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Is physical activity in pregnancy associated with prenatal and postnatal depressive symptoms?: Results from MAASTHI cohort study in South India

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ABSTRACT

Objective: Physical inactivity leads to depression and other adverse health consequences. Pregnant women are an important subgroup to study the health consequences due to physical inactivity since it can lead to adverse outcomes in pregnancy and even after delivery. Therefore, we aimed at understanding the level of physical activity among pregnant women, prevalence of prenatal and postnatal depressive symptoms and whether level of physical activity is associated with prenatal and postnatal depressive symptoms.
Methods: In an ongoing cohort study, we measured the physical activity using a validated Physical Activity Level (PAL) questionnaire. We administered the Edinburgh Postnatal Depression Scale (EPDS) during pregnancy and within seven days of delivery to assess depressive symptoms in 1406 women. Associations were adjusted for potential confounders such as maternal age, education, socioeconomic status, gravida, EPDS score during pregnancy, social support, skinfold thickness, blood pressure, blood sugar level.
Results: We found that 7.2% of pregnant women had low levels of physical activity. The prevalence of prenatal and postnatal depressive symptoms was 9.0% and 31.9% respectively. Pregnant women with a low level of physical activity had significantly higher odds of developing postpartum depressive symptoms (OR = 3.15, CI: 1.98–5.02, $p < 0.001$) when adjusted for potential confounders.
Conclusions: Moderate level of physical activity among pregnant mothers is essential and has its association with postnatal depressive symptoms. Health care professionals need to counsel pregnant women to assess depressive symptoms at both the prenatal and postpartum period and inform them about the importance of the optimal level of physical activity.

1. Introduction

Physical activity (PA) is essential in all stages of life, including pregnancy. Unless contraindicated, PA promotes health benefits during pregnancy and better birth outcomes. PA supports maintaining physical fitness, improves psychological well-being, and reduces the risk of Non-Communicable Diseases (NCDs) [1,2]. NCDs are the leading causes of early death in Low and Middle-Income Countries (LMICs), including India [3]. Physical inactivity is a major modifiable behavioural risk factor for NCDs and attributes to 1.6 million deaths annually due to Cardiovascular Disease (CVD), diabetes, and cancer [4]. In pregnancy, evidence suggests that moderate-intensity physical activity is also required for better health outcomes [5]. Pregnant and postpartum women are recommended to perform at least 150 min per week of some form of PA [6,7]; however, only about 10.7% of pregnant women meet the recommended guidelines for PA in India [8]. Women with healthy weight and higher educational attainment are likely to be physically active [9]. Pregnant women performing some form of physical activity are less likely to have a caesarean delivery, stillbirths, Gestational Diabetes Mellitus (GDM), hypertension, obesity, and maternal depression [10–14].

Maternal depression is the leading cause of Years Lived with

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Disability (YLD) in women [3,15]. During pregnancy and in the postnatal period, depression is a common psychiatric disorder [16]. Globally, 10% of pregnant women and 13% of the mothers in the postpartum period suffer from mental health disorders, especially depression [17]. Prenatal depressive symptoms have a strong association with postnatal depressive symptoms [18]. The pooled estimate of the prevalence of postpartum depression in Indian mothers is 22%, with the highest prevalence in South India (26%) [19]. Mothers with postnatal depression tend to have higher anxiety, fewer interactions, and affection [20]. Postpartum depressive symptoms also result in poor mother and child bonding and relationship [21], poor infant development [22,23], and has a subsequent impact on childhood development in terms of impaired cognitive, emotional and physical development in early infancy and adolescence [24].

PA and mental health are related to each other [25]. Physical inactivity is associated with prenatal [26] and postnatal depressive symptoms [27]. Muscle contractions during PA induce the release of myokines, and these factors decrease the expression of pro-inflammatory cytokines. PA also promotes the regulation of cortisol hormone [28]. Higher cortisol and cytokine levels result in depression [29,30]. PA promotes the release of endorphins among depressed individuals, which has a mood-enhancing effect and alleviates depressive symptoms [31]. PA enhances resilience mechanisms, including self-esteem, self-efficacy, and behavioural activation, which together are effective in alleviating the depression and its sequelae [32] In India, 53.5% of women attend public hospitals for antenatal care services [33]. Studies conducted at these facilities could better influence the policy recommendations. None of the studies explored the association of physical activity among pregnant women with both prenatal and postnatal depressive symptoms in Indian settings. Such evidence is essential for developing priority interventions for pregnant women. Therefore, we aimed to understand the level of physical activity, the prevalence of prenatal and postnatal depressive symptoms, and the association of PA level during pregnancy with prenatal and postnatal depressive symptoms.

2. Material and methods

2.1. Study design and setting

This study is nested within an ongoing cohort study titled, "Maternal antecedents of adiposity and studying the transgenerational role of hyperglycaemia and Insulin (MAASTHI)". A detailed protocol of the cohort study is published elsewhere [34]. In brief, the cohort recruited pregnant women between 14 and 36 weeks of gestational age attending public hospitals. Assuming an incidence of 7% postpartum depression among mothers with moderate to vigorous physical activity during pregnancy, and a relative risk of 1.8 in the low level of physical activity group [35], our estimated sample size for 80% power to detect a difference at a 95% confidence level, is 878. Further assuming a follow-up of up to 60%, we planned to recruit 1405 women. We collected information of eligible pregnant women during baseline data collection, including age (recorded birth date), education, occupation, and monthly income (to assess socioeconomic status), obstetrical history such as gravida, parity, number of living children, and stillbirths. We also collected information on tobacco and alcohol consumption in both the respondent and her husband. Respondent's blood pressure, GDM status at current pregnancy, and anthropometric characteristics were also recorded. Follow-up of mother-child pair was performed within a week of the delivery. Data collection was done using an application (app) designed specifically for the cohort and hosted on android tablets with strict safety measures to protect and safeguard the data.

2.2. Ethical considerations

The study was reviewed and approved by the Institutional Ethics Committee of the Indian Institute of Public Health, Bangalore campus (IEC approval no: IIPHHB/TRCIEC/091/2015; dated 13th November 2015). Participants who were willing to participate voluntarily, and those who have provided written, informed consent were enrolled. The informed consent of the participants was obtained after the nature of the procedures had been fully explained. The investigation was carried out as per the latest version of the Declaration of Helsinki [36].

2.3. Exposure assessment

We measured the PA of the pregnant women during recruitment using a pre-tested, validated Physical Activity Level (PAL) questionnaire [37] (Appendix A). This questionnaire was validated against accelerometry and a 24-h physical activity diary as reference methods, and these reference methods were validated against the heart rate–oxygen consumption (HRVO2) method. These questionnaires demonstrated acceptable validity with the reference methods. This questionnaire was used among pregnant women in similar study settings [38]. PAL was completed once during pregnancy at the time of recruitment. The domains of this questionnaire include details about exercise, other hobbies, household chores, sedentary activities, and other everyday daily activities. We also noted sleeping hours, total working hours, standing, sitting, walking, and strenuous activity hours. We recorded the frequency performed in a week and the duration of the activity in minutes for each activity in these domains. We calculated Metabolic Equivalent (MET) values of each activity by multiplying three components: MET allotted value, duration of activity done, and frequency done in a week. After obtaining these values for all individual activities, we calculated combined MET value by adding MET values of individual PA. Based on the International Physical Activity guideline [39], we categorised the level of PA as Low (<600 MET-minutes/week.), moderate (600–2999 MET-minutes/week.), and High (≥3000 MET-minutes/week.).

2.4. Outcome assessment

Depressive symptoms were measured using the Edinburgh Postnatal Depression Scale (EPDS) during the recruitment phase at pregnancy and in the follow- up during the postnatal period within a week of the delivery [40,41]. The EPDS is a useful screening tool in low resource settings and validated for use in India for both during pregnancy and the postnatal period [42,43]. It has ten simple questions to assess the risk of depression. Every question has four possible responses. Mothers were asked to identify the closest response in terms of how she is feeling over the past week. Care was taken to maintain privacy while this questionnaire was administered, and we assured confidentiality of the collected data. Trained research assistants assigned for data collection at a particular health facility collected the questionnaire. Based on the recorded responses of the mothers, scores were calculated according to the standard instructions. The total score for EPDS range from 0 to 30, and as per the validated norms for EPDS, we considered that women with scores above 13 had symptoms suggestive of depression [44,45].

2.5. Covariates assessment

The decision regarding selecting covariates was made based on prior evidence [46–49]. We measured social support using a validated tool [44]. We scheduled an Oral Glucose Tolerance Test (OGTT) for the diagnosis of GDM upon completion of 24 weeks of gestation, according to the WHO diagnostic criteria [50]. Trained research assistants performed all the anthropometric measurements involved in the study. Certification for performing anthropometry measurements are carried out annually. To assess obesity parameters among pregnant women, we calculated the Sum of Skinfold Thickness (SFT) using each skinfold thickness [51]. This included measurement of biceps, triceps, and subscapular skinfold thickness using Holtain Calipers (Holtain, UK) and taken three readings to the nearest 0.2 mm. We measured the Blood Pressure (BP) of the mother using an automated digital device (Omron

Digital BP measuring device) and noted two readings of systolic and diastolic BP readings. We used different sized cuffs such as 22-32 cm and 32–42 cm based on the pregnant women's Mid upper arm circumference. We used Joint National Committee 8 (JNC 8) criteria for diagnosing hypertension [52].

2.6. Statistical analysis

Research assistants entered all data in a validated system on an Android device. Initially, a backend system version 1.0 was developed on Microsoft. With version 2.0 of the mobile application, the complete backend was migrated to Microsoft.NET Core 2.1. We used statistical software to analyze data (IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp). We checked the normality of data before using parametric tests. Mean and standard deviation of the continuous variables according to the level of physical activity are presented using the independent sample *t*-test. Chi-square test was used to assess the relationship between pregnancy characteristics and the level of physical activity and pregnancy characteristics and EPDS score during the postnatal period.

Linear regression and binary logistic regression analysis were done to understand the effect of physical activity on postpartum depressive symptoms. The univariate and multivariate linear regression analysis was done to assess the relationship between pregnant women's physical activity and EPDS score during the postnatal period. Beta coefficient (β), Odds Ratio (OR), 95% Confidence Interval (95% CI), and *p*-value are presented. *P*-value of <0.05 is accepted for significance. In binary logistic regression, we had adjusted for confounders using different models for assessing predictions and neutralize the effect of confounding factors. In regression analysis, pregnancy characteristics such as age, gravida, pregnancy EPDS score, social support during pregnancy, blood pressure, sugar levels, and the sum of skinfold thickness were adjusted as these were considered as potential confounders based on the available evidence [27,53]. To understand the difference is the OR, we used three regression analysis models by adding other confounders to the initial model and arrived at the final model. Since sociodemographic factors were an underlying risk factor for the study outcome in model 1, we adjusted for socioeconomic status, respondent education [54]. Since pregnancy-related psychosocial factors are also stronger risk factors [55], we included pregnancy-related and psychosocial variables such as gravida, EPDS score at pregnancy, social support in model 2 to assess the combined effect of these confounding factors. Similarly, in Model 3, we examined if morbidity such as maternal obesity, hypertension, and GDM [56] alters this association.

3. Results

Among the total pregnant women interviewed, 97.2% underwent a complete baseline assessment, and 1549 were delivered mothers. For the final analysis, we have considered 1406 subjects after excluding missed follow-up (Fig. 1).

As shown in Table 1, a majority (92.8%) of pregnant women performed moderate levels, whereas 7.2% had low levels of physical activity, while none of them had a high level of physical activity. The prevalence of prenatal and postnatal depressive symptoms was 9.0% and 31.9%, respectively. Prenatal depressive symptom women who remained depressive during postpartum were 55.6% (70/126), and the remaining 44.4% (56/126) changed to no depressive symptom during postpartum. (Table 1).

Among the mothers with prenatal depressive symptoms, 6.3% had a low level of physical activity, and the findings were insignificant. Among the mothers with postnatal depressive symptoms, 50.8% had poor social

Table 1
Prevalence of physical activity levels, prenatal and postnatal depressive symptoms ($N = 1406$).

Variable (N = 1406)	Category	n (%)
Prenatal depressive symptoms	Yes	126 (9.0)
	No	1280 (91.0)
Level of physical activity	Low	101 (7.2)
	Moderate	1305 (92.8)
Postnatal depressive symptoms	Yes	*449 (31.9))*
	No	957 (68.1)
Prenatal depressive symptom women remained with postpartum depression (N = 126)	Yes	70 (55.6)
	No	56 (44.4)

Prenatal depressive symptoms: Yes: EPDS >13; No: EPDS ≤13.
Level of physical activity: Low: <600 METs; Moderate: 600–2999 METs.
Postnatal depressive symptoms: Yes: EPDS >13, No: EPDS ≤13.

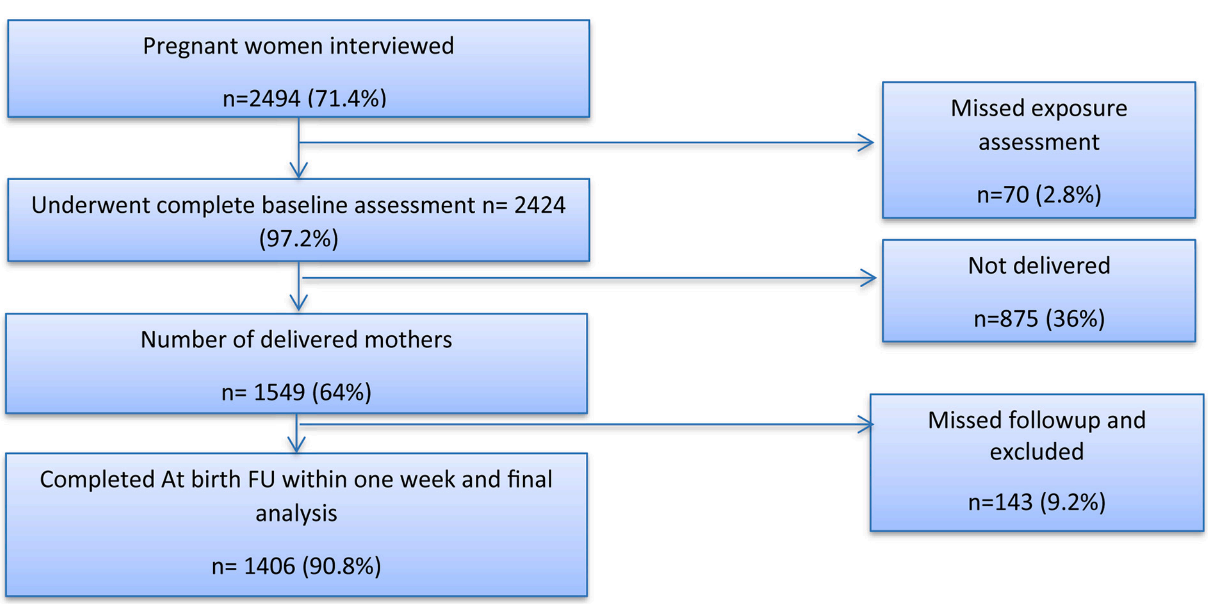

Fig. 1. Flow chart depicting study recruitment and follow-ups in the study.

Table 2
Baseline characteristics of the women based on prenatal and postnatal depressive symptoms.

Sample characteristics	Category	Women with prenatal depressive symptoms n (%)	Women without prenatal depressive symptoms n (%)	*p*-value	Women with postnatal depressive symptoms n (%)	Women without postnatal depressive symptoms n (%)	*p*-value
Age (years) (N = 1406)	18–25	88 (69.8)	850 (66.4)	0.42	307 (68.4)	631 (65.9)	0.35
	26–35	35 (27.8)	411 (32.1)		133 (29.6)	314 (32.8)	
	36–45	3 (2.4)	19 (1.5)		9 (2)	13 (1.4)	
Respondent education (N = 1406)	Illiterate	5 (4)	34 (2.7)		17 (3.8)	22 (2.3)	0.42
	Primary school	5 (4)	65 (5.1)	0.43	24 (5.3)	46 (4.8)	
	Middle school	27 (21.4)	216 (16.9)		78 (17.4)	165 (17.2)	
	High school and above	89 (70.6)	964 (75.4)		330 (73.5)	724 (75.7)	
Occupation (N = 1406)	Homemakers	117 (92.9)	1179 (92.2)	0.86	416 (92.7)	881 (92.1)	0.69
	Employed	9 (7.1)	100 (7.8)		33 (7.3)	76 (7.9)	
Socio-Economic status (N = 1406))	Lower Class	87 (69)	799 (62.5)	0.31	289 (64.4)	598 (62.5)	0.66
	Middle class	39 (31)	478 (37.4)		159 (35.4)	358 (37.4)	
	Upper class	0 (0)	2 (0.2)		1 (0.2)	1 (0.1)	
Gravida (N = 1406)	Primi gravida	54 (42.9)	478 (37.3)	0.24	151 (33.6)	381 (39.8)	**0.02**
	Multigravida	72 (57.1)	802 (62.7)		298 (66.4)	577 (60.2)	
Social support at pregnancy (N = 1406)	≤ 24	91 (72.2)	821 (64.1)	0.07	228 (50.8)	684 (71.5)	**<0.001**
	>24	35 (27.8)	459 (35.9)		221 (49.2))	273 (28.5)	
Husband's alcohol consumption (N = 1367)	No	95 (79.2)	1064 (85.4)	0.08	373 (87.1)	787 (83.8)	0.11
	Yes	25 (20.8)	182 (14.6)		55 (12.9)	152 (16.2)	
Blood Pressure (N = 1369)	Normal	116 (93.5)	1180 (94.8)	0.67	422 (95.5)	874 (94.3)	0.35
	Hypertension	8 (6.5)	65 (5.2)		20 (4.5)	53 (5.7)	
Blood sugar (N = 1338)	Normal	104 (85.2)	1002 (82.5)	0.45	366 (82.2)	741 (83)	0.73
	GDM	18 (14.8)	213 (17.5)		79 (17.8)	152 (17)	
Haemoglobin (N = 1354)	Normal	66 (54.5)	703 (57.1)	0.63	234 (52.6)	535 (58.9)	**0.02**
	Anaemic	55 (45.5)	529 (42.9)		211 (47.4)	374 (41.1)	
Physical activity during pregnancy (N = 1406)	Low	8 (6.3)	93 (7.3)	0.72	50 (11.1)	51 (5.3)	**<0.001**
	Moderate	118 (93.7)	1187 (92.7)		399 (88.9)	907 (94.7)	

Data are presented as n (%), and significance is presented as a p-value at a 5% level of significance.
Level of physical activity: Low if <600 METs, moderate when 600–2999 METs.
Women with prenatal and postnatal depressive symptoms: EPDS >13); women without prenatal and postnatal depressive symptoms: EPDS≤13.
EPDS: Edinburgh Postnatal Depression Scale, Hypertension: if the systolic blood pressure is ≥120 mmHg or diastolic blood pressure is ≥80 mmHg.
GDM: Gestational Diabetes Mellitus: If FBS ≥92 mg/dl or 2 h PPBS ≥153 mg/dl.
Anaemia: blood haemoglobin <11 g/dl.

support in pregnancy, 47.4% were anaemic during pregnancy, two-third were with multigravida, 11.1% had a low level of physical activity. We noted social support, PA, gravida, and haemoglobin levels were significantly associated with postnatal depressive symptoms (Table 2). Other factors such as age, education, socioeconomic status, blood sugar level during pregnancy were not significantly associated with postnatal depressive symptoms. The correlation coefficient found between level of physical activity and postnatal depressive symptoms was 0.88.

With the higher prenatal depressive symptoms, we found higher postnatal depressive symptoms with a significant association ($\beta = 0.536$, $p < 0.001$) when adjusted for potential confounders. (Table 3) However, with each MET value (kcal/kg/h) increase in physical activity, there was a decrease in the postnatal depressive symptoms ($\beta = -0.004$, $p < 0.001$). There was no significant linear relationship between gravida, blood pressure during pregnancy, haemoglobin levels, sugar level, and obesity and postnatal depressive symptoms.

Adjusted and unadjusted odds ratios are presented in Table 4 for the association between postnatal depressive symptoms and low level of physical activity during pregnancy. In the unadjusted model, we found that a low level of physical activity increased the odds of developing postnatal depressive symptoms (OR = 2.22, CI: 1.48–3.35, $p < 0.001$). This was also seen after adjusting for potential confounders. A low level

Table 3
Linear regression model depicting the relationship between pregnancy characteristics and postnatal depressive symptoms, MAASTHI birth cohort, South India (N = 1406).

Variables	Unadjusted			Adjusted		
	B	95% CI	*p*-value	B	95% CI	*p*-value
Physical activity	−0.004	−0.006, −0.002	**<0.001**	−0.004	−0.006, −0.001	**<0.001**
Age	−0.01	−0.16, 0.09	0.63			
Gravida	0.43	−0.13, 1.00	0.13	0.28	−0.29, 0.86	0.34
Pregnancy EPDS score	0.50	0.40, 0.60	**<0.001**	0.53	0.43, 0.64	**<0.001**
Social support at pregnancy	0.09	0.04, 0.14	**<0.001**	0.16	0.11, 0.21	**<0.001**
SBP	0.01	−0.03, 0.06	0.57	0.009	−0.04, 0.06	0.74
DBP	−0.06	−0.12, −0.002	**0.042**	−0.06	−0.12, 0.007	0.08
Haemoglobin	−0.44	−0.91, 0.01	0.05	−0.38	−0.84, 0.06	0.09
FBS	0.02	−0.02, 0.08	0.31	0.01	−0.04, 0.06	0.71
PPBS	0.01	−0.004, 0.04	0.10	0.01	−0.009, 0.03	0.24
Sum of skinfold thickness	0.006	−0.03, 0.04	0.76	0.007	−0.03, 0.04	0.75

Age, gravida pregnancy EPDS score, social support during pregnancy, blood pressure, sugar levels and sum of skinfold thickness during pregnancy have been adjusted.
EPDS: Edinburgh Postnatal Depression Scale; FBS: Fasting Blood Sugar; PPBS: Post Prandial Blood Sugar.
SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure.

Table 4
Binary logistic regression analysis for the association of low-level physical activity during pregnancy with postnatal depressive symptoms.

Model	OR	95% CI		*p*-value
		Lower	Upper	
Unadjusted (N = 1406)	2.0.22	1.48	3.35	<0.001
Model 1 (N = 1406)	2.34	1.53	3.58	<0.001
Model 2 (N = 1406)	2.96	1.90	4.62	<0.001
Model 3 (N = 1338)	3.15	1.98	5.02	<0.001

OR: Odds Ratio; 95% CI: 95% Confidence Interval.
Model 1: Age, Socioeconomic status, respondent education.
Model 2: model 1 + gravida, EPDS score at pregnancy, social support.
Model 3: model 2+ obesity, hypertension, Gestational Diabetes Mellitus.

of physical activity during pregnancy results in 2.3 times higher odds of developing postnatal depressive symptoms (Model 1, OR = 2.34, CI: 1.53–3.58, $p < 0.001$). Further higher odds persisted after adjusting for variables for gravida, prenatal depressive symptoms, and social support (model 2). Upon adjusting for maternal obesity, hypertension, and GDM (model 3), we observed that pregnant women with low levels of physical activity had 3.15 times higher odds of experiencing postnatal depressive symptoms (OR = 3.15, CI: 1.98–5.02, $p < 0.001$).

4. Discussion

We observed that 7.2% of pregnant women performed a low level of PA, and the prevalence of prenatal and postnatal depressive symptoms was 9.0% and 31.9%, respectively. Pregnant women were in the second and third trimester. The sample size in the 2nd trimester and 3rd trimester were 1019 and 387, respectively. All the participants (1406) were followed up within 1st week of postpartum (varies from 1 to 7 days of after delivery). We noted that gravida, social support score at pregnancy, haemoglobin status, and PA level during pregnancy were significantly associated with postnatal depressive symptoms. Also noted that a low level of PA during pregnancy had higher odds of developing postpartum depressive symptoms when adjusted for potential confounders. Previous studies on such a hypothesis were either conducted by measuring both exposure and outcome concurrently either during pregnancy [57] or in the postpartum period [58]. Prospective studies define temporality, and for the first time in India, we demonstrate the influential role of PA during pregnancy and its association with postnatal depressive symptoms [19].

Our findings on the prevalence of antenatal depression are similar to the other study findings, where the prevalence of antenatal depression ranges from 9.2% to 65.0% in India, which could be due to difference in the region, gestational age at the time of assessment, etc. [59]. Our findings on the prevalence of postnatal depressive symptoms were higher than the findings from a recent meta-analysis. This could be due to the difference in the use of screening tools, gestational age at the time of assessment, region, etc. The review suggests strong evidence that moderate-intensity PA was associated with reducing the risk of excessive gestational weight gain, gestational diabetes, and symptoms of postpartum depression [60].

The results from our study concur with evidence from the high-income countries in addition to established temporality. A multiethnic cohort in Oslo, Norway, found that moderate PA among mothers was associated with a lower risk of postpartum depressive symptoms compared to their counterparts [53]. Similarly, a systematic review and meta-analysis found that physically active women during pregnancy will have significantly lower postpartum depression scores [61]. Aerobic exercise was found to be associated with postpartum depressive symptoms [62]. A Randomized Controlled Trial (RCT) found that exercise intervention in pregnancy is associated with the prevalence of depression in late pregnancy and postpartum [63]. In India, an RCT found that structured PA and Health Care Education program effectively improves the well-being of primipara mothers in the postpartum period [58]. A multiethnic cohort of Asian women, including India, found that sufficient PA is associated with less likely antenatal depression and trait anxiety symptoms. However, the cause-effect relationship was not established since both were measured simultaneously [57].

We found that postnatal depressive symptoms are associated with both prenatal depressive symptoms and PA during pregnancy. Our study did not find a statistically significant association between physical activity and prenatal depressive symptoms. Since these factors were assessed simultaneously, clear causation cannot be defined. Similar to our findings, evidence also suggests that among the mothers who had postnatal depressive symptoms, half of them also had prenatal depressive symptoms [64]. Mothers with depressive symptom as assessed through questionnaire were immediately referred to the Gynaecologists or medical officers in the study centres for follow-up.

4.1. *Strengths and limitations*

Our findings may be useful in setting up priority PA interventions among pregnant women as it has a beneficial effect even in the prenatal and postpartum period. Using a prospective cohort study with a reasonable sample size and power, we proved an association of PA with postnatal depressive symptoms and found high correlation between level of PA and postnatal depressive symptoms. Our study was conducted in public hospitals where most pregnant women visit for antenatal care services, thus reducing selection bias. We used validated questionnaires for assessing PA as well as prenatal and postnatal depressive symptoms.

We used self-reported questionnaires and subjective data to assess the level of PA, and there may be social desirability bias. To minimize these effects, we maintained anonymity and confidentiality of the collected data. Our analysis of prenatal depressive symptoms and physical activity was cross-sectional. Also, the pregnant women's cultural and traditional practices, which we could not assess in the cohort, might have confounded the association between PA and postnatal depressive symptoms. We assumed that socioeconomic status could be used as proxies for cultural practices. However, this may not hold good in every circumstance, and hence to minimize these effects, we used a large sample size.

Future studies should focus on the association between PA and depressive symptoms and interventions to improve PA. Studies on an objectively measured level and intensity of PA are essential as it finds exact minutes of each activity. Awareness and imparting knowledge to pregnant and postnatal mothers must be improved regarding the optimal level of PA to be reached and its importance for the better health of both mother and baby. Strategies need to be made to promote and enhance PA among pregnant mothers. RCTs need to be done with the objectives to measure physical inactivity and its association with prenatal l and postnatal depressive symptoms.

Our study suggests that most pregnant women were with a moderate level of physical activity and found an alarming prevalence of prenatal and postnatal depressive symptoms. Also, a moderate level of physical activity during pregnancy is associated with depressive symptoms after the delivery. Health care professionals need to counsel pregnant women to assess depressive symptoms in both the prenatal and postnatal period. Specifically, they need to be informed that performing an optimal level of physical activity can prevent future risk of mental health disorders and its complications.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpsychores.2021.110390.

References

[1] Obstetricians ACo, Gynecol GJO, Physical activity and exercise during pregnancy and the postpartum period. Committee opinion no, 650. 126 (6) (2015) e135–e142.
[2] WHO, Physical activity, WHO, 2018 [cited 2019 July 17]. Available from, https://www.who.int/news-room/fact-sheets/detail/physical-activity.
[3] (IHME) IfHMaE, Findings from the Global Burden of Disease Study 2017, 2017.
[4] WHO, Physical activity, WHO, 2018 [updated 23, February; cited 2019 17, July]. Available from, https://www.who.int/news-room/fact-sheets/detail/physical-activity.
[5] K.R. Evenson, R. Barakat, W.J. Brown, P. Dargent-Molina, M. Haruna, E. M. Mikkelsen, et al., Guidelines for physical activity during pregnancy: comparisons from around the world, Am. J. Lifestyle Med. 8 (2) (2014) 102–121.
[6] ACOG, Exercise During Pregnancy [updated July 2019; cited 2019 August 28]. Available from, https://www.acog.org/Patients/FAQs/Exercise-During-Pregnancy?IsMobileSet=false, 2019.
[7] WHO, Global Strategy on Diet, Physical Activity and Health [cited 2019]. Available from, https://www.who.int/dietphysicalactivity/pa/en/, 2019.
[8] R.M. Anjana, V. Sudha, N. Lakshmipriya, C. Anitha, R. Unnikrishnan, B. Bhavadharini, et al., Physical activity patterns and gestational diabetes outcomes–the wings project, Diabetes Res. Clin. Pract. 116 (2016) 253–262.
[9] M. Lindqvist, M. Lindkvist, E. Eurenius, M. Persson, A. Ivarsson, I. Mogren, Leisure time physical activity among pregnant women and its associations with maternal characteristics and pregnancy outcomes, Sexual Reprod. Healthcare. 9 (2016) 14–20.
[10] S.C. Dumith, M.R. Domingues, R.A. Mendoza-Sassi, J.A. Cesar, Physical activity during pregnancy and its association with maternal and child health indicators, Rev. Saude Publica 46 (2) (2012) 327–333.
[11] E.N. Nielsen, P.K. Andersen, H.K. Hegaard, M. Juhl, Mode of delivery according to leisure time physical activity before and during pregnancy: a multicenter cohort study of low-risk women, J. Pregnancy 2017 (2017).
[12] S. Mishra, S. Kishore, Effect of physical activity during pregnancy on gestational diabetes mellitus, Indian J. Endocrinol. Metab. 22 (5) (2018) 661.
[13] E.D. Watson, S. Brage, T. White, K. Westgate, S.A. Norris, M.N. Van Poppel, et al., The influence of objectively measured physical activity during pregnancy on maternal and birth outcomes in urban black south African women, Matern. Child Health J. 22 (8) (2018) 1190–1199.
[14] G. Sanabria-Martínez, A. García-Hermoso, R. Poyatos-León, C. Álvarez-Bueno, M. Sánchez-López, V. Martínez-Vizcaíno, Effectiveness of physical activity interventions on preventing gestational diabetes mellitus and excessive maternal weight gain: a meta-analysis, BJOG Int. J. Obstet. Gynaecol. 122 (9) (2015) 1167–1174.
[15] P. Shidhaye, P. Giri, Maternal depression: a hidden burden in developing countries, Ann. Med. Health Sci. Res. 4 (4) (2014) 463–465.
[16] R. Cantwell, J.J.C.O. Cox, Psychiatric disorders in pregnancy and the puerperium, Gynaecology 13 (1) (2003) 7–13.
[17] WHO, Mental health, WHO, 2021 [cited 2019 18 July]. Available from, https://www.who.int/mental_health/maternal-child/maternal_mental_health/en/.
[18] F.A. Ogbo, J. Eastwood, A. Hendry, B. Jalaludin, K.E. Agho, B. Barnett, et al., Determinants of antenatal depression and postnatal depression in Australia, BMC Psychiatry. 18 (1) (2018) 49.
[19] R.P. Upadhyay, R. Chowdhury, A. Salehi, K. Sarkar, S.K. Singh, B. Sinha, et al., Postpartum depression in India: a systematic review and meta-analysis, Bull. World Health Organ. 95 (10) (2017) 706.
[20] M. Righetti-Veltema, A. Bousquet, J. Manzano, Impact of postpartum depressive symptoms on mother and her 18-month-old infant, Eur. Child Adolesc. Psychiatry 12 (2) (2003) 75–83.
[21] S. Myers, S.E. Johns, Postnatal depression is associated with detrimental life-long and multi-generational impacts on relationship quality, PeerJ. 6 (2018), e4305.
[22] L. Murray, P.J. Cooper, Effects of postnatal depression on infant development, Arch. Dis. Child. 77 (2) (1997) 99–101.
[23] C.E. Parsons, K.S. Young, T.J. Rochat, M.L. Kringelbach, A. Stein, Postnatal depression and its effects on child development: a review of evidence from low-and middle-income countries, Br. Med. Bull. 101 (1) (2012) 57.
[24] Kent Uo, Postnatal depression has life-long impact on mother-child relations, ScienceDaily. (2018).
[25] R.L. White, M.J. Babic, P.D. Parker, D.R. Lubans, T. Astell-Burt, C. Lonsdale, Domain-specific physical activity and mental health: a meta-analysis, Am. J. Prev. Med. 52 (5) (2017) 653–666.
[26] J.K. Mak, A.H. Lee, N.M. Pham, L. Tang, X.-F. Pan, Z.-P. Xu, et al., Physical activity during early pregnancy and antenatal depression: a prospective cohort study, Ment. Health Phys. Act. 16 (2019) 54–59.
[27] Z. Demissie, A.M. Siega-Riz, K.R. Evenson, A.H. Herring, N. Dole, B.N. Gaynes, Associations between physical activity and postpartum depressive symptoms, J. Women's Health 20 (7) (2011) 1025–1034.
[28] C. Phillips, A. Fahimi, Immune and neuroprotective effects of physical activity on the brain in depression, Front. Neurosci. 12 (2018) 498.
[29] J.C. Felger, F.E. Lotrich, Inflammatory cytokines in depression: neurobiological mechanisms and therapeutic implications, Neuroscience. 246 (2013) 199–229.
[30] K.A. Dienes, N.A. Hazel, C.L. Hammen, Cortisol secretion in depressed, and at-risk adults, Psychoneuroendocrinology. 38 (6) (2013) 927–940.
[31] L.L. Craft, F.M. Perna, The benefits of exercise for the clinically depressed, Primary Care Comp. J. Clin. Psychiatry. 6 (3) (2004) 104.
[32] A. Daley, Exercise and depression: a review of reviews, J. Clin. Psychol. Med. Settings 15 (2) (2008) 140.
[33] Sciences IIfP, ICF, National Family Health Survey (NFHS-4), 2015–16: India. IIPS Mumbai, 2017.
[34] G.R. Babu, G. Murthy, R. Deepa, H.K. Kumar, M. Karthik, K. Deshpande, et al., Maternal antecedents of adiposity and studying the transgenerational role of hyperglycemia and insulin (MAASTHI): a prospective cohort study, BMC Pregnancy Childbirth. 16 (1) (2016) 311.
[35] Z. Demissie, A.M. Siega-Riz, K.R. Evenson, A.H. Herring, N. Dole, B.N. Gaynes, Associations between physical activity and postpartum depressive symptoms, J. Women's Health (Larchmt) 20 (7) (2011) 1025–1034.
[36] Association WM, WMA Declaration of helsinki – ethical principles for medical research involving human subjects, World Medical Association, 2018 [updated 9th July 2018; cited 2020 August 17th]. Available from, https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/.
[37] A.V. Bharathi, R. Kuriyan, A.V. Kurpad, T. Thomas, S. Ebrahim, S. Kinra, et al., Assessment of physical activity using accelerometry, an activity diary, the heart rate method and the Indian migration study questionnaire in south Indian adults, Public Health Nutr. 13 (1) (2010) 47–53.
[38] P. Dwarkanath, S. Muthayya, M. Vaz, T. Thomas, A. Mhaskar, R. Mhaskar, et al., The relationship between maternal physical activity during pregnancy and birth weight 16(4), 2007, pp. 704–710.
[39] Committee IR, Guidelines for data processing and analysis of the International Physical Activity Questionnaire (IPAQ)-short and long forms, http://www ipaq ki se/scoring pdf, 2005.
[40] M.C. Fernandes, K. Srinivasan, A.L. Stein, G. Menezes, R. Sumithra, P. G. Ramchandani, Assessing prenatal depression in the rural developing world: a comparison of two screening measures, Archiv. Women's Mental Health. 14 (3) (2011) 209–216.
[41] V. Patel, M. Rodrigues, N. DeSouza, Gender, poverty, and postnatal depression: a study of mothers in Goa, India, Am. J. Psychiatr. 159 (1) (2002) 43–47.
[42] S. Shivalli, N. Gururaj, Postnatal depression among rural women in South India: do socio-demographic, obstetric and pregnancy outcome have a role to play? PLoS One 10 (4) (2015), e0122079.
[43] S.D. Shrestha, R. Pradhan, T.D. Tran, R.C. Gualano, J.R. Fisher, Reliability and validity of the Edinburgh postnatal depression scale (EPDS) for detecting perinatal common mental disorders (PCMDs) among women in low-and lower-middle-income countries: a systematic review, BMC Pregnancy Childbirth. 16 (1) (2016) 72.
[44] J.L. Cox, J.M. Holden, R. Sagovsky, Detection of postnatal depression: development of the 10-item Edinburgh postnatal depression scale, Br. J. Psychiatry 150 (6) (1987) 782–786.
[45] K.L. Wisner, B.L. Parry, C.M. Piontek, Postpartum depression, N. Engl. J. Med. 347 (3) (2002) 194–199.
[46] M. Azami, G. Badfar, A. Solemani, S. Rahmati, The association between gestational diabetes and postpartum depression: a systematic review and meta-analysis, Diabetes Res. Clin. Pract. (2019).
[47] E. Molyneaux, L. Poston, S. Ashurst-Williams, L.M. Howard, Obesity and mental disorders during pregnancy and postpartum: a systematic review and meta-analysis, Obstet. Gynecol. 123 (4) (2014) 857.

[48] M.R. Strapasson, C.F. Ferreira, J.G. Ramos, Associations between postpartum depression and hypertensive disorders of pregnancy, Int. J. Gynecol. Obstet. 143 (3) (2018) 367–373.
[49] A. Vaezi, F. Soojoodi, A.T. Banihashemi, M. Nojomi, The association between social support and postpartum depression in women: a cross sectional study, Women and Birth. 32 (2) (2019) e238-e42.
[50] Organization WH, Diagnostic Criteria and Classification of Hyperglycaemia First Detected in Pregnancy, World Health Organization, 2013.
[51] N.E. Marshall, E.J. Murphy, J.C. King, E.K. Haas, J.Y. Lim, J. Wiedrick, et al., Comparison of multiple methods to measure maternal fat mass in late gestation 103(4), 2016, pp. 1055–1063.
[52] K. Bell, J. Twiggs, B.R. Olin, I.R. Date, Hypertension: the silent killer: updated JNC-8 guideline recommendations, Alabama Pharma. Assoc. 334 (2015) 4222.
[53] N. Shakeel, K.R. Richardsen, E.W. Martinsen, M. Eberhard-Gran, K. Slinning, A. K. Jenum, Physical activity in pregnancy and postpartum depressive symptoms in a multiethnic cohort, J. Affect. Disord. 236 (2018) 93–100.
[54] A. Fiala, J. Švancara, J. Klánová, T. Kašpárek, Sociodemographic and delivery risk factors for developing postpartum depression in a sample of 3233 mothers from the Czech ELSPAC study, BMC Psychiatry. 17 (1) (2017) 104.
[55] M. Saligheh, R.M. Rooney, B. McNamara, R.T. Kane, The relationship between postnatal depression, sociodemographic factors, levels of partner support, and levels of physical activity, Front. Psychol. 5 (2014) 597.
[56] J.M. Nicklas, L.J. Miller, C.A. Zera, R.B. Davis, S.E. Levkoff, E.W. Seely, Factors associated with depressive symptoms in the early postpartum period among women with recent gestational diabetes mellitus, Matern. Child Health J. 17 (9) (2013) 1665–1672.
[57] N. Padmapriya, J.Y. Bernard, S. Liang, S.L. Loy, Z. Shen, K. Kwek, et al., Association of physical activity and sedentary behavior with depression and anxiety symptoms during pregnancy in a multiethnic cohort of Asian women, Archiv. Women's Mental Health. 19 (6) (2016) 1119–1128.
[58] A. Thiruppathi, B. Prasana, E. Mastaniah, N. Vamsidhar, P. Himabindu, A structured physical activity and health care education beats postpartum depression for primipara mothers: a pilot randomized controlled trial, Int. J. Theor. Phys. 1 (3) (2014) 144–151.
[59] P. Arora, B.T. Aeri, Burden of antenatal depression and its risk factors in Indian settings: a systematic review, Indian J. Med. Spec. 10 (2) (2019) 55.
[60] L. DiPietro, K.R. Evenson, B. Bloodgood, K. Sprow, R.P. Troiano, K.L. Piercy, et al., Benefits of physical activity during pregnancy and postpartum: an umbrella review, Med. Sci. Sports Exerc. 51 (6) (2019) 1292–1302.
[61] A. Nakamura, J. van der Waerden, M. Melchior, C. Bolze, F. El-Khoury, L. Pryor, Physical activity during pregnancy and postpartum depression: systematic review and meta-analysis, J. Affect. Disord. (2018).
[62] R.V. Pritchett, A.J. Daley, K. Jolly, Does aerobic exercise reduce postpartum depressive symptoms? A systematic review and meta-analysis, Br. J. Gen. Pract. 67 (663) (2017) e684-e91.
[63] M. Vargas-Terrones, R. Barakat, B. Santacruz, I. Fernandez-Buhigas, M.F. Mottola, Physical exercise programme during pregnancy decreases perinatal depression risk: a randomised controlled trial, Br. J. Sports Med. 53 (6) (2019) 348–353.
[64] A. Faisal-Cury, P.R. Menezes, Antenatal depression strongly predicts postnatal depression in primary health care, Rev. Bras. Psiquiatr. 34 (4) (2012) 446–450.