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Research paper

Physical activity in pregnancy and postpartum depressive symptoms in a multiethnic cohort

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ABSTRACT

Introduction: There is strong evidence that postpartum depression is associated with adverse health effects in the mother and infant. Few studies have explored associations between physical activity in pregnancy and postpartum depression. We aimed to investigate whether physical activity during pregnancy was inversely associated with postpartum depressive symptoms, PPDS in a multiethnic sample.

Method: Population-based, prospective cohort of 643 pregnant women (58% ethnic minorities) attending primary antenatal care from early pregnancy to postpartum in Oslo between 2008 and 2010. Data on demographics and health outcomes were collected during standardized interviews. PPDS was defined by a sum score ≥10 from the Edinburgh Postnatal Depression Scale (EPDS), 3 months after birth. Physical activity was recorded with Sense Wear™ Pro3 Armband (SWA) in gestational week 28 and defined as moderate-to-vigorous intensity physical activity (MVPA) accumulated in bouts ≥10 min.

Results: Women who accumulated ≥150 MVPA minutes/week had significantly lower risk (OR = 0.2, 95% CI: 0.06–0.90), for PPDS compared to those who did not accumulate any minutes/week of MVPA, adjusted for ethnic minority background, depressive symptoms in the index pregnancy and self-reported pelvic girdle syndrome. The results for MVPA persisted in the sub-sample of ethnic minority women.

Limitations: Numbers of cases with PPDS were limited. The SWA does not measure water activities. Due to missing data for SWA we used multiple imputations.

Conclusion: Women meeting the physical activity recommendation (>150 MVPA min/week) during pregnancy have a lower risk of PPDS compared to women who are not active during pregnancy.

1. Introduction

Depression in the postpartum period has been identified as the most common complication of childbearing years (Poyatos-Leon et al., 2017), with an estimated prevalence of 10–20% in Western countries (Dennis and Hodnett, 2007; Falah-Hassani et al., 2015). Some women have continuation of depression that presented in pregnancy. For others it is of new onset. Women who experience perinatal complications or have a co-existing chronic disease have an even higher risk for postpartum depression (Turner et al., 2006)

The Diagnostic and Statistical Manual of Mental Disorders, (DSM-5-2013) (Association, 2013) does not define postpartum depression (PPD) as a specific diagnostic category, but does allow for the addition of a "peripartum onset specifier" if depression starts in pregnancy or within four weeks after delivery (Dennis and Hodnett, 2007; O'Hara and McCabe, 2013). Manifestation of PPD can be mild to severe, and it is

Abbreviations: PPD, postpartum depression; PPDS, postpartum depressive symptoms; SEP, socioeconomic position; MVPA, moderate-to-vigorous intensity physical activity; CHC, child health clinic; EPDS, Edinburgh Postnatal Depression Scale; SWA, Sense Wear™ Pro3 Armband; DAG, Directed Acyclic Graph; OR, odds ratio; CI, confidence interval; BDI, Beck Depression inventory; RCT, randomized controlled trial

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associated with impaired maternal psychological, emotional and cognitive functions (O'Hara and McCabe, 2013).

Furthermore, PPD may negatively affect the relationships among family members and the attachment between the baby and the mother, which may have long-term negative influence on the child (Stein et al., 2014; Grace et al., 2003; Hay et al., 2003,2001; Murray et al., 2011)

Immigrant women in Western European countries often face multiple challenges due to stressors related to migration, integration, poor housing conditions and racism (Karlsen and Nazroo, 2002; Wittkowski et al., 2016; Fung and Dennis, 2010). This makes them vulnerable to mental health problems like depression (Williams, 1999). Ethnic minority women in Western countries have higher prevalence of PPD compared to native Western European (Falah-Hassani et al., 2015). We have earlier reported higher rates of depressive symptoms in pregnancy among ethnic minorities compared to Western Europeans (Shakeel et al., 2015). Risk factors associated with depression in pregnancy in that study included a low level of socioeconomic position (SEP), previous history of depression, recent adverse life events and a low level of integration.

While it is well documented that physical activity outside pregnancy prevents depression (Mammen and Faulkner, 2013; FYSS 2015), evidence on preventive effects of physical activity in pregnancy on PPD and postpartum depressive symptoms (PPDS) is inconclusive (Songoygard et al., 2012; Ersek and Brunner Huber, 2009; Nordhagen and Sundgot-Borgen, 2002).

We identified only one RCT study designed to determine the effect of a supervised exercise program implemented in pregnancy; no protective effect against depressive symptoms was found three months after birth (Songoygard et al., 2012).

Mixed findings have been reported in observational studies based on self-reported physical activity (Ersek and Brunner Huber, 2009; Nordhagen and Sundgot-Borgen, 2002). A lower risk of depression was reported in women who were moderately physically active in the 3rd trimester compared to inactive women (Nordhagen and Sundgot-Borgen, 2002). In contrast, in a retrospective study, no significant association was observed between physical activity in pregnancy and EPDS score three months after birth (Ersek and Brunner Huber, 2009). The use of self-reported physical activity in these two latter studies makes the results prone to measurement error, and to subsequently biased estimates. In addition, the study samples in above-mentioned studies have limited external validity with respect to multi-ethnic populations.

In addition to established forms of treatment for depressive symptoms in the postpartum period, other potentially feasible and cost-effective strategies like physical activity during pregnancy may represent a complementary strategy to attenuate depressive symptoms and reduce reliance on pharmaceutical treatment (Saligheh et al., 2017; Brandlistuen et al., 2017). Currently, healthy pregnant and postpartum women are recommended to undertake a minimum of 150 min of moderate-to-vigorous intensity physical activity (MVPA) per week for health benefits (Norweigan directorate of halth, 2016).

Our primary aim was to investigate if higher levels of MVPA in pregnancy were associated with reduced risk of postpartum depressive symptoms, PPDS, overall and in a sub-sample of ethnic minority women, as we hypothesized that MVPA during pregnancy was inversely associated with risk of PPDS.

2. Method

2.1. Design, study population and setting

This study is part of the prospective STORK Groruddalen Cohort Study of healthy pregnant women, based on data collected at three public Child Health Clinics (CHC) in multi-ethnic city districts in Oslo between 2008 and 2011 (Jenum et al., 2010). Relevant information material such as invitation leaflets and questionnaires were translated from Norwegian into Arabic, English, Sorani, Somali, Tamil, Turkish, Urdu and Vietnamese and quality-checked by bilingual health professionals. Data were collected at three study visits (at inclusion in mean gestational week 15; in gestational week 28; and 3 months after birth). Demographic and health questionnaire data were collected during standardized interviews. Physical activity was objectively recorded.

Women were eligible for participation if they: (1) lived in one of the study districts; (2) planned to give birth at one of two study hospitals; (3) were <20 weeks gestation at inclusion; (4) could communicate in either of the nine questionnaire languages; and (5) were able to give informed written consent. Women known to have diabetes and/or other diseases necessitating intensive hospital follow-up during pregnancy were excluded. The inclusion rate was 74% (range 64–83% among ethnic groups), and the participating women were found to be representative of pregnant women in the largest ethnic groups attending the Child Health Clinics (Jenum et al., 2010, 2012). Informed consent was obtained from all individual participants included in the study.

2.2. Primary outcome variable – postpartum depressive symptoms

We measured postpartum depressive symptoms approximately three months after birth using the validated screening instrument The Edinburgh Postnatal Depression Scale (EPDS) (Cox et al., 1987; Murray and Carothers, 1990). EPDS contains ten items scored on a four-point ordinal scale, and it yields a sum score between 0 and 30. A high score indicates depression, but in clinical practice, we need a diagnostic interview to set the diagnosis depression. An EPDS score ≥ 10 was used as indicative of an increased depression risk herby called PPDS, as this cut-off point has been used previously in several epidemiological studies (Shakeel et al., 2015; Harris et al., 1989; Hewitt et al., 2009; Eberhard-Gran et al., 2001).

We used eight official translations of the EPDS (Norwegian, Arabic, English, Somali, Tamil, Turkish, Urdu and Vietnamese). In addition, we used a version in Sorani, translated by the City Services Department's Interpreting Service in Oslo, for this study. All except the Somalian and Sorani versions have been validated (Marshall, 2006).

2.3. Main exposure–objectively measured physical activity

We collected physical activity data objectively with the activity monitor Sense Wear™ Pro3 Armband (SWA) (Body Media Inc., Pittsburgh, Pennsylvania, USA) (Berntsen et al., 2011) in gestational week 28. The SWA is a multi-phasic monitor which incorporates information from accelerometers with data from sensors for heat flux, skin temperature and galvanic skin response (Shephard and Tudor-Locke, 2016). Women were asked to wear the SWA across the right triceps brachia over 4–7 days following the study visit, and remove it only if performing water activities. We downloaded raw physical activity data integrated into 60 s epochs with the manufacturer's software (Sense Wear™ Professional Research Software Version 6.1, Body Media Inc.). A valid SWA day was defined as ≥ 19.2 h of SWA wear time, and physical activity data from a single participant was deemed eligible if ≥ 2 valid SWA days were recorded (Herrmann et al., 2014).

SWA provides valid measures of energy expenditure during free-living activities during pregnancy (Berntsen et al., 2011).

MVPA was restricted to bouts ≥ 10 min at intensities ≥ 3 metabolic equivalents (METs) (1 MET = 3.5 O^2 kg^{-1} min^{-1}). MVPA in bouts were extracted with SQL Server Management Studio (Microsoft®) and SQL Server Express version 11.0.50580 (Microsoft®). MVPA was treated as an ordinal variable with four levels: (1) 0 min per week, (2) 1–74 min per week, (3) 75–149 min/week, and (4 ≥ 150 min/week. These categories were selected to ensure a certain number of cases in each activity group. We defined the most active group as women who accumulated ≥ 150 min to ensure that one group represented women who met the recommended level of MVPA.

2.4. Other potentially confounding variables

We defined ethnicity by the participant's country of birth, or her mother's country of birth if her mother was born outside Europe or North America. In analyses, ethnicity was treated as a binary variable (ethnic minority women and Western-European women) (Shakeel et al., 2015). Maternal age at inclusion was treated as a continuous variable.

Data on socioeconomic position (SEP) collected at inclusion were expressed as a component score (Crohnbach's $\alpha > 0.7$) extracted using principal components analysis (Sommer et al., 2013), reflecting educational level, occupational class, employment status, renting tenure and rooms per person in the household. Higher SEP scores reflected a higher socio-economic position. The SEP scores were normally distributed and treated as a continuous measure and binary variable.

Data on adverse life events were collected at visit 1 and 2, referring to the preceding six months at each visit. Items reflected seven events (serious illness of self; serious illness in close family; death in close family; divorce/separation; unemployment; major concern for children; other major adverse event) with the response options being “yes” and “no”. In analyses, the total number of events from visit 1 and 2 was treated as an ordinal variable (no events; one event; two or more events).

Depressive symptoms in index pregnancy was assessed using the EPDS tool at visit 2 (gestational week 28) and defined as EPDS score ≥ 10.

Information on history of depression was obtained postpartum using Kendler`s lifetime major depression scale, which assesses lifetime history of major depression based on the DSM-IV criteria. This five-item scale covers sadness, appetite changes, lack of energy, self-blame and concentration problems. The response categories were “yes” and “no”. Prior depression was defined as having had at least two simultaneously concurrent symptoms with duration of at least two weeks in addition to a sad mood (Kendler et al., 1993; Kjeldgaard et al., 2017).

Self-reported pelvic girdle syndrome (PGS), was identified as a possible confounder (Bjelland et al., 2013) and defined as having pain from both iliac-sacral joints and the pubic symphysis (Albert et al., 2001).

Parity, age at inclusion, marital status and educational level were used for descriptive purposes. Parity was categorized as nulliparous or multiparous, marital status was categorized as living with a partner or living without a partner and education was categorized into four categories: <10 years schooling, secondary level 10–12 years, up to 4 years of further education and University/College education.

2.5. Statistical analysis

Descriptive statistics are provided as mean (SD) and frequency (%) as appropriate. To compare groups, chi-square tests were used for categorical data and T-tests for continuous variables.

We used a Directed Acyclic Graph (DAG) (Fig. 1) in the model building process as a flowchart to visualize the causal network, linking MVPA and PPDS, and identify confounders (Hernan et al., 2002) that should be adjusted for to attain unbiased and more precise estimates (Foraita and Zeeb, 2014).

Thereafter, we performed multiple logistic regression analyses to explore the association between MVPA and PPDS. Due to the rule of degrees of freedom, the number of confounders we could adjust for was limited as the sample contains only 60 cases with PPDS. A reduction of confounders was performed as we fitted the model using the “purposeful selection” approach (Marit et al., 2012) in which non-significant cofactors were removed by backward selection if they did not change the value of the main estimate. In model 1, we adjusted for ethnicity, age, SEP, adverse life events, depressive symptoms in index pregnancy, self-reported pelvic girdle syndrome and sedentary time. The final model contained MVPA, ethnicity, depressive symptoms in index pregnancy and self-reported pelvic girdle syndrome.

Missing data on exposure or covariates were identified in data on MVPA, sedentary time, adverse life events, depressive symptoms in index pregnancy, self-reported pelvic girdle syndrome and history of depression (Table 1). Missing MVPA values were significantly predicted by non-Western ethnicity. Thus, the inclusion of ethnicity among the variables, the imputation model supported the plausibility of the missing at random assumption (Sterne et al., 2009). We included ethnicity, EPDS at visit 3 (outcome in analytic model), age, BMI in the imputation model and imputed the following variables**:** MVPA/sedentary time, SEP, adverse life events, depressive symptoms in index pregnancy, and pelvic girdle pain. We generated 25 imputed datasets to obtain pooled estimates of the overall measures of association (Sterne et al., 2009) using the automatic mode in SPSS. The imputed values were used in the primary multiple logistic regression analyses.

The analyses were repeated in a sub-sample of ethnic minority women in accordance with our aim. We also performed a sensitivity analysis on the total sample based on complete cases.

The statistical significance level was set to $p < 0.05$. SPSS version25 (IBM SPSS statistics, NY, USA) was used for all analyses.

2.6. Study sample

Our sample consisted of 643 women with a valid EPDS score from postpartum, 78% of the total sample of 823 included in the STORK Groruddalen study (Shakeel et al., 2015).

3. Results

3.1. Sample characteristics

In our sample, we had 60 cases (9.3%) with PPDS and 42% of the women were ethnic minorities. The mean age in the whole sample was 30 years, 54% were nulliparous, 37% had low SEP and 15% had less than 10 years education.

Among women who recorded no MVPA minutes/week in bouts >10 min, a larger proportion were multiparous, had ethnic minority background, lower socioeconomic position (SEP) and fewer had higher education at university and college level, compared to those with ≥ 150 MVPA minutes/week (Table 1). More women in the group with no MVPA minutes/week had depressive symptoms in index pregnancy and PPDS. The average age and number of adverse life events, however, were similar for both groups.

3.2. Association between physical activity and postpartum depression

In bivariate logistic regression analysis with imputed values, PPDS were associated with inactivity, measured as no MVPA minutes/week, ethnic minority background, adverse life events, low socioeconomic position, history of depression and depression in index pregnancy, but not with pelvic girdle pain (Table 2).

Further, we observed that women who met the physical activity recommendation (≥ 150 MVPA min/week) had a significantly lower risk of PPDS (OR = 0.2; 95% Confidence interval (CI): 0.06–0.63), (Table 3: unadjusted values). After adjustment for ethnicity, depressive symptoms in index pregnancy and self-reported pelvic girdle syndrome, the association remained significant (OR = 0.2; 95% CI: 0.06–0.90) (Table 3). Analyses based on complete cases yielded similar results (added as appendix, Table A4).

We then repeated the analyses in the subgroup of ethnic minority women only. Women who met the physical activity recommendation had a significantly lower risk of PPDS (OR: 0.2 see appendix, Table A5). Again, similar results were found in the analysis for complete cases (added as appendix, Table A6).

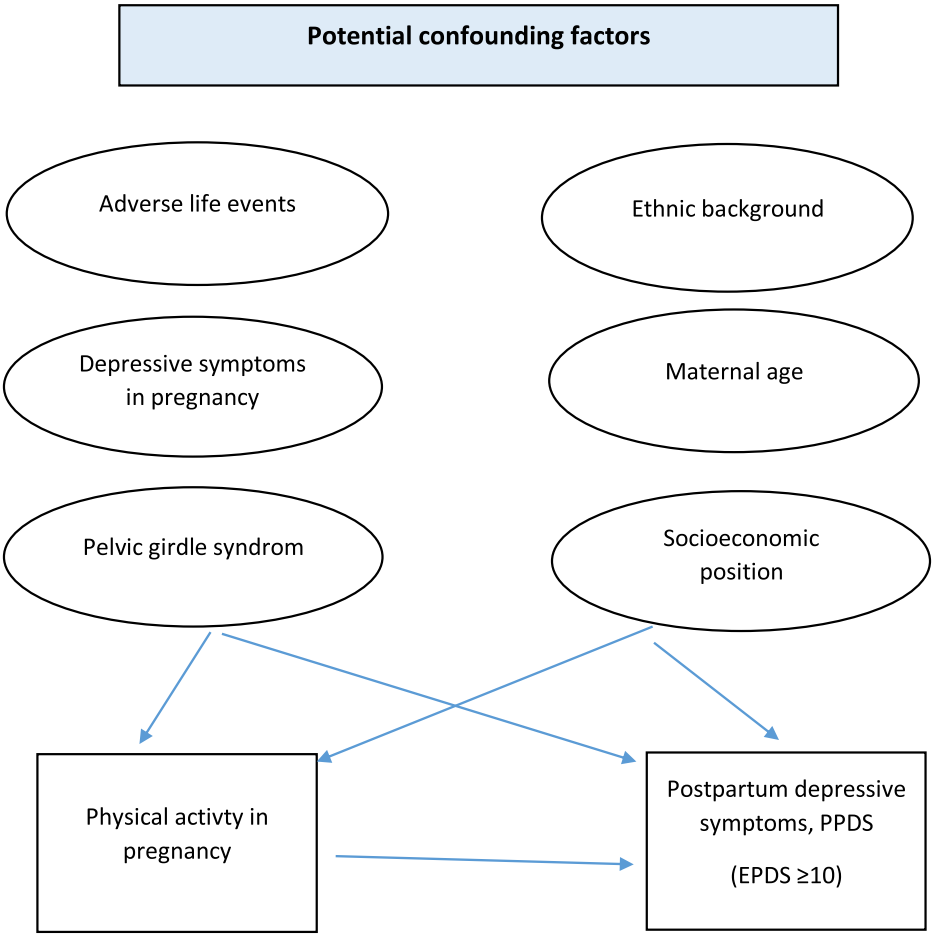

Fig. 1. Directed Acyclic Graph for the Association between physical activity in pregnancy and postpartum depressive symptoms, PPDS.

4. Discussion

To the best of our knowledge, this is the only study exploring the association between objectively recorded physical activity in pregnancy and PPDS in a multiethnic cohort. We observed that women who performed ≥150 min per week of moderate to vigorous physical activity in bouts ≥10 min had lower risk of PPDS, compared to those who did not accumulate any physical activity of at least moderate intensity. This finding was replicated in a sub-sample of ethnic minority women.

Very few studies have explored the relationship between physical activity in pregnancy and symptoms of depression after birth like us, and findings are contradictory (Songoygard et al., 2012; Ersek and Brunner Huber, 2009; Nordhagen and Sundgot-Borgen, 2002). Only one small study with high-income Caucasian women found an inverse association between physical activity and PPDS symptoms (Sexton et al., 2012).

In contrast to our study, one longitudinal prospective cohort study by Demisse et al. did not find any significant association between MVPA in pregnancy and PPDS in the full sample nor in analyses stratified by ethnicity (white, black and others) (Demissie et al., 2013).But this study used self-reported measures for physical activity which may have led to recall and social desirability biases. Further, the sample was self-selected and therefore not representative for the source population.

A review by Teychenne and York (2013) including cross sectional studies, randomized controlled trials (RCTs) and longitudinal cohort studies, reported that out of the ten high quality observational studies exploring the effect on PPDS, only four examined physical activity in pregnancy, all by self-reports. Timing of physical activity, measures and findings were inconsistent. This study concluded that physical activity in pregnancy is important for reducing the risk of postnatal depression.

Recently, two systematic reviews and meta-analyses addressing exercise both in pregnancy and postpartum and their association with both PPDS and postpartum depression respectively have been published (Poyatos-Leon et al., 2017; Pritchett et al., 2017). Poyatos-Leon et al. (2017) included 12 RCTs, showing that physical activity was associated with a lower incidence of depressive symptoms postpartum. However, in only two of these studies the exercise program started in pregnancy. For the rest of the studies, the physical activity programs for the intervention group were conducted only during the postpartum period. Generally, the quality of most of the studies included in this meta-analysis was low, with high risk of bias.

Pritchett et al. (2017) found 13 RCTs, and concluded that exercise might reduce depressive symptoms. However, all of these studies targeted women first in the postpartum period with interventions to promote physical activity. Six studies assessed the general postpartum population regardless of whether they had scored compatible with depression or not, while the other studies included postpartum women with high symptom scores on depression defined by different assessment tools (EPDS, diagnostic interviews using ICD-10/DSM-4 criteria and Beck depression inventory (BDI). A direct comparison with other studies is difficult as there is a dearth in the literature regarding studies exploring the same research question as ours.

However, we consider the dearth of studies of protective effects of physical activity during pregnancy makes our findings highly relevant.

Furthermore, only few of the studies carried out in Western Europe reported if ethnic minority women were included, but most included only women who spoke the majority language. None of the studies included translators, which indicate that those with insufficient host

Table 1
Sample Characteristics.

	Valid EPDS postpartum (n = 643), MVPA (n = 472)				
	0 min/week, n (%)	1–74 min/week, n (%)	75–149 min/week, n (%)	≥150 min/week, n (%)	Missing MVPA (n = 171), n (%)
[1]Postpartum depressive symptoms					
Yes	17 (14.9)	10 (7.4)	9 (9.4)	4(3.1)	20 (11.7)
No	97 (85.1)	125 (92.6)	87 (90.6)	123 (96.9)	151 (88.3)
Age at inclusion, mean (SD)	30 (5.04)	30.5 (4.78)	30 (4.68)	30 (4.56)	29 (4.82)
Parity					
Nulliparous	62 (54.4)	86 (63.7)	55 (57.3)	51 (40.2)	91 (53.2)
Parous	52 (45.6)	49 (36.3)	41 (42.7)	76(59.8)	80 (46.8)
Ethnicity					
Ethnic minority women	73 (64)	79 (58.5)	56 (58.3)	46 (36.2)	117 (68.4)
Western European women	41 (36)	56 (41.5)	40 (41.7)	81 (63.8)	54 (31.6)
Marital status					
Living without a partner	3 (2.6)	5 (3.7)	6 (6.3)	4 (3.1)	13 (7.6)
Living with a partner	111 (97.4)	130 (96.3)	90 (93.8)	123 (96.9)	158 (92.4)
[a]Educational level					
<10 years schooling	19 (16.7)	20 (14.9)	14 (14.6)	12 (9.4)	31 (18.1)
secondary level, 10–12 years	53 (46.5)	61 (45.5)	35 (36.5)	38 (29.9)	62 (36.3)
up to 4 years of further education	33 (28.9)	37 (27.6)	30 (31.3)	51 (40.2)	45 (26.3)
university/college	9 (7.9)	16 (11.9)	17 (17.7)	26 (20.5)	30 (17.5)
[2,b]Adverse life events					
0 event	47 (43.5)	72 (55.4)	43 (46.7)	63 (54.3)	83 (48.5)
1 event	32 (29.6)	26 (20)	29 (31.5)	27 (23.3)	36 (21.1)
2 ≥ events	29 (26.9)	32 (24.6)	20 (21.7)	26 (22.4)	37 (21.6)
Socioeconomic position score					
Lowest 40%	53 (46.5)	54 (40)	38 (39.6)	26 (20.5)	68 (39.8)
Highest 60%	61 (53.5)	81 (60)	58 (60.4)	101 (79.5)	103 (60.2)
[c]History of depression					
Yes	32 (28.6)	29 (21.5)	17 (17.7)	26 (20.6)	33 (19.3)
No	80 (71.4)	106 (78.5)	79 (82.3)	100 (79.4)	137 (80.1)
[3, d]Depressive symptoms in index pregnancy					
Yes	16 (14.3)	10 (7.5)	18 (19.1)	12 (9.5)	26 (15.2)
No	96 (85.7)	123 (92.5)	76 (80.9)	114 (90.5)	133 (77.8)
[4,e]Self-reported pelvic girdle syndrome					
Yes	23 (20.4)	32 (24.2)	24 (25.5)	14 (11.1)	39 (22.8)
No	90(79.6)	100 (75.8)	70 (74.5)	112 (88.9)	120 (70.2)

[1]EPDS ≥ 14 weeks postpartum [2] From inclusion to gestational week 28[3] EPDS ≥ 10 in gestational week 28[4] pain both ilio-sacral joints and the pubic symphysis.
[a]Missing n = 1, [b]Missing n = 26, [c]Missing n = 3, [d]Missing n = 7, [e]Missing n = 7.

language skills and those who are newly arrived to the host country most probably were excluded. Hence, the results are not generalizable to less integrated ethnic minority women. In contrast, in our study 58% of the Stork-Groruddalen Cohort was ethnic minority women, some of them had recently arrived in Norway and had limited command of the Norwegian language. Thus, the current cohort is more representative of current multi-ethnic populations in many European countries. A novel and important finding is the relative risk reduction associated with achieving ≥150 MVPA min/week in the sub-sample of ethnic minority women.

We do not know how the benefits of exercise are mediated. Generally, the effects of exercise on depression are widely known but poorly understood (Daley et al., 2007) and both psychological and neurobiological mechanisms are suggested. Relapse is common in depressive disorders, and continuous physical activity may be useful in the efforts to prevent future episodes. In general, a positive effect of exercise on depression may be long lasting.

4.1. Strengths and limitations

Our study has several strengths. This is a population-based prospective cohort study with a high attendance rate and a representative multi-ethnic sample. The prospective design reduced the likelihood of recall bias. We have succeeded in including illiterate and recently immigrated women by adapting the study methods to the needs of these women (Jenum et al., 2010). We used EPDS, which is a validated screening tool, with good agreement with the DSM IV criteria for major depression (100% sensitivity and 87% specificity) when using EPDS scores ≥10 as the cut-off (Harris et al., 1989; Eberhard-Gran et al., 2001). Furthermore, we used objectively recorded physical activity, which provides more valid estimates of habitual physical activity than self-report methods. The analytic models included potential confounders identified by a DAG, reducing the risk that the association between MVPA and PPDS is spurious.

Nevertheless, our study has some limitations. First, the cross-cultural validity of the EPDS is a concern. The expression of depression may differ according to cultural context; however, the EPDS has good psychometric properties when tested in different cultures (Marshall, 2006; Husain et al., 2011; Benjamin et al., 2005; Aydin et al., 2004; Berle et al., 2003). Different cut-off values have been suggested when EPDS is translated and validated into other languages (Marshall, 2006), and it is recommended that health care professionals review the summary of the research to best match the characteristics of their population. As we wanted to compare the symptom load in different ethnic groups in Europe living in the same residential area, we used the same cut-off level for all women.

Second, the physical activity monitor does not measure water activities. While the SWA provides valid measures of energy expenditure

Table 2
Characteristic of women with and without postpartum depression, Values are n (%) if not stated otherwise.

	Depression, N = 60 n(%)	No depression, N = 583 n(%)	P-value
[a]PA during pregnancy			
0 min a week	33 (56.9)	163 (31.8)	0.001
1–74 min a week	10 (17.3)	128 (25)	
75–149 min a week	10 (17.3))	91 (17.8)	
>150 min a week	5 (8.6)	130 (25.4)	
Ethnic minority women	47 (78.3)	324 (55.6)	<0.01
Western European women	13 (21.6)	259 (44.4)	
Age at inclusion, mean (SD)	28.8 (4.47)	30.0 (4.81)	0.07
Parity			
Nulliparous	27 (45)	271 (46.5)	0.83
parous	33 (55)	312 (53.5)	
[b]Marital status			
Living without a partner	4 (6.8)	30 (5.2)	0.61
Living with a partner	55(93.2)	549 (94.8)	
Educational level			
<10 years schooling	12 (20)	84 (14.5)	0.44
secondary level, 10–12 years	26 (43.3)	223 (38.5)	
up to 4 years of further education	15 (25)	181 (31.3)	
university/college	7 (11.7)	91 (15.7)	
[c]Adverse life events			
0 events	19 (33.9)	283 (53)	<0.001
1 event	11 (19.7)	136 (25.5)	
2 ≥ events	26 (46.4)	115 (21.5)	
Socioeconomic position score			<0.001
Lowest 40%	35 (58.3)	204 (35)	
Highest 60%	25 (41.7)	379 (65)	
dHistory of depression			<0.001
Yes	29(49.2)	108 (18.6)	
no	30 (50.8)	472 (81.4)	
[e]Depressive symptoms in index pregnancy			
Yes	23 (41.1)	59 (10.4)	<0.001
No	33 (58.9)	509 (89.6)	
fSelf-reported pelvic girdle syndrome			
Yes	16 (27.6)	116 (20.5)	0,208
No	42 (72.4)	450 (79.5)	

[a]Physical activity in gestational week28, [b]Exact fisher`s test used, [c]From inclusion to gestational week 28, [d]Data collected postpartum, [e]EPDS ≥ 10 in gestational week 28, [f]pain both ilio-sacral joints and the pubic symphysis.

Table 3
Odds Ratios (OR) for postpartum depressive symptoms in unadjusted and adjusted multiple regression analysis.

	Unadjusted values		Adjusted values[b]	
	OR	95% CI	OR	95% CI
[a] MVPA late pregnancy, 0 min a week = ref.				
1–74 min	0.5	0.23–1.01	0.5	0.21–1.32
75–149 min	0.5	0.24–1.18	0.5	0.21–1.35
≥150 min	0.2	0.06–0.63	0.2	0.06–0.90

[a] Objectively measured mean to vigorous physical activity in gestational week 28.
[b] Adjusted for ethnicity, depressive symptoms EPDS ≥ 10 in gestational week 28 and self-reported pelvic girdle syndrome in gestational week 28.

during pregnancy for a range of physical activity types, the validity during bicycling during pregnancy is unclear (Berntsen et al., 2011). Unpublished data from our study has shown that very few women were bicycling or participating in water activities during pregnancy. Third, participants' physical activity level may have increased because of wearing the armband; hence, the physical activity estimates may not reflect the true habitual level of physical activity during pregnancy.

Forth, a slight selection bias cannot be ruled out as women with higher SEP, more education and more time spent living with their partner participated compared to those who did not re-attend after their first or second visit. This is often the case in cohort studies with longer follow-up-times. Fifth, although power is limited and we primarily report results based on multiple imputations due to missing, complete cases gave similar results. Lastly, we cannot rule out unmeasured or residual confounding, and cultural factors and traditions may play a role.

4.2. Implications for practice and research

More awareness is needed among health personnel in antenatal and postnatal care about women at risk for PPDS, and more knowledge about the usefulness of physical activity to reduce the risk of PPDS is warranted among clinicians. The beliefs about physical activity and health in different cultures vary (Marshall, 2006), and in some groups, rest after birth is considered to be beneficial to health (Eberhard-Gran et al., 2010). Hence, culture sensitive preventive measures should contain information on the potential of regular physical activity to reduce PPDS, and strategies for facilitation of more physical activity during pregnancy in vulnerable groups. Nevertheless, there is still a lack of high quality RCT studies using objectively recorded physical activity in pregnancy to determine the effect on PPDS.

5. Conclusion

The study suggests that physical activity in late pregnancy may reduce the risk of PPDS. Importantly, the risk reduction was also seen in ethnic minority women.

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Appendix

Table A4
Odds Ratios (OR) for postpartum depressive symptoms in unadjusted and adjusted multiple regression analysis. Complete cases.

	Unadjusted values		Adjusted values[b]	
	OR	95% CI	OR	95% CI
[a] MVPA late pregnancy, 0 min a week = ref.				
1–74 min	0.5	0.20–1.04	0.6	0.26–1.56
75–149 min	0.6	0.25–1.49	0.6	0.21–1.42
≥ 150 min	0.2	0.06–0.57	0.3	0.08–0.88

[a] Objectively measured mean to vigorous physical activity in gestational week 28.
[b] Adjusted for ethnicity, depressive symptoms EPDS ≥ 10 in gestational week 28 and self-reported pelvic girdle syndrome in pregnancy week 28.

Table A5
Ethnic minorities only. Imputed values with postpartum depressive symptoms, PPDS 3 months after birth, PPDS defined as EPDS ≥10 Unadjusted and adjusted values.

	Unadjusted values			[a]Adjusted values		
	OR	95% CI	P-value	OR	95% CI	P-value
MVPA late pregnancy, 0 min a week = ref						
1–74 min	0.4	0.20–0.94	0.034	0.5	0.22–1.17	0.106
75–149 min	0.6	0.25–1.32	0.187	0.5	0.18–1.13	0.089
≥ 150 min	0.2	0.06–0.55	0.002	0.2	0.06–0.59	0.004

[a] Adjusted for depressive symptoms in index pregnancy and self-reprted pelvic girdle syndrom, PGS.

Table A6
Ethnic minorities only. Complete case analysis with postpartum depressive symptoms, PPDS 3 months after birth, PPDS defined as EPDS ≥ 10 Unadjusted and adjusted values.

	Unadjusted values			[a]Adjusted values		
	OR	95% CI	P-value	OR	95% CI	P-value
MVPA late pregnancy, 0 min a week = ref						
1–74 min	0.4	0.15–0.98	0.046	0.5	0.18–1.35	0.167
75–149 min	0.6	0.21–1.47	0.233	0.5	0.19–1.50	0.229
≥150 min	0.09	0.01–0.68	0.020	0.1	0.01–0.82	0.031

[a] Adjusted for depressive symptoms in index pregnancy and self-reprted pelvic girdle syndrom, PGS.

Authors' contributions

NS and KRR performed the statistical analysis (except the PCA analyses). NS wrote the first draft- KRR made the figure and did the multiple imputation analysis. KRR also helped revising the first draft of the paper. LS contributed with the data acquisition and performed the PCA analyses on socio-economic and integration variables, ME-G, KS, and EWM contributed with expert knowledge about the EPDS and other instruments to capture depression. AKJ initiated and was the project leader of the STORK Groruddalen study. All authors contributed to the interpretation of data, revised the manuscript critically, checked for clarity and content, and approved the final version.

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Ethics approval and consent to participate

The study was approved by The Regional Committee for Medical and Health Research Ethics for South Eastern Norway (reference number: 2007.894) and The Norwegian Data Inspectorate. All participants gave their written informed consent.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jad.2018.04.081.

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