Leisure-Time Physical Activity in Pregnancy and Risk of Postpartum Depression: A Prospective Study in a Large National Birth Cohort

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Objective: To explore the association between physical activity during pregnancy and postpartum depression (PPD) in a large, prospective cohort.

Method: Exposure information from the Danish National Birth Cohort, a large, prospective cohort with information on more than 100,000 pregnancies (1996–2002), was linked to the Danish Psychiatric Central Register and the Danish Register for Medicinal Product Statistics for data on clinically identified cases of depression up to 1 year postpartum. A total of 70,866 women from the Danish National Birth Cohort were included in the analyses. Duration, frequency, and type of physical activity were assessed by a telephone interview at approximately week 12 of gestation. Admission to hospital due to depression (PPD-admission) and prescription of an antidepressant (PPD-prescription) were treated as separate outcomes.

Results: Through linkage to national registers, we identified 157 cases of PPD-admission and 1,305 cases of PPD-prescription. Women engaging in vigorous physical activity during pregnancy had a lower risk of PPD-prescription compared to women who were not physically active (adjusted odds ratio, 0.81; 95% CI, 0.66–0.99). No association was observed between physical activity and PPD-admission; but, in women who were underweight prior to pregnancy, physical activity was associated with increased risk of PPD-admission.

Conclusions: Our data are compatible with a protective effect of vigorous physical activity, but not for other measures of physical activity, against postpartum depression requiring antidepressant therapy. No protective effect could be detected on PPD leading to hospitalization.

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Depression is an illness of serious public health concern, estimated by the World Health Organization to account for 4.4% of the global burden of disease.[1] Depression in the postpartum period is of particular interest, since it may damage the relationship between mother and child during a period of extraordinary vulnerability, with both short- and long-term consequences.[2–4]

The term *postpartum depression* (PPD) refers to a depressive episode that begins in or extends into the postpartum period[5]; the condition has been estimated to afflict 5% to 15% of all childbearing women.[6,7] There is little evidence that physiologic changes connected to pregnancy and childbirth are the basis for the disorder,[2] and there is some dispute as to whether PPD is a specific psychiatric entity. Some studies have found the incidence of depression postpartum to be the same as in other life periods,[8,9] while others find the rate of onset of depression to be elevated following childbirth.[5,10]

Several studies have shown past psychopathology and low social support to be strongly associated with PPD, while modifiable behavioral factors have not received similar attention. In nonpregnant populations, one such modifiable behavioral factor, physical activity, has been shown to be inversely associated with depression.[11–13] Although findings have not been consistent,[14,15] there seems to be a broad consensus that physical activity is advantageous for general well-being. The purpose of this study was to investigate the association between physical activity during pregnancy and PPD in the Danish National Birth Cohort.

METHOD

The Danish National Birth Cohort is a nationwide study covering 101,046 pregnancies and with more than 90,000 women enlisted. All pregnant women living in Denmark between 1996 and 2002 and fluent in Danish were eligible for recruitment, which took place at the first antenatal visit to the general practitioner, (at roughly weeks 6–10 of gestation). In short, the data collection comprised a recruitment form at inclusion and 4 computer-assisted telephone interviews lasting 10 to 15 minutes, administered at weeks 12 and 30 of gestation and when the child was 6 and 18 months

old, roughly. The rate of participation among women who were invited to the study was 60%, and it has been estimated that 35% of all eligible pregnant women entered the cohort, which is described in detail elsewhere.[16,17]

In this study, we primarily used data from the recruitment form and the telephone interview conducted in gestation week 12. Information on admissions to hospital and prescriptions for antidepressants were obtained from the Danish Psychiatric Central Register, which includes all admissions to psychiatric hospitals and to psychiatric wards in general hospitals,[18] and the Register of Medicinal Product Statistics, which contains information on all medicinal products sold by prescription in Denmark.

Measures of Physical Activity

Detailed information on leisure-time physical activity (hereafter referred to as *physical activity*) was obtained from the telephone interview. The women were asked, "Now that you are pregnant, do you engage in any kind of exercise?" and, if they responded positively to this question, they were asked about type, frequency, and duration of each activity session. Answers on type of activity were classified in the following predefined categories: special gymnastics/aerobics for pregnant women, aerobics/gymnastics, dancing, cycling, fast walking, jogging/orienteering, ball games, swimming, use of fitness/health centers, badminton, tennis, horseback riding, and "other" (a text variable for any activities not covered by the predefined types of activity). Women were asked to report walking and bicycling for transport if it made them sweaty and short of breath.

With the purpose of exploring different dimensions of physical activity, we defined 4 different measures of physical activity in our analytic approach based on the information described above.

First, in order to test whether there was an effect of any versus no physical activity on PPD, we categorized women according to the general question on physical activity.

Second, we defined 6 groups according to total time of physical activity to investigate whether increasing duration, regardless of the other dimensions of physical activity, was associated with decreasing risk of PPD.

Third, we categorized women according to the intensity of their physical activity to investigate whether engagement in higher intensity physical activity had an effect on PPD, regardless of duration of activity. Here we made use of the concept of metabolic equivalents (METs [$kcal \cdot kg^{-1}$ body $weight \cdot hour^{-1}$]), which allows the classification of types of physical activity by rate of energy expenditure. The MET score of a specific type of activity is defined as the ratio between a person's metabolic rate when engaged in that specific activity and the resting metabolic rate. Metabolic equivalent scores range from 0.9 (sleeping) to 18 (running at 10.9 mph).[19] The applied MET scores were our estimation based on the compendium by Ainsworth et al.[20] We defined *vigorously active women* as those reporting at least 25% of their total time in physical activity to be spent in activity of a higher intensity (> 6 METs) and *moderately active women* as those who spent less than 25% of their total physical-activity time in high intensity activity.

Fourth, we investigated whether energy expenditure in physical activity was associated with PPD. Intensity, duration, and frequency of physical activity were combined into 1 measure of physical activity. For each woman, we calculated total MET hours/week by summing the activity-specific products of MET score and duration (h/wk) over all activities reported. Total MET h/wk were divided into quartiles.

Outcome Measures

Women who were admitted to psychiatric hospitals and psychiatric wards due to depression were identified using the Danish Psychiatric Central Register. A case of *PPD-admission* was defined as a person admitted to a hospital or an outpatient contact with a diagnosis of a depressive episode (*International Classification of Diseases, Tenth Revision* [*ICD-10*], codes F320–F329). Information on antidepressants purchased with a prescription in a pharmacy was obtained from the Register of Medicinal Product Statistics. A case of *PPD-prescription* was defined as a person who filled a prescription for antidepressant medication (Anatomical Therapeutic Chemical Classification System code beginning with N06A).[21] Information on first admission and first prescription during a period of 1 year following childbirth was used to account for cases of PPD-admission and PPD-prescription, respectively.

Covariates Used for Analyses and Supplementary Analyses

Previous studies of PPD have identified several risk factors for the disease; based on these, we identified a priori and included as covariates age, parity, pre-pregnancy body mass index, alcohol intake during pregnancy, smoking during pregnancy, occupation, level of attained education, home ownership, marital status, and social support (a measure combining information on whether the woman has anyone besides a partner to talk with in confidentiality, whether she has help with practical matters, whether she has help economically, and the frequency of contact with family members). We also included history of previous depression as a covariate; this measure was obtained by combining data from the telephone interview, the Danish Psychiatric Central Register, and the Register of Medicinal Product Statistics. A woman was considered to have a history of previous depression if she (1) stated in the interview that she had previously suffered from depression, (2) had been admitted to hospital with a diagnosis of depression before, or (3) had previously filled a prescription for antidepressant medication.

For supplementary analyses, we constructed 2 measures of physical activity based on information from both

Table 1. Distribution of Participants, ORs for PPD-Admission,[a] and ORs for PPD-Prescription[b] by Measures of Physical Activity in Gestation Week 12 (N = 70,866)

			PPD-Admission					PPD-Prescription				
			No. of	Crude		Adjusted[d]		No. of	Crude		Adjusted[d]	
Measure	N	%[c]	Cases	OR	95% CI	OR	95% CI	Cases	OR	95% CI	OR	95% CI
Physical activity												
Not physically active	44,372	62.6	98	Reference	…	Reference	…	886	Reference	…	Reference	…
Active	26,494	37.4	59	1.01	0.73–1.39	1.10	0.79–1.53	419	0.79	0.70–0.89	0.90	0.79–1.02
Intensity												
Not physically active	44,372	62.6	98	Reference	…	Reference	…	886	Reference	…	Reference	…
Moderately active[e]	17,466	24.7	43	1.12	0.78–1.60	1.20	0.83–1.72	297	0.85	0.74–0.97	0.94	0.82–1.08
Vigorously active[f]	9,028	12.7	16	0.80	0.47–1.36	0.88	0.52–1.52	122	0.67	0.56–0.81	0.81	0.66–0.99
Duration (h/wk)												
Not physically active	44,372	62.6	98	Reference	…	Reference	…	886	Reference	…	Reference	…
0–1	5,091	7.2	12	1.07	0.59–1.95	1.19	0.65–2.17	84	0.82	0.66–1.03	0.93	0.73–1.17
>1–2	9,425	13.3	20	0.96	0.59–1.56	1.09	0.67–1.77	145	0.77	0.64–0.92	0.92	0.77–1.11
>2–3	5,023	7.1	8	0.72	0.35–1.48	0.78	0.38–1.62	66	0.65	0.51–0.84	0.75	0.58–0.98
>3–5	4,412	6.2	10	1.03	0.54–1.97	1.07	0.56–2.07	73	0.83	0.65–1.05	0.91	0.71–1.18
>5	2,543	3.6	9	1.61	0.81–3.18	1.54	0.77–3.07	51	1.00	0.76–1.34	0.98	0.73–1.32
MET score (MET h/wk)												
Not physically active	44,372	62.6	98	Reference	…	Reference	…	886	Reference	…	Reference	…
0–5	6,771	9.6	16	1.07	0.63–1.82	1.22	0.71–2.07	104	0.77	0.62–0.94	0.87	0.70–1.08
>5–8	6,475	9.1	14	0.98	0.56–1.72	1.09	0.62–1.92	104	0.80	0.65–0.98	0.97	0.79–1.21
>8–15	6,835	9.6	11	0.73	0.39–1.36	0.78	0.41–1.46	97	0.71	0.57–0.87	0.79	0.63–0.99
>15	6,413	9.1	18	1.27	0.77–2.10	1.31	0.79–2.19	114	0.89	0.73–1.08	0.97	0.79–1.19

[a]A person admitted to a hospital or an outpatient contact with a diagnosis of a depressive episode (*ICD-10*, codes F320–F329).
[b]A person who filled a prescription for antidepressant medication (Anatomical Therapeutic Chemical Classification System code beginning with N06A).
[c]Percentage within variable.
[d]Adjusted for maternal age, parity, pre-pregnant body mass index, alcohol intake, smoking, occupation, education, home ownership, marital status, social support, and history of previous depression.
[e]*Moderately active* defined as reporting less than 25% of total time in physical activity to be vigorous activity.
[f]*Vigorously active* defined as reporting at least 25% of total time in physical activity to be vigorous activity.
Abbreviations: MET = metabolic equivalent, OR = odds ratio, PPD = postpartum depression.

pregnancy interviews; first, we categorized women as not physically active at weeks 12 and 30, physically active at weeks 12 and 30, or changed activity level during pregnancy. Second, women were categorized in the same way according to intensity of physical activity at weeks 12 and 30. Furthermore, for supplementary analyses, we used information on work-related physical activity (whether the woman reported her job to be "sedentary/varying at own wish" or whether she had to "walk/stand for the most part") and self-reported eating disorders.

Statistical Methods

The Danish National Birth Cohort enrolled 91,827 women, with some women contributing more than 1 pregnancy. We used data from the first singleton pregnancy each woman contributed to the cohort, yielding a study population of 85,338 women. Of these, 89% participated in the first telephone interview in first or second trimester; 92% of respondents had nonmissing values for all covariates included in the analyses. Thus, data from 70,866 women were included in our analyses. Logistic regression was used to model risk of PPD-admission and PPD-prescription. Risk estimates are expressed as odds ratios (ORs) with 95% confidence intervals (CIs). Chi square tests were used to test bivariate associations. The 4 measures of exposure were treated as categorical variables, and all covariates were included in the adjusted model. We used SAS software, version 9.1 (SAS Institute Inc, Cary, North Carolina) for all statistical analyses.

RESULTS

During pregnancy, 37% of participants reported engaging in some type of physical activity (Table 1). Of the active women, approximately one-third were vigorously active, and less than 4% reported duration of physical activity of more than 5 hours/wk. The most frequently reported activities were swimming, cycling, aerobics, and walking (data not shown). The number of cases of PPD-admission was 157 (0.2%), and there were 1,305 cases of PPD-prescription (1.8%).

Table 2 shows associations of selected maternal characteristics with physical activity, PPD-admission, and PPD-prescription. Being physically active was strongly associated with all the demographic, socioeconomic, and behavioral characteristics shown in Table 2. For both PPD-admissions and PPD-prescriptions, there were more cases among single women, smokers, women with poor social support, and women of low socioeconomic status. Furthermore, there were more cases of PPD-prescription among underweight and overweight women; PPD-prescription was most frequent in the oldest age group, whereas PPD-admission was most frequent among young women.

Table 2. Participants Distributed by Maternal Characteristics According to Any Physical Activity in Gestation Week 12, PPD-Admission and PPD-Prescription (N = 70,866)

	Total		Physical Activity			PPD-Admission			PPD-Prescriptions		
Characteristic	N	%[a]	No. Active	%[b]	*P* Value[c]	No. Cases	%[b]	*P* Value[c]	No. Cases	%[b]	*P* Value[c]
Maternal age, y											
< 25	6,906	10	2,406	35	< .001	41	0.6	< .001	148	2.1	.01
25–35	53,677	75	20,642	38		146	0.3		941	1.8	
> 35–40	9,209	13	3,080	33		25	0.3		188	2.0	
> 40	1,074	2	366	34		3	0.3		28	2.6	
Parity											
Nulliparous	35,042	49	15,756	45	< .001	115	0.3	.24	615	1.8	.09
Parous	35,824	51	10,738	30		100	0.3		690	1.9	
Marital status											
Single	1,434	2	500	35	.05	10	0.7	< .01	64	4.5	< .001
Cohabiting	69,432	98	25,994	37		205	0.3		1,241	1.8	
Smoking											
Nonsmoker	51,786	73	20,730	40	< .001	127	0.3	< .001	730	1.4	< .001
Occasional smoker	9,300	13	3,379	36		41	0.4		230	2.5	
Daily smoker	9,780	14	2,385	24		47	0.5		345	3.5	
Alcohol intake											
≤ 1 drink/wk	54,973	78	20,048	36	< .001	172	0.3	.39	1,028	1.9	.29
> 1 drink/wk	15,893	22	6,446	41		43	0.3		277	1.7	
Pre-pregnant body mass index											
< 18.5	3,170	4	1,020	32	< .001	9	0.3	.51	68	2.2	.03
18.5–25	48,119	68	18,752	39		139	0.3		842	1.8	
> 25	19,577	28	6,722	34		67	0.3		395	2.0	
Occupation											
White-collar worker	26,203	37	10,964	42	< .001	47	0.2	< .001	346	1.3	< .001
Skilled worker	13,267	19	4,710	36		31	0.2		189	1.4	
Unskilled worker	15,694	22	4,884	31		47	0.6		191	2.4	
Students	8,080	11	3,569	44		41	0.3		272	1.7	
Unemployed	7,622	11	2,367	31		49	0.6		307	4.0	
Education											
> 4 years post secondary	5,268	7	2,334	44	< .001	12	0.2	< .001	62	1.2	< .001
2–3 years post secondary	20,179	29	8,544	42		48	0.2		305	1.5	
Vocational training	25,024	35	8,391	34		72	0.3		475	1.9	
High school	10,532	15	4,555	43		25	0.2		141	1.3	
< 10 years of school	9,863	14	2,670	27		58	0.6		322	3.3	
Home ownership											
Home owner	50,497	71	18,338	36	< .001	126	0.3	< .001	864	1.7	< .001
Renter	20,369	29	8,156	40		89	0.4		441	2.2	
Social support											
Good	61,654	87	23,667	38	< .001	172	0.3	< .01	1,056	1.7	< .001
Poor	9,212	13	2,827	31		43	0.5		249	2.7	
History of previous depression											
No	67,245	95	25,271	38	< .001	120	0.2	< .001	691	1.0	< .001
Yes	3,621	5	1,223	34		37	1.0		614	17.0	

[a]Percentage (columns) of women distributed by covariate.
[b]Percentage (rows) of active/cases within level of variable.
[c]Chi square test for overall differences between active/not active, cases/noncases.

Table 1 shows crude and adjusted ORs for PPD-admission and PPD-prescription, with women reporting no physical activity as the reference group. Overall, there was no effect of physical activity on risk of PPD-admission. Vigorously active women had a 12% lower risk of PPD-admission, and women exercising more than 5 hours/wk had a 50% higher risk of PPD-admission, but neither of these findings was statistically significant.

Regarding PPD-prescription, we found that physically active women had a lower risk of PPD-prescription, with an OR of 0.79 (95% CI, 0.70–0.89); however, this association was attenuated after adjustment for covariates (OR, 0.90; 95% CI, 0.79–1.02). Vigorously active women had a decreased risk of PPD-prescription, with an adjusted OR of 0.81 (95% CI, 0.66–0.99). Furthermore, women exercising 2 to 3 hours/wk had a 25% decreased risk of PPD-prescription compared to women who were not physically active, just as physical activity corresponding to 8 to 15 MET h/wk was associated with a 20% lower risk of PPD-prescription, whereas ORs for the other groups ranged from 0.87 to 0.97 with confidence intervals containing unity.

In supplementary analyses, we found that underweight women were at higher risk of PPD-admission if they reported any physical activity (adjusted OR, 8.69; 95% CI, 1.37–55.28). Risks were similarly elevated for measures of physical activity based on duration, intensity, and METs (Table 3). Including a history of previous eating disorders as a covariate in the analyses did not attenuate the higher

Table 3. Adjusted[a] OR for PPD-Admission and PPD-Prescription by Measures of Physical Activity in Gestation Week Stratified by Pre-Pregnant Body Mass Index

	PPD-Admission						PPD-Prescription					
	Underweight		Normal Weight		Overweight		Underweight		Normal Weight		Overweight	
Measure	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Physical activity												
Not physically active	Reference	…	Reference	…	Reference	…	Reference	…	Reference	…	Reference	…
Active	8.69	1.37–55.28	0.93	0.62–1.42	1.22	0.67–2.22	1.03	0.58–1.82	0.90	0.77–1.05	0.88	0.69–1.10
Intensity												
Not physically active	Reference	…	Reference	…	Reference	…	Reference	…	Reference	…	Reference	…
Moderately active[b]	8.12	1.17–56.40	1.03	0.65–1.63	1.33	0.69–2.57	0.90	0.48–1.72	0.95	0.80–1.13	0.92	0.71–1.20
Vigorously active[c]	11.37	0.73–176.63	0.74	0.37–1.46	1.00	0.38–2.61	1.52	0.61–3.83	0.79	0.62–1.01	0.78	0.54–1.14
Duration (h/wk)												
Not physically active	Reference	…	Reference	…	Reference	…	Reference	…	Reference	…	Reference	…
0–1	50.96	4.01–648.46	0.97	0.44–2.14	1.00	0.30–3.32	0.90	0.29–2.74	0.93	0.69–1.24	0.94	0.61–1.45
>1–2	NA[d]	NA[d]	1.06	0.59–1.90	1.10	0.45–2.66	1.83	0.83–4.03	0.92	0.74–1.16	0.83	0.58–1.18
>2–3	NA[d]	NA[d]	0.79	0.34–1.83	0.78	0.18–3.29	0.41	0.09–1.81	0.80	0.58–1.08	0.72	0.43–1.21
>3–5	16.01	0.9–284.41	0.70	0.28–1.77	1.72	0.60–4.95	0.60	0.14–2.64	0.92	0.68–1.25	0.96	0.60–1.54
>5	59.21	NA[d]	1.11	0.44–2.78	2.05	0.61–6.92	1.34	0.43–4.20	0.94	0.65–1.36	1.04	0.58–1.84
MET score (MET h/wk)												
Not physically active	Reference	…	Reference	…	Reference	…	Reference	…	Reference	…	Reference	…
0–5	16.88	1.03–278.13	0.86	0.41–1.81	1.79	0.78–4.11	0.90	0.33–2.46	0.90	0.69–1.16	0.79	0.53–1.19
>5–8	11.68	0.70–195.29	1.32	0.71–2.48	0.26	0.04–1.90	1.91	0.79–4.66	0.95	0.73–1.24	0.92	0.62–1.37
>8–15	NA[d]	NA[d]	0.76	0.36–1.59	0.79	0.24–2.60	0.53	0.16–1.82	0.83	0.63–1.07	0.75	0.49–1.14
>15	30.27	2.63–347.73	0.84	0.41–1.71	2.20	0.95–5.07	1.08	0.42–2.73	0.94	0.73–1.21	1.08	0.72–1.60

[a]Adjusted for maternal age, parity, alcohol intake, smoking, occupation, education, home ownership, marital status, social support, and history of previous depression.
[b]*Moderately active* defined as reporting less than 25% of total time in physical activity.
[c]*Vigorously active* defined as reporting at least 25% of total time in physical activity.
[d]Effect measure could not be estimated due to small numbers.
Abbreviations: OR = odds ratio, MET = metabolic equivalent, NA = not available, PPD = postpartum depression.

risk of PPD-admission among underweight women who were physically active (data not shown). For women who maintained the same level of activity at gestation weeks 12 and 30, findings were similar to the main analysis; indeed, women who were vigorously active at both measurements had a lower risk of PPD-prescription compared to the main analysis (adjusted OR, 0.67; 95% CI, 0.48–0.93) (Table 4). Stratifying by work-related physical activity did not alter the findings of the main analysis (data not shown).

DISCUSSION

Principal Findings

In this large cohort of Danish women, one-third of the study participants reported engaging in physical activity at 12 weeks' gestation. Being physically active did not reduce the risk of being admitted to a hospital due to depression in the first year following childbirth; indeed, in underweight women, physical activity appeared to be a strong risk factor for hospitalization due to depression in the postpartum period. Women who were vigorously active had a 20% lower risk of being prescribed an antidepressant within 1 year postpartum compared with women who were not physically active.

Comparison With Existing Data

This study is, to our knowledge, the first prospective cohort study to address the association between physical activity and PPD on a large scale. A recent review of 11 randomized controlled trials found a beneficial effect of physical activity on depression,[22] and another found physical activity to have a positive effect on mild to moderate depression in general populations.[23] However, a third review concluded that, due to lack of good quality research, the effectiveness of exercise in reducing symptoms of depression could not be determined.[24]

Two randomized controlled trials have examined therapeutic effects of physical activity on depression in the postpartum period: in the first, walks 3 times a week were combined with a social support group and compared to standard care; in the second, walks 3 times a week were compared with a social support group. Both studies showed significantly lower levels of depressive symptomatology in the intervention group compared to the control group.[25,26]

Table 4. Distribution of Participants, OR for PPD-Admission, and OR for PPD-Prescription by Measures of Physical Activity in Gestation Weeks 12 and 30 Combined (N = 70,866)

			PPD-Admission					PPD-Prescription				
			No. of	Crude		Adjusted[b]		No. of	Crude		Adjusted[b]	
Measure	N	%[a]	Cases	OR	95% CI	OR	95% CI	Cases	OR	95% CI	OR	95% CI
Physical activity, weeks 12 and 30												
Not physically active	33,802	48	75	Reference	…	Reference	…	680	Reference	…	Reference	…
Active	12,536	18	23	0.83	0.52–1.32	0.92	0.57–1.49	177	0.70	0.59–0.82	0.84	0.71–1.01
Changed activity level, weeks 12–30	24,528	35	59	1.08	0.77–1.53	1.09	0.77–1.54	448	0.91	0.80–1.02	0.94	0.82–1.06
Intensity, weeks 12 and 30												
Not physically active	33,802	48	75	Reference	…	Reference	…	680	Reference	…	Reference	…
Moderately active[c]	5,591	8	16	1.29	0.75–2.22	1.43	0.82–2.48	84	0.74	0.59–0.93	0.86	0.68–1.10
Vigorously active[d]	3,700	5	3	0.37	0.12–1.16	0.41	0.13–1.31	41	0.55	0.40–0.75	0.67	0.48–0.93
Changed activity level, weeks 12–30	27,773	39	63	1.02	0.73–1.43	1.04	0.74–1.46	500	0.89	0.80–1.00	0.94	0.83–1.07

[a]Percentage within variable.
[b]Adjusted for maternal age, parity, pre-pregnant body mass index, alcohol intake, smoking, occupation, education, home ownership, marital status, social support, and history of previous depression.
[c]*Moderately active* defined as reporting less than 25% of total time in physical activity as vigorous activity.
[d]*Vigorously active* defined as reporting at least 25% of total time in physical activity as vigorous activity.
Abbreviations: OR = odds ratio, PPD = postpartum depression.

In a controlled trial, women suffering from PPD were allocated alternately into an experimental group doing 3 group sessions of gentle stretching exercises a week or a control group receiving standard care, and a beneficial effect was found for the experimental group.[27] It is, however, difficult to separate any effects of physical activity from the psychological or social effect of being in the intervention group in the trials mentioned here.

Strengths and Limitations

Major strengths of this study include its prospective design, size, and the utilization of unique Danish national registers.

However, the use of register data on antidepressants as a measure of PPD implies that cases of PPD-prescription in this study do not necessarily fulfill the *DSM-IV* diagnostic criteria for PPD. A further limitation of this outcome measure might be that this type of medication can be prescribed on indications other than depression. However, in Denmark, antidepressants can be obtained only by a prescription from a medical doctor, and regulation and surveillance of the use of medication is quite strict. All prescriptions are kept in a central registry and can be linked to the relevant physician and patient for relevant authorities to check in accordance with official guidelines.

Another limitation inherent in the study is the intrinsic difficulty in accurately assessing something as complex as physical activity in an observational setting, particularly in a study population of the present size. We focused on activity in leisure time since this may be more modifiable than work-related physical activity and, as such, a more obvious target for disease prevention. The questions on physical activity were similar to those used in other studies of pregnant women[28] and were modified from the Minnesota Leisure-Time Physical Activity Questionnaire.[29] In the telephone interview, women were asked about physical activity in the period prior to the interview, and we therefore believe that there is relatively little error due to poor recall. We also believe the woman's reporting on physical activity in gestation week 12 was a reasonable representation of her habitual level of physical activity, although activity levels have been shown to decline during pregnancy.[28,30] By the time of the second interview, which took place in the third trimester, the pregnancy itself was likely to have influenced her level of physical activity to an extent that may be highly variable between individuals, so we chose a priori to use information from gestation week 12 as our main exposure. Even so, our findings remained largely unchanged after combining the measure of exposure with information on physical activity at gestation week 30; interestingly, a stronger protective effect regarding PPD-prescription was observed for women who maintained their level of vigorous physical activity at gestation week 30.

The prospective study design reduces the chance that depression may have influenced the level of physical activity, making "reverse causality" an unlikely explanation for the associations that we observed. However, women who experienced symptoms of depression prior to or early in pregnancy may have had less energy to engage in physical activity, and, in order to take this into account, we adjusted for history of previous depression in our analyses. As a sensitivity analysis, we excluded women with a history of previous depression, but the central estimate was essentially unchanged after the exclusion (data not shown).

The analyses presented in Table 1 represent a relatively large number of tests, as we used 4 different exposures and 2 different outcome measures to assess the association between physical activity and PPD. However, all these analyses were decided upon a priori, and our findings are thus not a result of explorative analyses. Therefore, we did not correct

for multiple testing but are aware that the lower risk of PPD-prescription for women who were vigorously active would not be statistically significant had we, for example, corrected by the (quite conservative) Bonferroni method.

Outcome

Information on outcome was extracted from 2 unique registers available for research in Denmark: the Danish Psychiatric Central Register and the Register of Medicinal Product Statistics. Recently, the point prevalence of major depression in Denmark was estimated to be 3.3%; of these cases, only 13% were currently under treatment by a physician.[31] Our measures of outcome yielded very low rates of PPD (0.2% and 1.8%), and it can be argued that only severe cases of PPD are detected by our case definitions. An outcome measure based on a validated self-report measure of PPD, such as the Edinburgh Postnatal Depression Scale,[32] would most likely have yielded a higher rate of PPD. However, the comprehensive data collection in the Danish National Birth Cohort may have caused depressed women to drop out of the cohort, and our use of register-based data bypassed this particular problem.

Taking into account that hospitalization is a serious life disruption for a new mother and her infant, the rate of PPD-admission in this study may reflect cases of postpartum psychosis rather than PPD. Postpartum psychosis afflicts 1 to 2 per 1,000 women postpartum,[6] which is comparable to the rate of PPD-admission in our study. It is interesting that, in a cross-cultural review of studies on postpartum mental illness, Kumar[6] argues that depression and psychosis may have distinct etiologic patterns. According to Kumar, the etiology of PPD is predominantly psychosocial, with rates of PPD varying greatly between cultures, whereas rates of postpartum psychosis are stable, pointing to an endogenous etiology for psychoses, possibly triggered by the physiology of childbirth.[6] In this study, PPD-admission and PPD-prescription had different associations with physical activity and with some of the covariates, and this may be taken to support Kumar's notion that the 2 outcomes represent 2 distinct etiologic entities.

Suggested Mechanisms

Several biologic and psychosocial pathways have been hypothesized to mediate an antidepressive effect of physical activity. The different mechanisms by which this effect is achieved are poorly understood since studies have not been conducted specifically to address this issue.[33]

Physical activity has been shown to be positively associated with changes in self-esteem[34] and body image,[35] while negative self-evaluations have been shown to be related to depression.[33] We found surprisingly high risks of PPD-admission in underweight women who were physically active in pregnancy, which was not explained by a self-reported measure of eating disorders. This subgroup may be particularly vulnerable to pregnancy-related body changes and limited possibilities of exercising postpartum, potentially resulting in negative self-evaluations or less self-esteem and, thus, increased risk of depression.

From our findings, it can be speculated that a certain intensity of activity is required for an antidepressive effect to occur. This is supported by trials that have found a negative association between physical activity of vigorous intensity and depression, but no effect of light/moderate intensity physical activity against depression,[15,36,37] and this may point in the direction of a biologic response mechanism. Several different mechanisms have been suggested here as well. The endorphin hypothesis proposes that physical activity produces changes in endorphin concentrations and binding in the brain, thereby affecting mood.[33] Another hypothesis suggests that a decreased rate of neurogenesis contributes to depression, and that physical activity increases the synthesis of new neurons in the adult brain, alleviating depressed mood.[38]

Studies showing associations between physical activity and depression at baseline, but not prospectively, indicate that the relationship between the 2 may be largely correlational and not causal; this was also the conclusion of a recent study investigating causality in the association between physical activity and depression.[39] It is possible that a common psychological vulnerability may underlie both lower levels of physical activity and a higher risk of depression. Another plausible explanation for the inverse association between vigorous physical activity and PPD-prescription found in this study is that physical activity in pregnancy is an indicator of better general health. Even though our results were robust to adjustment for a history of previous depression, we cannot exclude the possibility that women who have the energy to perform strenuous exercise in pregnancy may have greater mental and physical resources and, thus, are at decreased risk of depression postpartum.

Perspectives

Findings from this large, prospective cohort of pregnant women are, in part, consistent with evidence from previous randomized controlled trials suggesting that vigorous physical activity may be associated with lower risk of depression. For the more severe cases of depression, those resulting in hospitalization of the woman, we did not find any association with physical activity in pregnancy. It is not possible, based on these data, to discern whether an association between vigorous physical activity and PPD reflects causal effects or is merely correlational in nature.

Underweight women who were physically active during pregnancy were at higher risk of PPD, and this finding needs to be tested in other large, prospective cohorts, which are now emerging in several other countries.

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