HHS Public Access
Author manuscript
BJOG. Author manuscript; available in PMC 2016 September 01.

Published in final edited form as:
BJOG. 2015 September ; 122(10): 1322–1330. doi:10.1111/1471-0528.13290.

Pre-pregnant body mass index and recreational physical activity: the effects on perinatal mortality in a prospective pregnancy cohort

Linn Marie Sorbye, MPH (LMS)[1,2,*], **Kari Klungsoyr, MD, PhD (KK)**[3,4], **Oddrun Samdal, PhD (OS)**[2] **[Cand.polit]**, **Katrine Mari Owe, PhD, (KMO)**[5,6], and **Nils-Halvdan Morken, MD, PhD (NHM)**[3,7]

[1]Department of Obstetrics and Gynaecology, Haukeland University Hospital, Bergen, Norway.

[2]Department of Health Promotion and Development, Faculty of Psychology, University of Bergen, Norway.

[3]Department of Global Public Health and Primary Care, University of Bergen, Norway.

[4]Medical Birth Registry of Norway, Norwegian Institute of Public Health, Bergen, Norway.

[5]Norwegian National Advisory Unit on Women's health, Oslo University Hospital, Rikshospitalet.

[6]Department of Psychosomatics and Health behavior, Norwegian Institute of Public Health.

[7]Department of Clinical Sciences, University of Bergen, Norway.

Abstract

Objective—To examine the effect of maternal pre-pregnant body mass index (BMI) and recreational physical activity on perinatal mortality.

Design—A prospective cohort study.

Setting—The Norwegian Mother and Child Cohort (MoBa), 1999-2008.

Population—Singleton pregnancies without congenital anomalies (n=77 246).

---

[*]Correspondence to: Department of Obstetrics and Gynaecology, Haukeland University Hospital. 5021 Bergen, Norway Telephone: +4747057201 linndin@online.no.

Disclosure of interest There are no conflicts of interest, including specific financial interests and relationships and affiliations relevant to the subject of this manuscript.

Contribution to authorship LMS takes the responsibility for the integrity of the data and the accuracy of the data analysis. LMS designed the study, performed the analyses of data and was responsible for the interpretation of data analysis and in the completion of the manuscript. KK contributed in interpretation of data analysis and in the completion of the manuscript. OS contributed in designing the study and completion of the manuscript. KMO gave supportive help in making the syntax for the variable on recreational physical activity and contributed in the completion of the manuscript. NHM designed the study and contributed in interpretation of data analysis and completion of the manuscript.

Details of Ethics Approval Informed consent was obtained from all participants in MoBa upon recruitment (24). The current study has been approved by the MoBa steering committee, and an ethic approval was made by the Western Regional Ethical Review Board (project number 270.08, approval no: 2008/14908-CAG) the 8th of January 2009. Data contained no personal identifiable information, securing anonymous data.

Methods—Pre-pregnant BMI was classified as underweight (<18.5), normal weight (18.5-24.9), overweight (25-29.9), obese (30-34.9) and morbidly obese (BMI≥ 35). Risk estimates were obtained by logistic regression and adjusted for confounders.

Main outcome measures—Perinatal death **(**stillbirth ≥ 22 weeks plus early neonatal death 0-7 days after birth).

Results—An increased risk of perinatal death was seen in obese (odds ratio (OR) 2.4, 95% CI 1.7-3.4) and morbidly obese women (OR 3.3, 2.1-5.1), when compared to normal weight women. In the group participating in recreational physical activity during pregnancy, obese women had an OR of 3.2 (95% CI 2.2-4.7) for perinatal death relative to non-obese. In the non-active group the corresponding OR was 1.8 (95% CI 1.1-2.8) for obese women relative non-obese. The difference in perinatal mortality risk related to obesity between the active and non-active groups was statistically significant (p-value for interaction = 0.046, multiplicative model).

Conclusions—Maternal obesity was associated with a two- to three-fold increased risk of perinatal death when compared to normal weight women. For women with a BMI <30 the lowest perinatal mortality was seen in those performing recreational physical activity at least once a week.

Keywords

perinatal death; BMI; obesity; overweight; recreational physical activity; MoBa

Introduction

The prevalence of overweight and obesity is increasing at an alarming rate worldwide and on average, 15% of the adult population in Europe are obese (1). There is growing evidence that pre-pregnant overweight and obesity represent significant risk factors for maternal and fetal complications during pregnancy, delivery and in the neonatal period (2-4). A feared complication is the occurrence of perinatal death comprising stillbirth (fetal death ≥ 22 gestational weeks) and early neonatal death (death of a live born within the first seven days after birth) (5). Perinatal death has short and long-term consequences for the health and well-being of the mother and her family, and it represents a loss of social and economic development (6, 7).

Previous studies have reported an increased risk of stillbirth and early neonatal death among obese women (8-10). A similar association has been found between overweight and stillbirth (11, 12). Several mechanisms have been proposed for the increased risk of stillbirth in these women, however, no biological pathway has been established (13, 14).

The importance of physical activity in promoting health and well-being in the general population has been identified as vital for public health (15), and may also have an important role in the prevention of perinatal mortality. As there is no uniform categorizing of physical activity, previous studies vary according to the definitions used to classify intensity, amount and type of physical activity (16, 17). Studies have shown that moderate physical activity early in pregnancy may improve placental growth and function, and hence have beneficial effects on pregnancy outcomes (18, 19). Physical activity before and during pregnancy may also modify the risk of gestational diabetes mellitus (GDM) and preeclampsia (15, 16, 20). Only one study has found that women practising physical activity during pregnancy are less likely to have a stillbirth (21), but no previous study has assessed the direct modifying effect of recreational physical activity on the relation between overweight and perinatal mortality. The objective of our study was to examine the effect of maternal pre-pregnant body mass index (BMI) and recreational physical activity on perinatal mortality.

Methods

Data sources

We used data from the Norwegian Mother and Child Cohort study (MoBa) (22), with linked data from the Medical Birth Registry of Norway (MBRN) (23), using the unique personal identification number given to all Norwegian citizens at birth. The MBRN was established in 1967 and is based on compulsory notification of all live- and stillbirths from 16 weeks of gestation (12 weeks from 2001). Midwives and doctors attending the birth complete a standardized notification form with data on demographics, maternal health before and during pregnancy, previous reproductive history, complications during pregnancy and delivery and pregnancy outcomes (24). MoBa is a prospective population-based pregnancy cohort study conducted by the Norwegian Institute of Public Health (25). All pregnant women giving birth in Norway were invited to participate early in pregnancy through a postal invitation after signing up for the routine ultrasound examination (performed at 17-20 weeks of pregnancy). The ultrasound screening is provided free of charge and more than 95% of all pregnant women in Norway attend (23). Participants were recruited during 1999-2008 from all Norwegian hospitals and maternity units with more than 100 annual deliveries. The proportion of women consenting to participate was 40.6% (22). The MoBa study has collected data from numerous questionnaires during pregnancy and after delivery.

Inclusion and definitions

Singleton pregnancies without major congenital anomalies at gestational age ≥ 22 weeks were included. Congenital anomalies notified to the MBRN are diagnosed at birth or during the following stay at the delivery unit, or at the neonatal intensive care units for infants transferred to such units after birth. Diagnoses are notified as codes based on the International Classification of Diseases (ICD) version 10 (26), or as free text, coded at the MBRN according to the ICD10. Pregnancies with offspring major congenital anomalies (according to European Surveillance of Congenital Anomalies) (27) were excluded from the present study. Participants in MoBa were included if complete data on pre-pregnant weight and height were available. Women with pre-pregnant BMI below 15, above 60 and with maternal height below 1.40 metres were excluded, as the recorded data were considered biologically implausible. Women contributed with their first registered pregnancy in the MoBa cohort.

The main outcome variable was perinatal death, obtained from the MBRN, and comprised stillbirth ≥ 22 weeks gestation and early neonatal death (live born dying 0-7 days after birth) (23). The main exposure was pre-pregnant BMI calculated as weight in kilograms divided by pre-pregnant height in meters squared, and was obtained from the first MoBa questionnaire (Q1), completed in weeks 13-17 of pregnancy. BMI was categorized as underweight (<18.5), normal weight (18.5-24.9), overweight (25-29.9), obese (30-34.9) and morbidly obese (≥35) (28). Normal weight women were the reference group. In the analyses including recreational physical activity, BMI was categorized into ≥30 representing obesity and < 30 being the reference group. We defined physical activity as participating in any combination of recreational physical activities. Information on recreational physical activity was retrieved from Q1 in which participants were asked how often they engaged in 14 different recreational activities the last three months before pregnancy and until 13-17 weeks in pregnancy. Only women who had answered both the question on recreational physical activity last three months before pregnancy and until week 17 in the actual pregnancy were included. The questions were identical for the two periods and the level of each activity was defined as never, one to three times per month, once a week, twice a week, or at least three times per week. The following activities were included in a total score representing recreational physical activity three months before pregnancy and during the first three months of pregnancy: brisk walking, running/jogging/orienteering, bicycling, fitness training/resistance training, aerobics for pregnant women, low impact aerobics, high impact aerobics, dancing, skiing, ball games, swimming, horseback riding, strolling and other. “Strolling” and “other” were included in the analyses, but were coded as 0 score. Women were categorized into two categories: *physically active* (performing recreational physical activity at least once a week) and *non-active* (performing recreational physical activity less than once a week).

Data on maternal smoking at the beginning of pregnancy (none, sometimes, daily) was retrieved from the MBRN. In cases with missing information, information in MoBa Q1 was used. Maternal age (from the MBRN) represented years at the time of delivery (<20, 20-35, >35 years), and parity (from the MBRN) number of previous births (nulliparous or multiparous). Marital status (married/cohabitant or other) was retrieved from the MBRN. Education level was retrieved from MoBa Q1 and represented maternal fulfilled education at the start of pregnancy (9-12 years, 13-16, ≥17). Maternal medical conditions before and during pregnancy were notified to the MBRN by check boxes or free text on the notification form, and free text was coded at the MBRN according to the ICD-10.

Statistical analyses

Univariate logistic regression was used to estimate the association between pre-pregnant BMI and perinatal death. Odds ratios (OR) with 95% confidence interval (CI) were calculated for each BMI group with normal weight as the reference group. Multivariate logistic regression models were used to adjust for maternal age at delivery, parity, marital status, smoking and chronic hypertension. All potential confounders were modelled as categorical factors, as shown in footnotes to Table 2. To estimate the role of recreational physical activity as a moderator in the relationship between BMI and perinatal death, we studied whether there was a significant interaction between BMI and physical activity in a multiplicative model, using logistic regression analysis. Associations were considered statistically significant at the 5% level. All statistical analyses were performed using SPSS (Statistical Package for the Social Sciences, version 20, www.spss.com).

Results

The MoBa cohort included 95 200 mothers and 108 843 pregnancies were available when analysing MoBa Q1. In the primary analyses, 77 246 pregnancies were included. As displayed in Figure 1, women with pregestational diabetes, multiple pregnancies and women with offspring major congenital anomalies were excluded, as these are independent factors predisposing for perinatal death (29-31). In the logistic regression analyses, women with missing data on smoking or chronic hypertension (2 592 mothers, 3.4%) were included by simple imputation methods, by assigning a separate value for the missing data. Women who had answered the questionnaire on recreational physical activity from the first version of Q1 were excluded as the questions differed from the latter version. In the analyses assessing recreational physical activity, information on this variable was missing for 4 940 mothers (6.4 %), giving 72 306 pregnancies for the secondary analyses.

Among the included women, 65.6 % were classified as normal weight, 3.1% as underweight, 21.7% as overweight, 7.0% as obese and 2.6% as morbidly obese according to their pre-pregnant BMI (Table 1). The overall perinatal mortality was 3.9 per 1000 births (n=299). Generally, there was a significant trend towards increasing perinatal mortality with increasing BMI (Table 2).

In the univariate analyses, obese mothers had more than doubled risk of a perinatal loss compared to normal weight mothers, while morbidly obese mothers had a three-fold increased risk for perinatal death (Table 2). Maternal age, parity, education, marital status, smoking and chronic hypertension were evaluated as potential confounders for the relation between BMI and perinatal death. However, education was not significantly related to perinatal mortality and was not included in the final model. The final logistic regression model only slightly changed the crude estimates (Table 2).

The levels of recreational physical activity before and during pregnancy according to maternal BMI are illustrated in Figure 2. For women with BMI at and above 18.5, the proportion participating in recreational physical activity decreased linearly with increasing level of BMI (Fig 2). The level of physical activity decreased in pregnancy across all BMI groups.

Overall, performing physical activity at least once a week was associated with a non-significant decrease in perinatal mortality relative to not participating in physical activity, with crude OR at 0.8 (0.6-1.1) for physical activity before pregnancy and OR 0.8 (0.7-1.1) for physical activity during pregnancy. For *physically active* women in pregnancy the absolute risks of perinatal mortality (per 1000) in underweight, normal weight, overweight and obese women were 3.53, 2.91, 3.58 and 9.85. The corresponding absolute risks for the *non-active* women were 4.76, 3.84, 3.85 and 6.78. Due to limited numbers of deaths in each group, all confidence intervals were wide and overlapping. Hence, in women with a BMI below 30, the lowest absolute perinatal mortality was found in women performing recreational physical activity at least once a week during pregnancy. However, in obese women (BMI $\geq$ 30), the lowest absolute perinatal mortality was in the *non-active* group. The same trend was found for women engaging in physical activity prior to pregnancy.

Being obese (BMI ≥30) was associated with a 150 % excess risk of a perinatal loss relative to women with BMI < 30 (crude OR 2.5, 95% CI 1.9-3.4). When testing the interaction between BMI and recreational physical activity (≥ once a week) during pregnancy in a logistic regression model, the interaction term was statistically significant (p-value for interaction = 0.046, multiplicative model). Obese women in the *non-active* group (n=25 432) had 80% excess risk of a perinatal loss (crude OR 1.8, 95% CI 1.1-2.8), compared to women with BMI < 30, while the corresponding excess risk for obese women performing physical activity at least once a week during pregnancy (n=46 874) was 220% (crude OR 3.2, 95% CI 2.2-4.7). Adjusting for confounders only marginally changed the estimates (ORs 1.7 (95% CI 1.1-2.8) and 3.1 (95% CI 2.1-4.5), respectively.

In a sensitivity analysis, we assigned all the 4 940 women with missing information on recreational physical activity, to be in the active group and second in the non-active group. Independent of which group they were assigned, adding the 4 940 women with missing information on recreational physical activity did not alter our results or conclusions.

Testing the interaction between BMI and recreational physical activity before pregnancy, the interaction term was not statistically significant (p-value for interaction = 0.172, multiplicative model). Including recreational physical activity as a potential confounder in the logistic regression model in addition to the previously described confounders, the adjusted OR of a perinatal loss for women with BMI ≥ 30 relative to BMI < 30 was 2.4 (95% CI 1.8-3.3) when adjusting for physical activity before pregnancy and 2.4 (95% CI 1.8-3.2) when adjusting for physical activity during pregnancy.

Figure 3 shows the relationship between BMI and perinatal mortality when using four BMI categories and stratified on recreational physical activity during pregnancy (at least once a week, yes/no) Normal weight women performing physical activity at least once a week was chosen as the common reference group due to the lowest absolute risk of perinatal death in this group. For all BMI groups except the highest, the OR point estimates of a perinatal loss were higher among the non-active than the active women, although confidence intervals overlapped. In the highest BMI group (≥ 30), however, this relation was reversed. Among the obese women, the non-active women had a lower OR point estimate of a perinatal loss than the active women, but again, confidence intervals overlapped (Fig 3).

We compared obese women in the physically *active group* (n= 3 656) with the *non-active* group (n=3 244) with regards to maternal age, parity, marital status, education, smoking and maternal comorbidity. Obese women in the *active* group had higher proportion of nulliparous women (p<0.001, Chi-Square test), lower proportions of women with the lowest education and higher proportions of women with the highest education (p<0.001). Chronic hypertension (p=0.029) and GDM (p=0.003) were less common in the *active* group. There were no statistical differences with regards to smoking (p=0.836), marital status (p=0.247), maternal age (p=0.559) or preeclampsia (p=0.460) between the *active* and *non-active* group of obese women.

We looked closer at obese women with a perinatal loss (n=58) and obese women with no loss (n=6842) with regards to recreational physical activity pattern before and during pregnancy. Among the obese women with a perinatal loss, 60% were *physically active* both before and during pregnancy, 17% were *physically active* before pregnancy and *non-active* during pregnancy, 21% were *non-active* both before and during pregnancy and only one woman was *non-active* before pregnancy and was *physically active* during pregnancy. The corresponding figures for obese women with no loss were 50%, 24%, 23% and 3%. The differences were however not statistically significant (p=0.402, Chi-Square test).

Discussion

Main Findings

Obese mothers had a two- to three-fold increased risk of a perinatal loss when compared to normal weight women, and recreational physical activity during pregnancy played a role in this relation. Unexpectedly, the OR of a perinatal loss associated with BMI ≥ 30 was higher among women performing recreational physical activity at least once a week during pregnancy than among non-active women, when relating to corresponding women with BMI < 30. When using four BMI categories, women in all categories except the highest (≥ 30), had lower OR point estimates of perinatal loss when they were active than non-active during pregnancy, although the differences were not statistically significant.

Previous studies demonstrate that maternal pre-pregnancy obesity is associated with an increased risk of perinatal loss when compared to normal weight women (4, 9, 10, 13), but conflicting findings exist (3). We found a non-significant increase in the risk of a perinatal loss among overweight women (BMI 25-29.9), similar to other studies (9, 10). However, there are large population-based studies and meta-analyses that have concluded that overweight women have an increased risk of stillbirth (4, 12, 13) and perinatal mortality (13), illustrating the importance of large sample sizes when studying rare outcomes.

Recreational physical activity may prevent gestational diabetes and preeclampsia (15, 16, 20). Unexpectedly, we found a stronger association between obesity (BMI ≥ 30) and perinatal mortality among women participating in recreational physical activity during pregnancy than among women who did not. For physical activity during pregnancy, the associations between obesity (BMI ≥ 30 versus < 30) and perinatal mortality differed significantly between the active and non-active groups. Another study from the MoBa cohort, assessing the effect of physical activity on preeclampsia, concluded that the protective effect was strongest for women with BMI less than 25 and absent in women with BMI >30 (32). To our knowledge, only one previous study exists (21), which has reported an association between physical activity during pregnancy and a reduced prevalence of stillbirth. This study did not, however, take BMI into consideration and the generalizability of this study was limited (21). A prospective study from the Danish National Birth Cohort that treated physical activity during pregnancy as a confounder, did not find that physical activity significantly influenced the association between obesity and stillbirth (33).

Strengths and limitations

Data from this large prospective population-based cohort together with a long recruitment period contribute to variability and strengthen our study (25). The MoBa study has been validated and represents a valid source for exposure-outcome association studies (34). Record linkage with the MBRN with compulsory notification of perinatal deaths ensured ascertainment of the outcome variable. Possible misclassification in exposure is non-differential and unrelated to the outcome due to the prospective design.

There are, however, some limitations to our study. The MoBa cohort is not quite representative for the Norwegian population, as women with lower socioeconomic status are underrepresented (34). Although this selection bias has implications for generalizing prevalence estimates, it does not seem to have implications for exposure-outcome associations (34). Lack of diversity in ethnicity limits the generalizability to more inhomogeneous populations (25). We relied on self-reported data on weight, height and recreational physical activity. Due to social desirability, self-reported weight is likely to be underreported and height over reported (35), causing a possible misclassification of the exposure variable. This is likely to underestimate the true BMI and the risk associated with overweight and obesity.

The MoBa questionnaires on recreational physical activity in week 15-17 have been validated in a subsample of pregnant women and a significant association between self-reported and objectively measured recreational physical activity was found (36). However, there is evidence that physical activity is generally over reported, making underestimation of the true effect of physical activity likely (37). An over reporting of activity with the following underestimation of true effect would be independent of pregnancy outcome, and non-differential. We lacked information on intensity and duration of recreational physical activity, and according to Bouchard et al. (38), the intensity, these factors are important to take into account when assessing the nature of recreational physical activity. Other domains of physical activity may interfere the relationship between pre-pregnant BMI and perinatal death. This was beyond the scope of our study, but should be included in future studies.

Despite a large sample size, the number of perinatal deaths was limited, and our numbers were too few when analysing the potentially modifying effect of physical activity when using more than two categories of BMI.

Interpretation

The biologic underpinnings of the excess risk of perinatal death in obese women remain unknown though several mechanisms have been proposed (12). The presence of endothelial dysfunction in obese women might be associated with impaired early placental function causing stillbirth (9, 33). According to Kristensen et al. (9) a similar trend for causes of neonatal death (0-28days) was not found. Obesity has been associated with a 5-fold increase in risk of stillbirth due to placental dysfunction (33). In an intervention study using an animal model, high fat diet early in life led to increases in body fat, serum leptin and triglycerides prior to pregnancy and a three-fold increase in fetal death and decreased neonatal survival(39). The outcome was associated with a poor development of the placental vasculature with reduced blood flow to the placenta and reduced oxygenation of foetal tissues. This may contribute to hypoxia, poor fetal growth and fetal and neonatal mortality, and underlines the importance of future studies focusing on the placental effect.

Regular physical activity during pregnancy may stimulate placental growth and be an important mechanism for improving placental functional capacity (18, 40). A physiologic explanation could be the link to the intermittent reductions in uterine blood flow that occurs during sustained weight-bearing exercise and the expanded blood volume observed in pregnant exercisers (18). However, our study suggests the possibility that the effect of physical activity on perinatal mortality is dependent on maternal BMI. It is a possibility that metabolic alterations in obese women make them more vulnerable and less adaptive to stress during physical activity in pregnancy. Our results were unexpected, and need to be tested in other studies. If replicated, investigations on the underlying mechanisms explaining the interaction between categories of BMI and physical activity on risk of perinatal loss are needed.

Our study underlines the importance of preventing obesity in women before conception in order to reduce perinatal mortality in their offspring. As a predictor, obese women do seem to have increased risk of perinatal losses, and should be monitored closely during pregnancy. Current guidelines on physical activity in pregnancy do not differentiate between pre-pregnant BMI categories, only between those who have been physically active before pregnancy and those who have not (41). Given the many comorbidities associated with obesity, guidelines on physical activity may need to be customized for obese women.

Conclusions

Pre-pregnant obesity was associated with a two- to three-fold risk increase of perinatal death when compared to normal weight women. For women with a BMI below 30, the lowest risk of perinatal death was found among women performing recreational physical activity. For obese women, the risk associated with overweight was highest in those participating in recreational physical activity during pregnancy. Our results were unexpected and need to be replicated. The use of self-reported data may represent a bias in our study, however, misclassifications are likely to be non-differential. Future studies should endeavour the use of objective measures of physical activity in addition to self-reported data.

Acknowledgements

MoBa is supported by the Norwegian Ministry of Health, and the Ministry of Education and Research, NIH/NIEHS (contract no N01-ES-75558), NIH/NINDS (grant no.1 UOI NS 047537-01 and grant no.2 UOI NS 047537-06A1). We are grateful to all the participating families in Norway who took part in this ongoing cohort study.

Funding The Schering Plough Research Foundation through the Norwegian Gynecological Society has contributed with a research grant and is acknowledged. Haukeland University Hospital, Department of Research and Development, has granted financial support in a six months scholarship.

References

1. OECD. Health at a Glance: Europe 2010. 2010. OECD Publishing. ISBN 978-92-64-09031-6http://dx.doi.org/10.1787/health-glance-2010-en
2. Sebire NJ, Jolly M, Harris JP, Wadsworth J, Joffe M, Beard RW, et al. Maternal obesity and pregnancy outcome: a study of 287,213 pregnancies in London. Int J Obes Relat Metab Disord. 2001; 25(8):1175–82. [PubMed: 11477502]
3. Khashan AS, Kenny LC. The effects of maternal body mass index on pregnancy outcome. Eur J Epidemiol. 2009; 24(11):697–705. [PubMed: 19653107]

4. Ovesen P, Rasmussen S, Kesmodel U. Effect of prepregnancy maternal overweight and obesity on pregnancy outcome. Obstet Gynecol. 2011; 118(2 Pt 1):305–12. [PubMed: 21775846]
5. WHO. Country, regional and global estimates 2004. World Health Organization; Geneva: 2007. Neonatal and perinatal mortality.
6. Turton P, Evans C, Hughes P. Long-term psychosocial sequelae of stillbirth: phase II of a nested case-control cohort study. Arch Womens Ment Health. 2009; 12(1):35–41. [PubMed: 19137447]
7. Frøen JF, Cacciatore J, McClure EM, Kuti O, Jokhio AH, Islam M, et al. Stillbirths: why they matter. Lancet. 2011; 377(9774):1353–66. [PubMed: 21496915]
8. Cnattingius S, Bergström R, Lipworth L, Kramer MS. Prepregnancy weight and the risk of adverse pregnancy outcomes. N Engl J Med. 1998; 338(3):147–52. [PubMed: 9428815]
9. Kristensen J, Vestergaard M, Wisborg K, Kesmodel U, Secher NJ. Pre-pregnancy weight and the risk of stillbirth and neonatal death. BJOG. 2005; 112(4):403–8. [PubMed: 15777435]
10. Tennant PW, Rankin J, Bell R. Maternal body mass index and the risk of fetal and infant death: a cohort study from the North of England. Hum Reprod. 2011; 26(6):1501–11. [PubMed: 21467206]
11. Stephansson O, Dickman PW, Johansson A, Cnattingius S. Maternal weight, pregnancy weight gain, and the risk of antepartum stillbirth. Am J Obstet Gynecol. 2001; 184(3):463–9. [PubMed: 11228504]
12. Chu SY, Kim SY, Lau J, Schmid CH, Dietz PM, Callaghan WM, et al. Maternal obesity and risk of stillbirth: a metaanalysis. Am J Obstet Gynecol. 2007; 197(3):223–8. [PubMed: 17826400]
13. Aune D, Saugstad OD, Henriksen T, Tronstad S. Maternal body mass index and the risk of fetal death, stillbirth, and infant death. A systematic review and meta-analysis. JAMA. 2014; 311(15): 1536–46. [PubMed: 24737366]
14. Meehan S, Beck CR, Mair-Jenkins J, Leonardi-Bee J, Puleston R. Maternal obesity and infant mortality: A meta-analysis. Pediatrics. 2014; 133(5):863–871. [PubMed: 24709933]
15. Ferraro ZM, Gaudet L, Adamo KB. The potential impact of physical activity during pregnancy on maternal and neonatal outcomes. Obstet Gynecol Surv. 2012; 67(2):99–110. [PubMed: 22325300]
16. Hegaard HK, Pedersen BK, Nielsen BB, Damm P. Leisure time physical activity during pregnancy and impact on gestational diabetes mellitus, pre-eclampsia, preterm delivery and birth weight: a review. Acta Obstet Gynecol Scand. 2007; 86(11):1290–6. [PubMed: 17851805]
17. Aune D, Saugstad OD, Henriksen T, Tonstad S. Physical activity and the risk of preeclampsia: a systematic review and meta-analysis. Epidemiology. 2014; 25(3):331–343. [PubMed: 24713878]
18. Clapp JF, Kim H, Burciu B, Lopez B. Beginning regular exercise in early pregnancy: effect on fetoplacental growth. Am J Obstet Gynecol. 2000; 183(6):1484–8. [PubMed: 11120515]
19. Melzer K, Schutz Y, Boulvain M, Kayser B. Physical activity and pregnancy: cardiovascular adaptations, recommendations and pregnancy outcomes. Sports Med. 2010; 40(6):493–507. [PubMed: 20524714]
20. Dempsey JC, Butler CL, Williams MA. No need for a pregnant pause: physical activity may reduce the occurrence of gestational diabetes mellitus and preeclampsia. Exerc Sport Sci Rev. 2005; 33(3):141–9. [PubMed: 16006822]
21. Dumith SC, Domingues MR, Mendoza-Sassi RA, Cesar JA. Physical activity during pregnancy and its association with maternal and child health indicators. Rev Saude Publica. 2012; 46(2):327–3. [PubMed: 22331181]
22. MoBa. Norwegian Mother and Child Cohort Study. Revised Protocol 2012. End of Enrollment-Protocol II. http://www.fhi.no/dokumenter/3972b9ec5c.pdf
23. FHI. Norwegian Institute of Public Health. The Medical Birth registry of Norway (MBRN). General information available at http://www.mfr.no General information regarding registration of births available at http://www.fhi.no/artikler/?id=100997 and http://www.fhi.no/tema/dodsaarsaker-og-levealder/icd-koder
24. Irgens LM. The Medical Birth Registry of Norway. Epidemiological research and surveillance throughout 30 years. Acta Obstet Gynecol Scand. 2000; 79(6):435–9. [PubMed: 10857866]
25. Magnus P, Irgens LM, Haug K, Nystad W, Skjaerven R, Stoltenberg C, et al. Cohort profile: the Norwegian Mother and Child Cohort Study (MoBa). Int J Epidemiol. 2006; 35(5):1146–50. [PubMed: 16926217]

26. WHO. International statistical classification of diseases and related health problems. Vol. Vol. 2. World Health Organization; Geneva: 1993. ICD-10. Tenth revisionhttp://www.who.int/classifications/icd/ICD-10_2nd_ed_volume2.pdf
27. European Surveillance of Congenital Anomalies (Eurocat). http://www.eurocat-network.eu/
28. Consultation WE. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet. 2004; 363(9403):157–63. [PubMed: 14726171]
29. Kalter H. Five-decade international trends in the relation of perinatal mortality and congenital malformations: stillbirth and neonatal death compared. Int J Epidemiol. 1991; 20(1):173–9. [PubMed: 1712348]
30. Eidem I, Vangen S, Hanssen KF, Vollset SE, Henriksen T, Joner G, SteneL C. Perinatal and infant mortality in term and preterm births among women with type 1 diabetes. Diabetologia. 2011
31. U.S. Department of Health and Human Services. Centers for Disease Control and Prevention. National Center for Health Statistics. Fetal and Perinatal Mortality. Vol. Vol 60. United States: 2012. 2006. (National Vital Statistics Reports.http://www.cdc.gov/nchs/data/nvsr/nvsr60/nvsr60_08.pdf
32. Magnus P, Trogstad L, Owe KM, Olsen SF, Nystad W. Recreational physical activity and the risk of preeclapsia: a prospective cohort of Norwegian women. Am J Epidemiol. 2008; 168:952–957. [PubMed: 18701444]
33. Nohr EA, Bech BH, Davies MJ, Frydenberg M, Henriksen TB, Olsen J. Prepregnancy obesity and fetal death: a study within the Danish National Birth Cohort. Obstet Gynecol. 2005; 106(2):250–9. [PubMed: 16055572]
34. Nilsen RM, Vollset SE, Gjessing HK, Skjaerven R, Melve KK, Schreuder P, et al. Self-selection and bias in a large prospective pregnancy cohort in Norway. Paediatr Perinat Epidemiol. 2009; 23(6):597–608. [PubMed: 19840297]
35. Connor Gorber S, Tremblay M, Moher D, Gorber B. A comparison of direct vs. self-report measures for assessing height, weight and body mass index: a systematic review. Obes Rev. 2007; 8(4):307–26. [PubMed: 17578381]
36. Brantsaeter AL, Owe KM, Haugen M, Alexander J, Meltzer HM, Longnecker MP. Validation of self-reported recreational exercise in pregnant women in the Norwegian Mother and Child Cohort Study. Scand J Med Sci Sports. 2010; 20(1):e48–55. [PubMed: 19486481]
37. Sallis JF, Saelens BE. Assessment of physical activity by self-report: status, limitations, and future directions. Res Q Exerc Sport. 2000; 71(2 Suppl):S1–14. [PubMed: 10925819]
38. Bouchard, C.; Shephard, RJ.; Stephens, T. Physical activity, fitness, and health consensus statement. Vol. xv. Human Kinetics; Champaign, Ill.: 1993.
39. Hayes EK, Lechowicz A, Petrik JJ, Storozhuk Y, Paez-Parent S, Dai Q, et al. Adverse fetal and neonatal outcomes associated with a life-long high fat diet: role of altered development of the placental vasculature. PLoS One. 2012; 7(3):e33370. [PubMed: 22442686]
40. Bergmann A, Zygmunt M, Clapp JF. Running throughout pregnancy: effect on placental villous vascular volume and cell proliferation. Placenta. 2004; 25(8-9):694–8. [PubMed: 15450386]
41. Mudd LM, Owe KM, Mottola MF, Pivarnik JM. Health benefits of physical activity during pregnancy: An international perspective. Med Sci Sports Exerc. 2013; 45(2):268–277. [Published Ahead of Print]. [PubMed: 22895379]

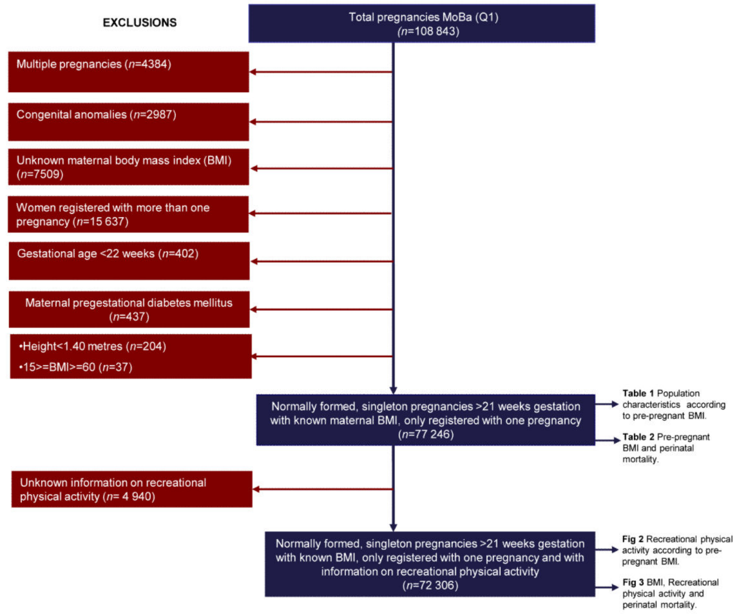

Fig 1.

Flowchart showing inclusion of mothers in the study, The Mother and Child Cohort Study 1999-2008.

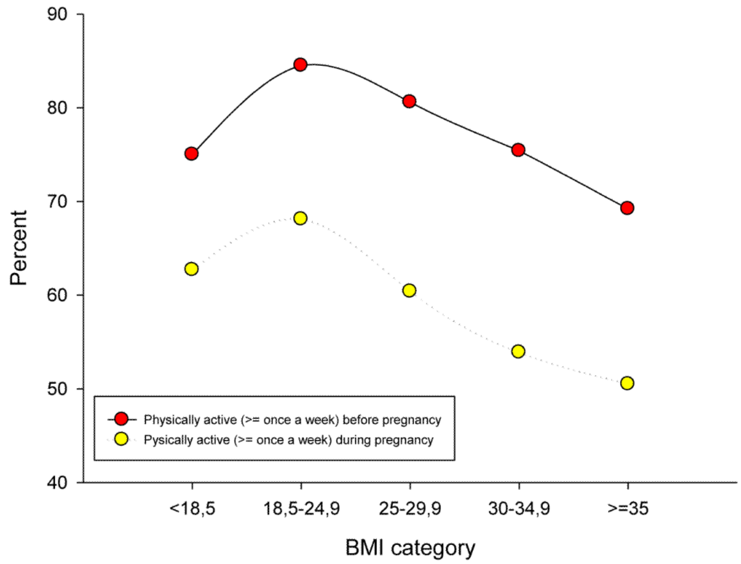

Fig 2.

Recreational physical activity last three months before pregnancy and in the first three months of pregnancy, according to body mass index (BMI) category (n=72 306), The Mother and Child Cohort Study 1999-2008.

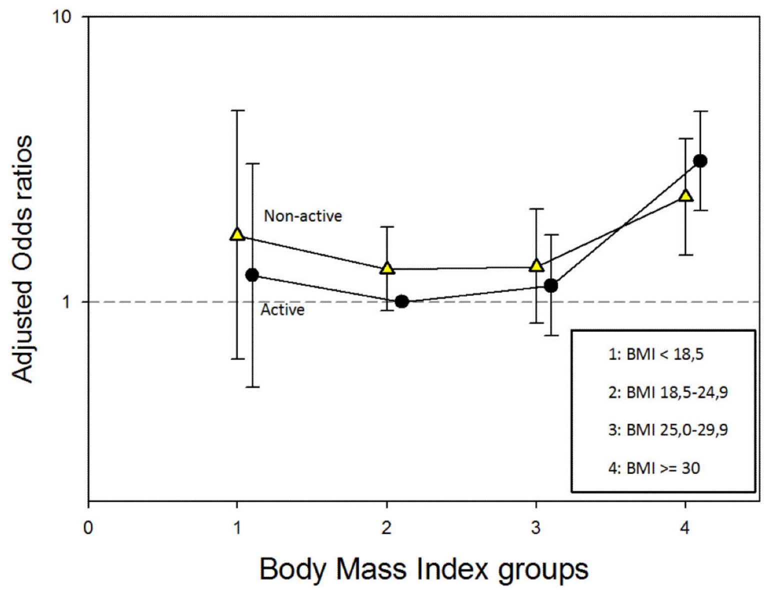

Fig 3.

Pre-pregnant body mass index (BMI), recreational physical activity in pregnancy and the risk of perinatal mortality. Logistic regression analysis adjusted for maternal age, parity, marital status, chronic hypertension and smoking (n=72 306). The Norwegian Mother and Child Cohort Study, 1999-2008.

Table 1

Population characteristics according to pre-pregnant body mass index (n=77 246), The Norwegian Mother and Child Cohort Study 1999-2008.

Body mass index	**<18.5 (%)**	**18.5-24.9 (%)**	**25-29.9 (%)**	**30-34.9 (%)**	**≥35 (%)**	**Total (%)**
Total	2423 (3,1)	50 676 (65,6)	16 791 (21,7)	5 376 (7,0)	1 980 (2,6)	77 246 (100)
Maternal age						
<20 years	99 (4,1)	497 (1,0)	115 (0,7)	47 (0,9)	17 (0,9)	775 (1,0)
20-35 years	2 049 (84,6)	41 750 (82,4)	13 578 (80,9)	4 373 (81,3)	1 594 (80,5)	63 344 (82,0)
>35 years	275 (11,3)	8 429 (16,6)	3 098 (18,5)	956 (17,8)	369 (18,6)	13 127 (17,0)
Parity						
Nulliparous	1 239 (51,1)	23 410 (46,2)	6 809 (40,6)	2 161 (40,2)	769 (38,8)	34 388 (44,5)
Multiparous	1 184 (48,9)	27 266 (53,8)	9 982 (59,4)	3 215 (59,8)	1 211 (61,2)	42 858 (55,5)
Education						
9-12 years	1 000 (41,3)	15 377 (30,3)	6 627 (39,5)	2 610 (48,5)	1 085 (54,8)	26 699 (34,6)
13-16 years	755 (31,2)	20 209 (39,9)	6 547 (39,0)	1 846 (34,3)	635 (32,1)	29 992 (38,8)
≥17 years	492 (20,3)	12 438 (24,6)	2 832 (16,9)	661 (12,3)	181 (9,1)	16 604 (21,5)
Missing	176 (7,3)	2 652 (5,2)	785 (4,7)	259 (4,8)	79 (4,0)	3 951 (5,1)
Married/cohabitant						
Yes	2 228 (92,0)	48 754 (96,2)	16 203 (96,5)	5 135 (95,5)	1 869 (94,4)	74 189 (96,0)
No	195 (8,0)	1 922 (3,8)	588 (3,5)	241 (4,5)	111 (5,6)	3 057 (4,0)
Maternal smoking						
None	2 056 (84,9)	44 345 (87,5)	14 644 (87,2)	4 713 (87,7)	1 747 (88,2)	67 505 (87,4)
Sometimes	72 (3,0)	1 527 (3,0)	525 (3,1)	162 (3,0)	53 (2,7)	2 339 (3,0)
Daily	227 (9,4)	3 573 (7,1)	1 277 (7,6)	400 (7,4)	135 (6,8)	5 612 (7,3)
Missing	68 (2,8)	1 231 (2,4)	345 (2,1)	101 (1,9)	45 (2,3)	1 790 (2,3)
Chronic hypertension [1]						
No	2 375 (98,0)	49 760 (98,2)	16 499 (98,3)	5 243 (97,5)	1 913 (96,6)	75 790 (98,1)
Yes	3 (0,1)	174 (0,3)	98 (0,6)	68 (1,3)	42 (2,1)	385 (0,5)
Missing	45 (1,9)	742 (1,5)	194 (1,2)	65 (1,2)	25 (1,3)	1 071 (1,4)
Gestational diabetes mellitus						
No	2 420 (99,9)	50 428 (99,5)	16 600 (98,9)	5 256 (97,8)	1 876 (94,7)	76 580 (99,1)
Yes	3 (0,1)	248 (0,5)	191 (1,1)	120 (2,2)	104 (5,3)	666 (0,9)
Gestational hypertensive disorders [2]						
No	2 301 (95,0)	47 946 (94,6)	15 400 (91,7)	4 679 (87,0)	1 651 (83,4)	71 977 (93,2)
Yes	77 (3,2)	1 988 (3,9)	1 197 (7,1)	632 (11,8)	304 (15,4)	4 198 (5,4)
Missing	45 (1,9)	742 (1,5)	194 (1,2)	65 (1,2)	25 (1,3)	1 071 (1,4)

[1] Blood pressure ≥140/90 mm prior to pregnancy or before week 20.

[2] Includes both preeclampsia/eclampsia (Blood pressure ≥140/90 in at least 2 readings ≥ 6 hours apart accompanied by proteinuria (2 urinary dipstick readings of ≥ 1) and gestational hypertension (Blood pressure ≥140/90 only during pregnancy).

Table 2

Perinatal death in relation to pre-pregnant body mass index (BMI) (n=77 246), The Norwegian Mother and Child Cohort Study 1999-2008.

Maternal BMI	Total No		Perinatal death			
	Births	Death (per1000)	Crude OR[1]	95% CI	Adjusted OR[2]	95% CI
<18.5	2 423	9 (3.7)	1.1	0.6-2.2	1.1	0.6-2.2
18.5-24.9	50 676	166 (3.3)	1.0	Reference	1.0	Reference
25.0-29.9	16 791	61 (3.6)	1.1	0.8-1.5	1.1	0.8-1.5
30-34.9	5 376	42 (7.8)	2.4	1.7-3.4	2.4	1.7-3.3
>= 35	1 980	21(10.6)	3.3	2.1-5.1	3.1	1.9-4.9

[1] γ p-value for trend = 0.001.

[2] Odds ratio adjusted for maternal age (<20 years, 20-35(reference), >35), parity (nulliparous/multiparous(reference)), marital status (married/cohabitant yes(reference)/no), chronic hypertension (yes/no(reference)) and smoking (none(reference), sometimes, daily).