an effective treatment of depression during pregnancy (30). To our knowledge, there are very few RCTs that have investigated whether exercise improves the mental health of pregnant women, and the nature of the longitudinal association between mental health symptoms and changes in exercise frequency throughout the perinatal period has not been previously examined.

In this study, we address this issue by using data from a relatively large cohort study (Mercy Pregnancy and Emotional Wellbeing Study; MPEWS) designed to specifically examine the course of common mental health disorders over the perinatal period, which allows for sophisticated modelling of the longitudinal pattern of symptoms. We use data on weekly exercise frequency over the perinatal period (at first and third trimesters, and six and 12 months postpartum) and investigate bidirectional associations with maternal mental health during the same period. Another advantage of MPEWS is that antidepressant medication use has been thoroughly documented; for the first time, we are able to examine patterns of exercise reported by women whose depression is being treated by an antidepressant.

First, we examine at each time point over pregnancy the differences in exercise frequency over the perinatal period, comparing three groups of women: those taking antidepressants, those with depression but not taking antidepressant medication, and control women. Although we expect that, on average, exercise frequency will reduce during pregnancy and increase again in the postpartum, we hypothesize that control women will report significantly more frequent exercise at each time-point during the perinatal period.

Second, after controlling for a depression diagnosis and antidepressant use, we will examine bidirectional associations between changes in exercise frequency during the perinatal period and changes in both depressive and anxious symptoms during the same
period. In a second hypothesis, for women whose exercise frequency reduces more steeply compared to the average, we hypothesise their depressive and anxious symptoms will increase more steeply compared to the average.

**Method**

**Participants**

The sample in this paper is drawn from the Mercy Pregnancy and Emotional Wellbeing Study (MPEWS), based in Melbourne, and uses data collected at four time-points: first and third trimester, and six and 12 months postpartum. A study protocol can be found in Galbally et al. (31). Women with only one out of four points of data were not included in this paper leaving a subsample from this cohort of $n = 258$ (92% of the full cohort). The study recruited three groups: women taking antidepressants ($n = 44$), non-medicated women who met diagnostic criteria for Major Depressive Disorder ($n = 28$), and control women who did not meet criteria for diagnosis of depression or taking antidepressant medication ($n = 186$). A diagnosis of Major Depressive Disorder was used to stratify recruitment so that depression, which is a major focus of service delivery and prevention efforts in Australia, could be specifically examined.

**Measures**

*Mental Health*

*Depression.* A diagnosis of Depression including Major Depressive Disorder and Dysthymia was established using the mood module of the Structured Clinical Interview for the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (SCID-IV) administered to all participating women upon recruitment to the study (i.e., prior to 20 weeks). In addition to the resulting groups of the recruitment framework, we also used a binary variable to group women with and women without a depression diagnosis. Women
 meeting DSM-IV criteria for major depressive disorder, regardless of antidepressant use, were coded as 1 (Currently depressed; n = 55) and all other women coded as 0 (Not currently depressed; n = 203).

Depressive symptoms were measured using the Edinburgh Postnatal Depression Scale (EPDS) (32) at four time-points: during first and third trimesters, and six and 12 months postpartum. The EPDS comprises ten items measuring depressive symptom severity on a 4-point (0-3) scale, producing a total score ranging between 0 and 30, where higher scores indicate higher levels of depressive symptoms. Although several cut-off scores have been used to screen for postpartum depression (33), the most common being 12 or 13 (34), in this study we treat depression symptoms data as continuous. The EPDS has been shown to be a valid scale for use with Australian women during the perinatal period (35). In our sample, the EPDS scale at each measurement demonstrated strong internal consistency, with Cronbach’s alphas ranging .85 to .86.

Anxiety. Anxiety was measured using the state anxiety subscale from the State-Trait Anxiety Inventory (STAI, Y-form; 36) at all four time-points during the perinatal period. The inventory measures situational anxiety symptoms using 20 items. Each item is measured using a 1 (Not at all) to 4 (Very much so) Likert scale. The sum of the items, ranging 20 through 80, indicates the magnitude of situational anxiety reported by the participant at the point in time of completion, with higher scores indicating more state anxiety. Australian norms are available for a general Australian adult population, suggesting a normative mean of approximately 34 (SD ~ 12), with women scoring slightly higher than men on average (37). In our sample, the internal consistency of the STAI state scale was strong at each measurement, with Cronbach’s alphas ranging .93 to .94.

Antidepressants

At recruitment, women were asked about current and ongoing use of antidepressant
medication. Women who reported taking antidepressant medication during the first 20 weeks of pregnancy were recruited to comprise the antidepressant use group. This group included women who met diagnostic criteria for depression and those who did not. In this paper, we also use a binary variable to group the sample into no antidepressant use (0; n = 214) and antidepressant use (1; n = 44), irrespective of a depression diagnosis.

**Exercise Frequency**

Women were asked at first and third trimesters, and six and 12 months postpartum about their frequency of exercising. Specifically, women are asked to self-report the number of days per week they exercised in response to the question: “Over the last month, how many days per week would you do at least 30 minutes of vigorous physical activity (including activities such as walking briskly, riding a bike, gardening, tennis, swimming, running, etc.?)” Possible responses range between 0 and 7.

**Covariates**

We also examined potential covariates of exercise frequency and mental health symptoms, including seasonality, sleep quality, and social support. Seasonality was measured using the date of survey completion at each time-point to code Autumn and Winter months (0), and Spring and Summer months (0) as a potential predictor of variation in exercise frequency due to extreme weather. Sleep quality was measured using the total Pittsburgh Sleep Quality Index (PSQI) (38) and partner social support was measured using both subscales of the Social Support Effectiveness Questionnaire, Help with Tasks and Responsibilities and Emotional Support (39).

**Statistical Analyses**

To describe the cohort’s exercise frequency during the perinatal period (first trimester pregnancy through to 12 months postpartum) and address the first hypothesis, we present
descriptive statistics for reported exercise frequency (measured as frequency of 30-minute sessions of moderate to vigorous physical activity per week for the last month) at each time-point for women taking antidepressants, women with depression not taking antidepressant medication, and healthy controls. We also conducted between-groups comparisons at each time-point using four analyses of variance (ANOVA) tests, accompanied by Tukey HSD post-hoc tests. We report Cohen’s d to describe the magnitude of between-group differences for pairwise comparisons, and regard effect sizes of 0.2, 0.5, and 0.8 as small, medium and large effects, respectively. Where group variances were not homogeneous, which is more likely when groups are unequal and one or more groups are small, the robust Welch F test is conducted and followed up with Dunnett’s C post-hoc tests. To aid interpretation of the effects, we present exact p-values for tests as well as 95% confidence intervals (CIs) for estimates. These analyses were conducted using SPSS version 24 (40).

To address the second hypothesis, we conducted multivariate latent growth curve modelling to test for bidirectional associations between growth in exercise frequency and growth in both depressive and anxious symptoms during the perinatal period. Latent growth modelling was conducted using Mplus version 7 (41). We used Bollen and Curran’s (42) guide to conducting parallel process modelling, in which univariate growth models are initially developed for each construct separately and then combined in multivariate growth models (i.e., parallel processes) in order to test for bidirectional associations between constructs over time. First, we estimated separate unconditional within-person growth for weekly exercise frequency (reported in the results below as Model 1), depressive symptoms (Model 3), and state anxiety symptoms (Model 5), using univariate latent growth curve models. Second, we estimated separate conditional between-person effects on individuals’ growth for weekly exercise frequency (Model 2), depressive symptoms (Model 4), and state anxiety symptoms (Model 6), with the inclusion of time-invariant covariates: depression
diagnosis and antidepressant use. In the final step, we conducted two parallel process models: one to test the associations between latent growth factors for exercise frequency and depression symptoms (Model 7), and the second to test these associations between exercise frequency and state anxiety symptoms (Model 8). To be supportive of hypothesis 2, the regressions of the linear slope latent factor on the intercept latent factor between constructs in needs to be significant Models 7 and 8; these results are reported in Figures 3 and 4.

All models are estimated using maximum likelihood with robust standard errors (MLR) due to univariate and multivariate deviations from the normal distribution. For the three constructs, missing data ranged between 2.3% and 4.3% at the first trimester, 1% and 2.7% at the third trimester, 9.7% and 11.2% at 6 months postpartum, and 18.6% and 21.7% at 12 months postpartum. During modelling, missing data was handled using the Full Information Maximum Likelihood estimator, which is able to deal with this amount of missing data in a latent growth modelling framework resulting in relatively unbiased estimates (43). Model fit for each model is evaluated using Hu and Bentler’s (44) criteria for model fit (the Chi-square goodness-of-fit test, p < .05; Standardized Root Mean Square Residual, SRMR ≤ .08; and, Root Mean Square Error of Approximation, RMSEA ≤ .08) and reported in Table 2.

Results

Sample Characteristics

The mean age of the women at recruitment was 31.24 years (SD = 4.70, range: 19 – 48); most were nulliparous (n = 236, 91.5%) and identified as Oceanic or European ethnicity (n = 224, 86.8%). Thirty women (11.6%) met criteria for gestational diabetes mellitus during their pregnancy with no significant proportional variation in rates between recruitment groups (women taking antidepressants: 9.1%, depressed women: 7.1%, and control women: 13.1%; Fisher’s Exact p = .385). Fifteen women (5.8%) had pregnancy-induced hypertension during pregnancy; the rate was higher in women taking antidepressants (15.9%) and depressed
women (14.3%) compared to the rate in control women (2.2%; Fisher’s Exact \( p < .001 \)).

Average infant gestational age (\( M = 39.38 \) weeks, \( SD = 1.60 \)), and weight (\( M = 3.41 \) kg, \( SD = .50 \)), length (\( M = 50.62 \) cm, \( SD = 2.46 \)) and head circumference (\( M = 34.43 \) cm, \( SD = 1.63 \)) at birth, did not differ significantly between the groups.

Most women reported completing high school (\( n = 233, 90.3\% \)), with nearly two-thirds reporting completion of a bachelor’s degree or equivalent (\( n = 171, 66.3\% \)). One hundred and seventy-two (66.7%) women reported working full-time, 59 (22.8%) reported working in part-time or casual employment, five (1.9%) women reported study as their employment status, another five (1.9%) women reported full-time home duties, and four (1.6%) women reported unemployment but were actively looking for work. Most of the women reported either being married or in a partnership (\( n = 243, 94.2\% \)), with 13 (5.1%) women reporting being either single or separated.

**Group Differences on Frequency of Exercise**

Figure 1 displays observed exercise frequency at each time-point for the three groups of women recruited into the study: women taking antidepressants during pregnancy, women diagnosed with depression but not medicated, and healthy control women. The figure shows that women taking antidepressants reported, on average, a marked increase from a low baseline level of exercise in first trimester to nearly three times per week by six months postpartum and maintaining this frequency to 12 months postpartum. In comparison, the control group remained relatively stable during the perinatal period at approximately two and a half days per week, whereas the depressed group steadily reduced their exercise frequency by nearly one day between first trimester and 12 months postpartum. During the first trimester, women taking antidepressants (range: 0 – 5 days) reported a smaller range in number of days per week they exercised compared to non-medicated depressed women (range: 0 – 7 days) and the control women (range: 0 – 7 days). In the third trimester, non-
medicated depressed women reported a smaller range for exercise frequency (range: 0 – 5 days) compared to women taking antidepressants (range: 0 – 7 days) and control women (range: 0 – 7 days). By six months postpartum, the range of exercise frequency for each group was the same (range: 0 – 7 days), and by 12 months non-medicated depressed women reported a smaller range for exercise frequency (range: 0 – 5 days) compared to women taking antidepressants (range: 0 – 7 days) and control women (range: 0 – 7 days).

In order to test the first hypothesis, we ran four ANOVA tests comparing exercise frequency between the three groups at each time-point. During the first trimester, women in the antidepressant use group reported exercising between a day and a half and two days per week, compared to two and a half days per week for both depressed and control women. Controlling for unequal variances, these differences in exercise frequency during first trimester were significant, Welch $F(2, 58.29) = 5.34, p = .007$. Post-hoc tests demonstrated that women taking antidepressants ($Median = 1.50$) exercised almost one day per week less during the previous month than control women ($Median = 2.00$) in the first trimester.

**Figure 1.** Weekly exercise frequency per day for previous one-month period by each group (Antidepressant Use: $n = 44$; Depression: $n = 28$; Controls: $n = 186$). Error bars represent standard error of the mean.
(Dunnet’s C = -.78, 95% CI’s: -1.51, -.05, Cohen’s d = .46). However, the two remaining pairwise comparisons, between both control and depressed groups (Median = 2.00), and antidepressant use and non-medicated depression groups, were not significant. Despite visual differences shown in exercise frequency at each subsequent time-point (Figure 1), the groups did not differ in their average exercise frequency at third trimester ($F[2, 255] = 1.63, p = .314$), and six ($F[2, 229] = 1.33, p = .267$) and 12 months postpartum (Welch $F[2, 43.41] = 2.03, p = .143$).

**Exercise Frequency and Mental Health Symptoms**

Table 1 displays descriptive data and correlations for all variables included in the modelling. For all three constructs, the quadratic model fit the data better than both the linear slope and the intercept-only models of change as is apparent from inspection of model fit Statistics displayed in Table 2. This table also presents standardized path coefficients for the univariate unconditional (i.e., Models 1, 3 and 5) and conditional models (i.e., Models 2, 4 and 6).

Model 1 for growth in exercise frequency demonstrates that, on average, woman reported exercising for 30 minutes per day between two and three days per week during the first trimester. The women reported significant increases in their exercise frequency across the perinatal period to 12 months postpartum; however, increasing growth in exercise frequency slowed significantly. In fact, between six months and 12 months postpartum, women reported exercising, on average, fewer days per week compared to at six months postpartum. Average exercise frequency in the first trimester and average linear slope growth factors varied significantly in Model 1. In Model 2 for exercise frequency, the addition of a variable indicating a depression diagnosis on the SCID was not associated with any difference in both first trimester exercise frequency and linear growth. Antidepressant use, however, was associated with lower exercise frequency during the first trimester and
significant growth in exercise frequency during the perinatal period that did not slow to 12 months postpartum, when compared to women who did not report antidepressant use. Figure 2 illustrates the growth trends, using model-estimated exercise frequency means adjusted for diagnosed depression and antidepressant use using. Although antidepressant use did predict both first trimester exercise frequency and linear slope growth, the estimated variance for these growth factors remained significant, suggesting that antidepressant use does not account for all the variability in women’s exercise frequency.

In Model 3, the average woman in the cohort reported a low EPDS score during the first trimester, which did not change significantly during the perinatal period. However, there was significant variance around the model-estimated averages for EPDS in both the first trimester and the linear slope growth factors. In Model 4, only a depression diagnosis significantly differentiated women’s depressive symptoms during the first trimester, such that women diagnosed with depression reporting significantly higher EPDS scores (see Figure 2). Neither depression, nor antidepressant use, were significant predictors of the EPDS linear slope growth factor.

Model 5 focused on state anxiety and this analysis showed that during the first trimester, women, on average, reported a symptom level of state anxiety consistent with normative adult levels (37). On average, state anxiety reduced significantly over the perinatal period; however, this negative linear slope slowed significantly, and, in fact, state anxiety increased on average between six and 12 months postnatally. There were significant variances around first trimester state anxiety and the average declining linear slope of these symptoms. Of note, the unconditional model fit the data only moderately well; with the inclusion of the two time-invariant covariates, Model 6 for state anxiety was a better fit of the data (see Table 2). In Model 6, a depression diagnosis differentiated between first trimester state anxiety, such that women with a depression diagnosis reported significantly higher state
anxiety symptoms. Both a depression diagnosis and antidepressant use did not predict the first trimester and linear slope latent growth factors in state anxiety over the perinatal period (see Figure 2). Model estimated means and variances for all estimated growth factors remained significant after adjusting for the time-invariant covariates.
Table 1 Descriptive Statistics and Zero-order Bivariate Correlations for all Variables Included in the Modelling.

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<td>.57**</td>
<td>.61***</td>
<td>.57***</td>
<td>.78***</td>
<td>-.014</td>
<td>-.17*</td>
<td>-.15*</td>
<td>-.23**</td>
<td>.49***</td>
<td>.62***</td>
<td>.62***</td>
<td>-</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>0.21</td>
<td>0.17</td>
<td>6.55</td>
<td>6.35</td>
<td>5.95</td>
<td>6.46</td>
<td>2.39</td>
<td>2.49</td>
<td>2.67</td>
<td>2.38</td>
<td>34.91</td>
<td>34.50</td>
<td>31.70</td>
<td>33.92</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td></td>
<td>0.41</td>
<td>0.38</td>
<td>4.75</td>
<td>4.52</td>
<td>4.55</td>
<td>4.89</td>
<td>1.77</td>
<td>1.86</td>
<td>1.86</td>
<td>1.86</td>
<td>11.19</td>
<td>10.35</td>
<td>9.20</td>
<td>10.39</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td>0 - 1</td>
<td>0 - 1</td>
<td>0 - 27</td>
<td>0 - 25</td>
<td>0 - 24</td>
<td>0 - 25</td>
<td>0 - 7</td>
<td>0 - 7</td>
<td>0 - 7</td>
<td>0 - 7</td>
<td>20 - 75</td>
<td>20 - 73</td>
<td>20 - 58</td>
<td>20 - 65</td>
</tr>
</tbody>
</table>

*aCorrelations with Depression and Ad Use are point-biserial correlation coefficients.

**p < .05, ***p < .01, ****p < .001.
Table 2

Unconditional (Models 1, 3 & 5) and Conditional (Models 2, 4 & 6) Univariate Models for Exercise Frequency, Depression Symptoms and State Anxiety (N = 258).

<table>
<thead>
<tr>
<th>Fixed Effects</th>
<th>Exercise Frequency</th>
<th>Depression Symptoms</th>
<th>State Anxiety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 3</td>
</tr>
<tr>
<td>B (SE)</td>
<td></td>
<td></td>
<td>B (SE)</td>
</tr>
<tr>
<td>Intercept Factor (1st trimester mean)</td>
<td>2.37*** (.11)</td>
<td>2.53*** (.13)</td>
<td>6.60*** (.29)</td>
</tr>
<tr>
<td>Depression Diagnosis (0 = no diagnosis)</td>
<td>-.27 (.30)</td>
<td></td>
<td>3.89*** (.84)</td>
</tr>
<tr>
<td>Antidepressant Use (0 = no use)</td>
<td>-.55† (.31)</td>
<td></td>
<td>1.33 (.94)</td>
</tr>
<tr>
<td>Slope Factor (time)</td>
<td>.18* (.07)</td>
<td>.14 (.08)</td>
<td>-.29 (.18)</td>
</tr>
<tr>
<td>Depression Diagnosis</td>
<td></td>
<td>-.15 (.37)</td>
<td></td>
</tr>
<tr>
<td>Antidepressant Use</td>
<td>.46* (.23)</td>
<td></td>
<td>.08 (.63)</td>
</tr>
<tr>
<td>Quadratic Growth Factor (time^2)</td>
<td>-.03* (.01)</td>
<td>-.03* (.01)</td>
<td>.05 (.03)</td>
</tr>
<tr>
<td>Depression Diagnosis</td>
<td></td>
<td>.05 (.04)</td>
<td></td>
</tr>
<tr>
<td>Antidepressant Use</td>
<td>-.05 (.04)</td>
<td></td>
<td>-.00 (.10)</td>
</tr>
</tbody>
</table>

Random Effects

<table>
<thead>
<tr>
<th>Random Effects</th>
<th>Exercise Frequency</th>
<th>Depression Symptoms</th>
<th>State Anxiety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 3</td>
</tr>
<tr>
<td>B (SE)</td>
<td></td>
<td></td>
<td>B (SE)</td>
</tr>
<tr>
<td>Intercept Factor</td>
<td>2.08*** (.27)</td>
<td>2.02*** (.27)</td>
<td>14.19*** (1.85)</td>
</tr>
<tr>
<td>Slope Factor</td>
<td>.06*** (.02)</td>
<td>.06*** (.01)</td>
<td>.32** (.09)</td>
</tr>
<tr>
<td>Quadratic Growth Factor</td>
<td></td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

χ^2 (d.f.) | 2.80 (4) | 2.64 (6) | 3.36 (4) | 3.15 (6) | 14.08* (4) | 10.67 (6) |
RMSEA (95% CI's) | 0 (0, .08) | 0 (0, .50) | 0 (0, .09) | 0 (0, .05) | 0.10 (.05, .16) | 0.06 (0, .11) |
SRMR | 0.03 | 0.02 | 0.03 | 0.02 | 0.08 | 0.03 |
† p < .10, * p < .05, ** p < .01, *** p < .001.
Figure 2. Model-estimated exercise frequency means at each time-point, adjusted for depression diagnosis and antidepressant use.
Exercise and Mental Health Parallel Process Models

Figures 3 and 4 present the latent growth variables and their correlations and standardized regression estimates for parallel process Models 7 and 8, respectively. Both models showed strong model fit indices indicating good fit to the data (see notes to Figures 3 & 4). In both models, neither the exercise frequency nor the mental health measures – depression symptoms and state anxiety – during the first trimester (i.e., the intercept latent variable) predicted linear slope growth in the other. The intercept levels, however, were associated significantly in both models. This means that women who reported exercising more frequently than the sample average (i.e., > 2.5) during the first trimester, also reported lower than the average depression symptoms scores (i.e., < 5.5) with a correlation of \( r = -0.21 \). The same pattern emerged with respect to anxiety, with a slightly stronger negative association (\( r = -0.38 \)), more frequent exercise during the first trimester was associated with lower than average (i.e., < 33) state anxiety scores. Also, exercise frequency and mental health linear slope growth factors were negatively correlated in both models (depression linear slope and exercise, \( r = -0.21 \); anxiety linear slope and exercise \( r = -0.41 \)). Although only approaching the conventional value for significance (\( p = 0.095 \)), decreasing weekly exercise frequency during the perinatal period was weakly associated with increasing depression symptoms during the perinatal period. Decreasing linear change in exercise frequency demonstrated a moderate and significant association with a steeper increasing change in state anxiety score during the perinatal period.

We also ran alternate models for Models 7 and 8, adjusting for the effect of several time-varying covariates that may confound the results of the final multivariate growth models. After accounting for seasonality, the PSQI and the SSEQ, there was no change to the substantive interpretations for Models 7 and 8 presented above. The results of the alternate models are presented in the online Supplementary Material.
Figure 3. Significant standardised regression coefficients and correlations estimated in the parallel process model between exercise frequency and depressive symptoms (Model 7; N = 258). Greyed-out, dashed lines denote non-significant paths. Standard error for parameter estimates are parenthesized. Model fit: χ²(28) = 26.46, p = .548, RMSEA = 0.00 (95% CIs: 0.00, 0.05), SRMR = 0.03.

Note. Although included in the modelling, the observed repeat measurements indicating the latent growth factors (i.e., Intercept and Linear Slope) and the Quadratic latent growth factor are all excluded from the figure to simplify presentation of the results that address hypothesis 2.

† p < .10, ** p < .01, *** p < .001.
Figure 4. Significant standardised regression coefficients and correlations estimated in the parallel process model between exercise frequency and state anxiety symptoms (Model 8; N = 258). Greyed-out, dashed lines denote non-significant paths. Standard error for parameter estimates are parenthesized. Model fit: $\chi^2(28) = 37.77$, $p = .103$, RMSEA = 0.04 (95% CIs: 0.00, 0.06), SRMR = .05. Note. Although included in the modelling, the observed repeat measurements indicating the latent growth factors (i.e., Intercept and Linear Slope) and the Quadratic latent growth factor are all excluded from the figure to simplify presentation of the results that address hypothesis 2. ** $p < .01$, *** $p < .001$.

Discussion

In this study, we described the trajectory of exercise frequency during the perinatal period in a cohort of Australian women and investigated how major depression, antidepressant use, and mental health symptoms were associated with exercise frequency during this period. Our results only partially support hypothesis 1, such that only during the first trimester, control women reported significantly more frequent weekly exercise compared to women taking antidepressants. However, exercise frequency reported by control women did not differ compared to non-medicated depressed women, and there were no significant differences in exercise frequency between the groups during third trimester, and at six and 12 months postpartum. In early pregnancy, women taking antidepressants reported significantly
fewer days per week exercising (< 2 days/week) when compared to both healthy controls and depressed women who were not taking antidepressants; women in these two groups reported approximately two and a half day of exercise on average per week. However, after early pregnancy, the groups did not differ in reported exercise frequency at each of the subsequent time-points.

One of the key findings in this study is that women taking antidepressants in the first trimester reported significantly lower levels of weekly exercise frequency, compared to women in both other groups. However, their average exercise frequency increased to nearly three days per week by six months postpartum, which was similar to the level of exercise reported by control women. Overall, exercise frequency was significantly increasing for women taking antidepressant medication, compared to women not taking antidepressants. Possible explanations include the idea that women on antidepressant treatment have been encouraged by their treating clinicians to exercise as an adjunctive behavioural strategy to pharmacological treatment to improve their mental health, or that women taking antidepressants gradually feel less fatigued due to the efficacy of the medication and this leads to greater physical activity.

We also examined the longitudinal bidirectional associations between changes in exercise frequency and changes in mental health symptoms during the perinatal period. Results from the parallel process models support our second hypothesis: women who reported faster reductions in their exercise frequency during the perinatal period, reported increasing symptoms of depression and state anxiety. This finding is consistent with other studies that have demonstrated the same association in non-pregnant populations (45, 46). This may have important practice and public health implications and suggests that those women with higher anxious and depressive symptoms early in pregnancy, and particularly for those treated with antidepressants, maintaining, or increasing to a healthy level of exercise
frequency during the perinatal period may lead to improvements in depression or anxiety symptoms.

Notably, these results are potentially useful for general practitioners and obstetricians, as recommending exercise as part of a healthy lifestyle across pregnancy and the postpartum may represent an opportunity for improvements in mental health. Furthermore, the findings of this study support the associations between exercise and mental health during pregnancy and particularly so for women diagnosed with depression. With existing research to support the safety of exercise during pregnancy and the benefits of exercise for mother and child, these results provide preliminary evidence to support these benefits specifically for pregnant women with depression.

The results of this study make important contributions to understanding the bidirectional relationship between exercise, pregnancy and maternal mental health. To our knowledge, this is the first study to report repeat measurement of both exercise and depression across the perinatal period and to include a diagnostic measure of depression and a group treated with antidepressant medication. Although the exercise frequency was relatively stable in the modelling, the finding of a significant negative quadratic factor suggests that at each subsequent time-point after early pregnancy, an accelerating reduction in exercise frequency began to emerge. This finding is contrary to previous research, which has documented exercise frequency in healthy women to reduce closer to delivery, but then returns to early pregnancy levels (and if this were the case, it would manifest in our models as a positive quadratic curve function) (25, 26).

Healthy levels of physical exercise have been associated with broad psychological benefits, such as improvements in self-esteem, perceptions of physical appearance and quality of life (27, 28), which may improve depressive and anxiety symptoms. At a biochemical level, increased and maintained physical activity improves biological
functioning, such as optimising stress regulation via the HPA axis and enhanced regulation of the anti-inflammatory response. There is also evidence that maternal cortisol regulation influences vascular function, which is particularly important for the role of the placenta in pregnancy (47, 48). Maintenance of healthy levels of physical activity or appropriate increases in physical activity during pregnancy and the postpartum may assist in the regulation of cortisol, vascular and inflammatory functions.

How exercise is measured is important in interpreting our findings. Most studies to date have utilised the number of steps taken during the day, how many minutes per day spent in context-specific activities, and defining physiological changes (i.e., heavy breathing and sweating) in response to the intensity of exercise. Whereas, we have specifically operationalised exercise frequency as the number of days per week during the previous month where the woman engaged in 30 minutes or more of moderate to vigorous physical activity. Our choice of operationalising exercise in this way was informed by an RCT study that reported a reduction in the rates of gestational diabetes mellitus in overweight/obese pregnant women who commenced 20- to 30-minute bouts of cycling exercise three times per week early in pregnancy (22).

Several limiting factors affect the generalizability of the results. There was a small non-medicated depressed group of women (n = 28) and the range of EPDS and STAI scores and linear change estimates are limited due to greater proportion of healthy controls in the sample. Leptokurtic and negatively skewed distributions for the slope factor and average low first trimester values suggest that most women in the sample are commencing pregnancy with non-clinical depressive and anxious symptoms, and they tracked relatively stably toward 12 months postpartum. A larger group of women with major depression, both medicated and non-medicated, may improve normality in the intercept and slope distributions and improve the robustness of the results. Although we measure exercise at four time-points during the
perinatal period, our measure of exercise frequency was limited to a single question, asking retrospectively about the prior month for an estimate of weekly moderate to vigorous physical activity. With objective measures of activity now readily accessible and relatively inexpensive, such as accelerometry, future observational research should aim to include these activity measures to improve validity and robustness of results. Future investigations could also benefit by including potentially confounding contextual variables associated with exercising, such as individual versus group exercise and whether or not the exercise is structured with an instructor.

It is recommended that future research conduct randomised control trials for pregnant women with depression and anxiety to determine whether targeted exercise can reduce these symptoms during the perinatal period. For clinicians, this could provide a safe, evidence-based treatment, in addition to psychological interventions or psychopharmacology that can improve mental and physical health for women during pregnancy.
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Competing Interests Statement

MG has previously received honorarium for speaking from Lundbeck. The other authors declare that they have no competing interests. The organizations that funded the study did not contribute to any of the following elements of the paper: study design, the collection, analysis, and interpretation of data, the writing of the report, and the decision to submit the paper for publication. MG and SW wrote the first draft of this paper, and no honorarium or other form of payment was given to any of the authors to produce the manuscript.
Highlights

- On average, women’s weekly exercise frequency declined during pregnancy
- On average, women’s weekly exercise frequency bounced back one year after birth
- Women with non-medicated depression reported declining frequency of exercise
- Women taking antidepressants reported lowest exercise frequency in early pregnancy
- Women taking antidepressants increased exercise frequency during the perinatal period
- Declining exercise frequency associated with increasing anxious, depressive symptoms