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Exercise before and during pregnancy and reproductive outcomes: A population based cohort study

The Norwegian Mother and Child Cohort Study

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To Emilie and Theodor

SUMMARY

Regular physical activity is an important component of a healthy pregnancy due to its potential beneficial effects on both maternal and fetal health such as reduced risk of developing gestational diabetes mellitus, pregnancy induced hypertension and preeclampsia, urinary incontinence and reduced postpartum depression. Consequently, current guidelines for exercise during pregnancy are now proactive and recommend both strength-conditioning exercises in addition to aerobic exercises of moderate intensity on most, if not all, days of the week for women with normal pregnancies.

Objectives

The overall objective was to expand our knowledge about level of exercise during pregnancy, and to assess factors associated with regular exercise during pregnancy, and to estimate how exercise performed at different time points during pregnancy affects reproductive outcomes such as excessive birth weight, gestational age and Cesarean delivery.

Subjects and methods

This dissertation is based on data from pregnancies included in the Norwegian Mother and Child Cohort Study (MoBa), a pregnancy cohort of 100,000 pregnancies enrolled between 1999 and 2008, conducted by the Norwegian Institute of Public Health. This dissertation is based on data from the second and the fourth version of the quality assured data file released for research in 2006 and 2009, respectively. Linkage to the Medical Birth Registry of Norway was also provided. Women completed three questionnaires during pregnancy weeks 17 and 30. The questions used to assess exercise in the present study have been compared with accelerometer measurements in a sub-sample within the MoBa study and have shown positive correlations. We applied different approaches and effect measures to explore associations with exercise during pregnancy. In Papers III and IV, we used directed acyclic graphs (DAGs) to assess possible associations.

Main results

The main findings were: 1) Participation in regular exercise declined from three months prepregnancy to pregnancy week 30. Exercising regularly before pregnancy was the strongest correlate for regular exercising in pregnancy weeks 17 and 30. 2) A protective effect of exercise in week 17 and 30 and excessive newborn birth weight was observed in nulliparous women only. 3) Women who exercise during pregnancy had on average one day longer gestation than their non-exercising counterparts. Exercise during pregnancy was associated with reduced risk of preterm birth and slightly increased risk of post-term birth. 4) Cesarean delivery rates, including both acute and elective type, were reduced in women who exercised during pregnancy. The greatest risk reduction was observed in women who reported a high weekly frequency of exercise and in those participating in high impact exercises.

Conclusions

In a large population based pregnancy cohort, we observed a decline in exercise level from prepregnancy to pregnancy week 30. Women exercising regularly prepregnancy were more likely to exercise regularly during pregnancy. Exercise during pregnancy was associated with reduced probability of delivering a newborn with excessive birth weight, gestational age was slightly longer among exercising women and a reduced risk of preterm birth was observed. Cesarean delivery rates were also reduced in women who exercised during pregnancy.

Key words: pregnancy, women, exercise, gestation, birth weight, physical activity, mode of delivery, preterm delivery.

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Oslo, June 2011.
Katrine Mari Owe

LIST OF PAPERS

The dissertation is based on the following original research papers, which are referred to in the text by their Roman numerals.

Paper I

Owe K. M., Nystad W., Bø K. Correlates of regular exercise during pregnancy: the Norwegian Mother and Child Cohort Study. Scand. J. Med. Sci. Sport. 2009; 19(5): 637-45. Epub. 2008 Jul 8.

Paper II

Owe K. M., Nystad W., Bø K. Association between regular exercise during pregnancy and excessive newborn birth weight. Obstet Gynecol. 2009; 114(4): 770-6.

Paper III

Owe K. M., Nystad W., Skjærven R., Stigum H., Bø K. Exercise during pregnancy and the gestational age distribution: A cohort study. (In press in Med Sci Sport Exer.).

Paper IV

Owe K. M., Nystad W., Vangen S., Stigum H., Bø K. Antenatal exercise decreases Cesarean delivery rate in nulliparous women. (Submitted).

Abbreviations

ACOG	American College of Obstetricians and Gynecologists
ACSM	American College of Sports Medicine
BMI	Body Mass Index
CI	Confidence Interval
GA	Gestational Age
LGA	Large-for-gestational-age
LMP	Last Menstrual Period
MoBa	the Norwegian Mother and Child Cohort Study
PA	Physical Activity
RCOG	Royal College of Obstetricians and Gynaecologists
SGA	Small-for-gestational-age
WHO	World Health Organization
OR	Odds ratio
CI	Confidence Intervals

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1. BACKGROUND

This chapter mainly reviews the literature published up until the date when each of the four papers was initiated: 2006 (paper I), 2008 (paper II), 2010 (paper III), and 2011 (paper IV).

1.1 Physical activity and related concepts

Physical activity (PA) is a behavior broadly defined as any bodily movement produced by skeletal muscles that result in energy expenditure [1]. Its complex nature makes it difficult to assess and quantify in epidemiological studies because it occurs in a variety of forms and settings [2], which reflect the different purposes or circumstances under which physical activities are performed.

Physical fitness, in contrast with physical activity, is not a behavior but relates to various characteristics [3]. Fitness may be operationalized focusing on two goals: performance and health. Performance-related fitness is linked to characteristics associated with performance outcomes and is dependent of the sport. In contrast, health-related fitness often includes body composition, cardiorespiratory fitness, muscular strength and endurance, and flexibility [4]. The level of fitness ranges from low to high.

Leisure-time physical activity (LTPA) includes all kinds of activities one participates in during free time and is selected on the basis of personal interests and needs [5]. Examples of LTPA include formal exercise programs and walking, hiking, gardening, sport, swimming, and dancing. A common feature of these activities is the substantial energy expenditure, although the intensity and duration may vary considerably [4].

Exercise is a subcategory of LTPA that is planned, structured, repetitive and purposeful, whereas the objective is to improve or maintain one or more components of physical fitness [1]. Exercise mode refers to the specific type of exercise performed (e.g. walking, cycling, dancing), but can also be classified into broader types of exercise categories including aerobic, anaerobic, weight bearing or non-weight bearing, high or low impact, resistance or strength exercises. Aerobic exercise involves continuous, rhythmic movement of large muscle groups in dynamic activities that results in substantial increase in heart rate and energy expenditure. High impact exercise refers to any exercise where both feet leave the ground simultaneously (e.g. running and jumping), whereas during low-impact exercise one foot is on the ground at all times (e.g. walking and step aerobics) [4]. Even though all exercises are defined as physical activities, all physical activities cannot be defined as exercises according to the definition.

The dose of LTPA can be described by its *frequency*, *duration*, *intensity* and *typ*e or *mode* of activity. Frequency refers to how often PA is performed and is the number of days or sessions the activity is performed within a particular time frame (e.g., per day, week, or month). The duration of an exercise session is usually expressed in minutes or hours, and refers to the amount of LTPA performed within a fixed time period (e.g., per session, per day, per week). The *intensity* of PA denotes the physical effort required to perform the activity [5], and is the most difficult dimension to assess [6]. It can be expressed in either absolute or relative terms. In absolute terms, intensity is often described by the metabolic equivalent (MET) [5]. One MET is equivalent to the energy expenditure of resting metabolic rate (RMR), and is considered equal to an oxygen uptake (VO_2) of 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$ or 1 $kcal \cdot kg^{-1} \cdot min^{-1}$ for adults at rest [4;7-9]. These expressions of intensity are important in estimating the energy expended during a session or over the course of a training program (intervention) [4]. Hence, Ainsworth and co-workers developed the Compendium of Physical Activities (CPA), which documents the energy expenditure of a wide variety of activities[7;10]. However, in the CPA, MET values assigned for each activity are standardized values for an average adult, and may underestimate the energy expenditure of physical activities performed by pregnant women. Given that both heart rate (HR) and oxygen uptake, and the relationship between these two, are altered in pregnant women, the energy expenditure at rest and during PA will be over- and underestimated, respectively [11], especially in late pregnancy. Hence, applying compendium values to pregnant women may introduce biased estimates of energy expenditure. METs are also used to further categorize PA into light, moderate or vigorous activities based on their intensity [9]. Relative intensity is the percentage of the individual's maximal aerobic power output, or maximal heart rate [5].

However, even though PA by definition expends energy, PA is a behavior, while energy expenditure is the result of this behavior [12;13]. Together with intensity, exercise mode, frequency and duration of exercise determine the physiological responses to exercise [9].

Other dimensions of PA are occupational physical activity (OPA), which includes activities that are associated with performing a job (paid work) [4], and household and other chores such as gardening, dusting and care giving (unpaid work) [5].

In the following, the terms exercise and LTPA will be used and the literature including both terms will be reviewed only.

1.2 Pregnancy, physical activity and exercise

Pregnancy is characterized by a wide range of physiological, biomechanical, endocrine, and psychological changes. For example, pregnancy induces alterations in maternal hemodynamics including increased blood volume, cardiac output, resting heart rate and a decrease in systemic vascular resistance [14;15]. Additional changes occur in the respiratory system, due to increased tidal volume that increases minute ventilation by almost 50% [16;17]. Also, endocrine changes occur which alter the regulation of metabolic and cardiopulmonary functions and contribute to maternal responses to exercise during pregnancy [18]. Some of the pregnancy-related physiological changes that occur may interfere, however, with the ability to engage safely in specific types of exercise and physical activities [19]. The increased body weight is perhaps the most visible change during pregnancy, and may potentially cause discomfort to normal joints due to increased force across joints such as pelvis, hips and knees [20-22], Hence, pregnancy is associated with an increased risk of musculoskeletal disorders [21]. This may in turn affect the ability to perform weight bearing exercises such as running and aerobic dancing [21]. Other anatomical changes that occur as pregnancy progresses are the shift in center of gravity and change in body posture, predisposing pregnant women to falls due to loss of balance. However, scientific data on the influence of increased body weight on joint injury and the risk of falls are lacking [22;23]. The physiological responses to exercise in pregnant women are influenced by exercise mode, intensity, whether the stimulus is acute or chronic (regularity, frequency), and time of gestation [18].

Traditions of women either working hard throughout pregnancy, isolation in the puerperium, or "confinement" have all been based more on social customs rather than scientific data [24]. Historically, there have been concerns that exercise performed during pregnancy could lead to adverse pregnancy outcomes due to three postulated risks: 1) fetal hyperthermia caused by increasing maternal core temperature during embryogenesis, increasing the risk of congenital malformations [25;26]; 2) a redistribution of oxygenated blood to working muscles in the mother, leading to reduced uterine blood flow and fetal hypoxia [27]; and 3) a reduced glucose availability for the fetus because of increased muscular uptake of glucose in combination with reduced blood flow during maternal exercise [28;29]. Towards the end of pregnancy the fetal demand for glucose is increased and it has been hypothesized that exposing the fetus repeatedly to low maternal glucose levels may influence fetal growth [19]. Hence, the medical advice has been to reduce exercise levels for previously exercising women, and for previously non-exercising women to refrain from initiating exercise programs during pregnancy [23;30;31].

1.3 Recommendations for physical activity and exercise in pregnancy

In 1985, the American College of Obstetricians and Gynecologists (ACOG) published their first guidelines for exercise during pregnancy. Due to the limited research available at the time, these guidelines were strictly conservative, stating that pregnant women should avoid intense activities (i.e. jogging or cycling) for more than 15 minutes per session and limit their HR to 140 beats per minutes (bpm) [30]. In practical terms, these first recommendations were similar to the lower limit recommendation for maintaining cardiovascular fitness in non-pregnant adults [8], and precluded obese and sedentary pregnant women. In 1994, a revised version of the guidelines was published, focusing more on the many health benefits of physical activity than was evident in those published in 1985. The heart rate restriction of 140 bpm was removed and it was recommended that pregnant women should preferably participate in physical activity at least three days per week [19]. Eight years later, in 2002, the most recently revised version of the ACOG guidelines was published, reflecting the increasing number of studies on the health benefits of maternal physical activity, instead of the risks. These guidelines now recommended that all pregnant women without medical or obstetric complications, independent of prepregnancy exercise levels, should follow PA guidelines for the non-pregnant population. With the accumulation of 30 minutes of moderate intensity physical activity on most, if not all, days of the week [22], these guidelines are the most pro-active to date.

In addition to the guidelines provided by ACOG, similar guidelines exist in Canada (The Society of Obstetricians and Gynaecologists of Canada, SOGC) [23], Great Britain (The Royal College of Obstetricians and Gynaecologists, RCOG) [32], Australia (Sports Medicine Australia, SMA [33], Denmark [34] and Norway (The Directorate for Health and Social Affairs 2005 [35]). There are, however, some important distinctions to make about these guidelines regarding recommendations for resistance training in pregnancy and contraindications for exercise (Table 1).

Even though very few studies have investigated the effect of resistance training during pregnancy and how it affects the growing fetus [36;37], both the British [32], Australian [33;38], Danish [34], Norwegian[35] and Canadian guidelines encourage pregnant women to participate in strength-conditioning exercises together with aerobic exercises [23]. These guidelines, especially from the SOGC, seem more specific than the American guidelines which state that "activities that promote musculoskeletal fitness, including both resistance training (weight lifting) and flexibility exercises, are typically part of an overall exercise prescription" [22].

Both the Canadian (SOGC) and the American Guidelines (ACOG) provide a list of absolute and relative contraindications in addition to warning signs for when to terminate exercise during pregnancy (Table 1).

Table 1. Contraindications and warning signs for when to stop exercising while pregnant (ACOG [22], SOGC [23]).

Absolute contraindications	Haemodynamically significant heart disease Restrictive lung disease Incompetent cervix/ cerclage Persisted 2nd or 3rd trimester bleeding	Placenta previa after 26 weeks [1] Preterm labor Ruptured membranes Pregnancy induced hypertension
Relative contraindication	Severe anemia Unevaluated maternal cardiac arrhythmia Chronic bronchitis Poorly controlled type-I diabetes [2] Extreme morbid obesity Extreme underweight (BMI <12) Intrauterine growth restriction [2]	Poorly controlled hypertension and preeclampsia Orthopedic limitations Poorly controlled seizure disorder Poorly controlled thyroid disease Heavy smoker History of extremely sedentary lifestyle
Warning signs	Vaginal bleeding Excessive shortness of breath Dizziness (presyncope) Headache [3] Chest pain Muscle weakness [3]	Calf pain or swelling (in case of thrombophlebitis) [3] Preterm labor [3] Decreased fetal movement [3] Leakage of amniotic fluid Painful uterine contractions [4]

[1] SOGC: Placenta previa after 28th week.
[2] SOGC: Absolute contraindications (current pregnancy).
[3] Only ACOG
[4] Only SOGC

1.4 Patterns of LTPA and exercise during pregnancy

In spite of the encouraging guidelines, pregnant women in the western part of the world seem to be less physically active than their non-pregnant counterparts, with a large proportion not exercising at all during pregnancy [39].

The proportion of pregnant women participating in physical activity at any time during pregnancy ranges from 41-66% [39;40], depending on the methods used to assess physical activity and exercise levels and the population under study. It has been anticipated that pregnancy is a period in life when physical activity levels decline [41;42], but a search on PubMed in 2006 when I started this thesis, revealed that only three studies had addressed this question [39;42;43]. Zhang and Savitz [43] assessed leisure time physical activity in US women before and during pregnancy. They did this retrospectively, on average 17 months postpartum, using the National Maternal and Infant Health Survey (NMIHS, 1988). The prevalence of exercising during pregnancy in their study was 42%. Evenson and co-workers [39] conducted a population-based cross-sectional study with pregnant US women, reporting their physical activity level at random times during pregnancy. The prevalence of any PA in the past month was 65.6% among pregnant women compared to 73.1% in non-pregnant women. A study by Mottola and Campbell [42], was also a questionnaire-based survey and was based on a case-control study originally designed to examine the influence of exercise on birth weight. The levels of physical activity before and during the third trimester of pregnancy (70 and 49%, respectively) were based on retrospective recall and defined as activities undertaken for the purpose of exercise (i.e. structured exercise). All three studies describing exercise and leisure time physical activity (LTPA) among pregnant women were based on pregnant women living in North America. Little is known about physical activity and exercise patterns in pregnant women living in other countries. Large differences in the ethnic composition of different populations, geographical and seasonal variations, and cultural and social differences may have an impact on women's participation in physical activity and exercise during pregnancy.

Studies that identify important maternal and fetal benefits or risks of exercise and physical activity during pregnancy have recently been emphasized [44;45]. In light of the lack of data in this area, there is however a need to identify exercise patterns among pregnant women and to explore how this health-related behavior changes from prepregnancy until late pregnancy.

Correlates of LTPA and exercise in pregnant women

Besides identifying patterns of exercise and LTPA, it is also crucial to understand and identify different sociodemographic factors that are associated with these behaviors in order to target groups within a population for interventions [46;47]. Given the potential beneficial effects of exercise during pregnancy, such as the possible prevention of preeclampsia, gestational diabetes, and chronic musculoskeletal conditions, support of healthy weight, and improved mental health [23;48-50], understanding patterns of exercise during pregnancy and their correlates has great implications for public health. However, studies on correlates and predictors of regular exercise during pregnancy are few, and most population-based studies have been retrospective in nature [40;43], or collected data on LTPA at random time points during pregnancy [39]. Both younger age, educational level, parity, marital status, prepregnancy BMI and smoking have been found to be associated with physical activity and exercise during pregnancy among women living in North America [39;40;43;51], whereas little is known about these factors in association with PA and exercise during pregnancy in other populations. Knowledge on how pregnancy-related health complaints, such as nausea, urinary incontinence and pelvic girdle pain, may influence exercise patterns have not been evaluated in a population based setting.

1.5 Exercise during pregnancy and reproductive outcomes

In this dissertation, reproductive outcomes are defined as excessive birth weight, gestational age and cesarean delivery (mode of delivery).

Newborn birth weight

Birth weight has become one of the most commonly reported reproductive outcomes, both in the field of reproductive epidemiology and in sports medicine. In addition to being highly accessible, birth weight is also precise and easy to measure. In most developed countries, including Norway, birth weight is registered by law as part of the birth certificate data. The strong association between low birth weight, defined as less than 2500 g, and high infant mortality is perhaps the most important reason for its popularity. Nevertheless, there are questions about the role of birth weight as a substitute for infant health and whether the link between birth weight and mortality is causal [52;53]. Some even argue that birth weight may mask other underlying causes such as preterm birth, fetal growth restriction and a genetic predisposition for being small at birth [54].

Low birth weight (LBW) is defined as newborn birth weight less than 2500 grams, and may occur because of a shorter gestational length, intrauterine growth retardation, or a combination of the two. In Norway, the incidences of low birth weight and very low birth weight (<1500 grams) are 5.3% and 1.3%, respectively (2009), and have remained rather stable over the last decade [55].

There is no widely agreed upon definition of high birth weight and both absolute and relative measures have been used. Fetal macrosomia is often defined as birth weight above 4000 or 4500 grams, regardless of gestational length [56]. When birth weight exceeds an upper limit, often set at 4000 g, both mother and child are at greater risk of morbidity, including perineal lacerations, postpartum hemorrhage, cesarean delivery, shoulder dystocia, low Apgar score, birth trauma and obesity [57-59]. Between 1990 and 2000, mean birth weight in Norway increased from 3474 (SD 639) g to 3532 (SD 662) g. At the same time, we also experienced an increased proportion of newborns with a high birth weight (>4000 g) from 17.9% in 1990 to 21.9% in 2000. A similar increase was also observed for birth weight above 4500 g (3.3% and 4.7%, respectively) [55]. The reason for this increase is unknown and we do not have national data on modifiable factors such as diet and/ or LTPA among pregnant women, and therefore can only speculate on the influence of these factors.

Normal fetal growth is a critical component of a healthy pregnancy and influence the long-term health of the offspring [60]. Abnormal fetal growth and fetal growth restriction in particular, have been linked to some of the common lifestyle diseases such as type 2 diabetes mellitus and cardiovascular conditions in later life [61].

Exercise and birth weight

Previous studies investigating the relationship between maternal exercise and birth weight were primarily concerned that exercise during pregnancy would decrease mean birth weight and/or increase the risk of having a low birth weight baby (<2500 g). These concerns originate from early studies reporting a redistribution of blood flow to working muscles away from the uterus leading to reduced uterine blood flow [62-64]. Reduced energy supply to the fetus during exercise was also reported, because of increased maternal utilization of carbohydrates during exercise [65;66], again leading to restriction in fetal growth. However, two of these early studies were animal studies [62;63] and replication in human studies has been difficult. Furthermore, studies that have assessed the association between LTPA or exercise during pregnancy and *mean* birth weight in humans, have been inconsistent and shows both *increased* mean birth weight [67-69], *reduced* mean birth weight [65;70;71] and no difference in mean birth weight [72-77].

Nevertheless, a shift in mean birth weight may be of little relevance to the practicing obstetrician or midwife, whose main concern is at the two extremes of the birth weight range where maternal and perinatal complications increase [78]. Thus, extrapolating from effects on mean birth weight to other parts of the distribution can be misleading, if a factor which causes a shift in mean birth weight exerts more or all of its influence at one extreme, and little or nothing at the other. Furthermore, a factor which only affects the variation of the birth weight distribution will make no difference to the mean but would increase (or decrease) the proportion at both extremes [78]. Regular exercise may be an example of such a factor, rendering physical inactivity a risk factor for excessive newborn birth weight. Before I started with paper II, only two small studies, a retrospective and a cross-sectional study, had assessed the association between LTPA during pregnancy and excessive newborn birth weight. Hence, stating a causal relationship is difficult because the exposure (maternal LTPA and exercise) and outcome (excessive birth weight) are measured at the same time. Another weakness is failure to account sufficiently for possible confounders associated with both exposure and outcome. Despite an extensive literature on the relationship between regular exercise during pregnancy and *mean* birth weight, studies on the association with the upper range of the birth weight distribution are needed.

Gestational age at birth

It has been argued that gestational age is the most important measurement in reproductive epidemiology because it separates miscarriages from stillbirths and preterm births. In humans, a normal pregnancy lasts 9 months or 40 weeks (280 days), but the duration of a healthy term pregnancy has wide biological variations. Unlike birth weight, length of gestation is relatively constant across variables such as sex of the baby, maternal smoking and parity [79]. Even though gestational age is such an important reproductive outcome, it can only be estimated approximately. In Norway, the mean gestational age is 39.2 (SD 2.4) completed weeks [55].

Preterm birth is defined as birth occurring before 37 completed weeks of gestation and is a serious global health problem and one of the leading causes of child death worldwide [80]. Infants born preterm are at greater risk for short and long term complications, including disabilities and impairments in growth and mental development [81].

However, when born preterm, a neonates' ability to survive and the extent to which neurological, psychological and physical development follows, is determined by birth weight [82]. Significant progress has been made in the care of premature infants, but not in reducing the prevalence of preterm delivery. Women are identified as being at increased risk for preterm delivery on the basis of their past obstetric history or the presence of known risk factors such as maternal age (<20 or >40 years), parity, high prepregnancy BMI, smoking, low educational level and socioeconomic status [83;84]. Preterm birth is a significant cost factor in healthcare, and the expenses of long-term care for individuals with disabilities due to preterm birth are considerable [81]. Despite extensive investigation, little progress has been made in identifying modifiable behavioral causes of preterm birth [85]. Hence, from a public health perspective it is important to know whether factors such as those related to lifestyle and behavior influence gestational age and thereby preterm delivery.

Also, when gestational age exceeds 41 completed weeks, both perinatal mortality and morbidity are increased [86;87]. Very few studies have been carried out looking at prolonged pregnancies, but studies focusing on the adverse effects of inductions of labor are increasing. Heimstad et al [87] showed that the perinatal death rate increased with increasing gestational age, but that implementing routine induction of labor at 41 weeks gestation would need more than 14,000 inductions a year. According to current national guidelines [88], pregnancies are allowed to continue beyond 294 days (42 weeks) of gestation.

Exercise and gestational age

Theoretically, exercise during pregnancy could induce preterm delivery via uterine contractions due to increased levels of noradrenalin, which affect the uterus. Mechanical stimulation of the uterus during exercise may also explain the increased uterine contractility observed in relation with physical exercise/activity [89;90]. The literature shows conflicting results as to whether physical exercise actually increases uterine contractility [91-93]. Grisso et al [92] found stair climbing and walking influenced the frequency of uterine contractility, whereas structured exercise did not. Previously published studies have shown a reduced risk of preterm delivery among regular exercisers [84;94-99], and regardless of the definition of PA, no observational study has found LTPA or exercise to be associated with an increased risk of preterm delivery [100].The Cochrane review by Kramer and McDonald [44] also reported absence of effect on mean gestational age when assessing eleven small randomized controlled trials involving 472 women. However, Madsen et al [101] found an increased risk of miscarriage with increasing amount of exercise, with the greatest risk among women exercising more than 7 hours/week compared no non-exercisers (HR = 3.7, 95% CI 2.9-4.7), and the risk was particularly increased in women doing high-impact exercise. After week 18 of pregnancy, however, no association was seen between exercise and risk of miscarriage [101].

Nevertheless, the existing literature has primarily focused on the association between exercise during pregnancy and *preterm* delivery. The possible link between exercise performed at different time points during pregnancy across the entire distribution of gestational age, including both preterm and post-term birth, has not been studied.

Cesarean delivery

Cesarean delivery (CD) rates have increased during the last decades in developed countries [102;103]. A corresponding increase in non-medical indications for cesarean delivery has also been reported, implying that some of the CDs performed may be medically unnecessary, exposing both woman and fetus to risks without proven benefits [104]. Factors such as maternal age (>35 years), low level of education, having assisted reproduction, women who are overweight or obese, who experience GDM or hypertension are more likely to have a CD [105;106].

In Norway, the majority of childbirths are vaginal, either spontaneous or induced. In 2009, the Medical Birth Registry of Norway [55] registered 61,400 live births of which 17.2% were delivered by Cesarean section, both acute and elective type.

Exercise during pregnancy and Cesarean delivery

Even though mode of delivery in relation to exercise during pregnancy has been a topic of interest in this field for several decades, few population based studies have been carried out to investigate this. The results have varied, with two studies indicating no association between exercise and CD [107;108], and two showing a positive association [37;109]. However, previous studies have used clinical populations, small sample sizes, and have failed to adjust for confounding factors. Moreover, CD is often only one out of many reproductive outcomes assessed. In a RCT by Barakat and co-workers [107], the effect of light-intensity resistance training was assessed during the 2nd and 3rd trimester in previously sedentary women, on mode of delivery, as a secondary outcome. They did not find any differences in the prevalence of Cesarean delivery among the intervention or control group [107].

Bungum et al [109] reported an adjusted OR of 4.5 for having a CD among sedentary women compared to women who were physically active during the first and second trimesters. In the study by Clapp [110], women who maintained their exercise level at or above 50% of their preconceptional level through pregnancy had a significantly lower CD rate compared with women who discontinued their exercise routines. Meanwhile, women who exercised at moderate intensity and for 40 minutes at least twice a week had significantly fewer CD, in the study by Zeanah and Schlosser [111]. Due to small sample sizes, neither Clapp nor Zeanah and Schlosser had the power to perform multivariable analyses to produce adjusted CD rates in their studies. None of the previous studies has estimated the separate associations between exercise during pregnancy and the different types of CD (i.e. acute versus elective).

2. THE PRESENT STUDY

In Norway, large population based health registries and a large population based pregnancy cohort are made available for research, providing a unique opportunity to explore the associations between recreational exercise during pregnancy and reproductive outcomes.

2.1 Objectives

The aims of the study in the four papers included in this dissertation are:

a) First, to describe the level of exercise during pregnancy and to assess factors associated with regular exercise.
b) Second, to estimate the association between regular exercise before and during pregnancy and excessive infant birth weight.
c) Third, to estimate the associations between exercise performed during pregnancy and gestational age at birth.
d) Fourth, to examine the association between exercise during pregnancy and Cesarean delivery, both acute and elective CD, in nulliparous women.

2.2 Material and Methods

The Norwegian Mother & Child cohort study (MoBa)

MoBa is a nationwide population-based pregnancy cohort study conducted by the Norwegian Institute of Public Health. Recruitment started in 1999 and by the end of 2008 more than 108,000 children and 90,700 mothers had been included. The overall aim of the study is to elucidate the etiology and pathogenesis of disorders that may originate in early life. The study is based on health data from mother and child during pregnancy and the adolescence of the child, and includes all geographical parts of Norway representing both rural and urban areas. Women were recruited into the study through a postal invitation sent out two weeks ahead of the routine ultrasound examination which is offered to all pregnant women in Norway in weeks 17-18. Hence, the majority of pregnant women in Norway were invited and the participation rate is around 44% (second and fourth version of the quality assured MoBa data file) [112]. Mothers completed three questionnaires during pregnancy weeks 15-17 (Q1 and Q2) and 30 (Q3). Q1 and

Q3 covered maternal health, demographics, lifestyle behaviors and medical history, whereas Q2 was a food frequency questionnaire (FFQ). Fathers also completed a questionnaire at gestational week 17-19. Additional questionnaires are administered at 6, 18, 36 months, 5, 7, and 8 years after birth [112]. Genome-wide association study and candidate gene studies of MoBa material are in progress, and results from these will be made available for researchers [112;113]. All questionnaires are available at www.fhi.no/morogbarn.

The Medical Birth Registry of Norway (MBRN)

The MoBa data set was linked to the MBRN which is based on compulsory recording of all live births and stillbirths in Norway from 12 weeks gestation. All records are matched with the files of the Central Person Registry, to ensure registration of every newborn in Norway [114]. The birth registry provides a unique opportunity to study birth outcomes in this population.

The current dissertation is based on information on pregnancies included in the second (papers I and II) and the fourth (papers III and IV) quality assured versions of the MoBa data file released for research in April 2006 and January 2009, respectively. Due to the fact that MoBa is an ongoing cohort study with a long lasting recruitment period (1999 – 2008), the study populations for each study varied according to the version of the data file used and the number of questionnaires required for inclusion in the different studies. In papers I, II and IV we included pregnancies with available data from both the first (Q1) and third questionnaires (Q3), whereas in paper III only Q1 had to be completed to be included. In paper II we also used information on energy intake from Q2, which was a Food Frequency Questionnaire (FFQ). Figure 1 shows the flow of participants into each of the four papers, which data file was used, the number of questionnaires required, exclusion criteria, and the final study sample in each study (analytic sample). Multiple pregnancies (twins or triplets) were excluded from all study populations except for the study population in paper I.

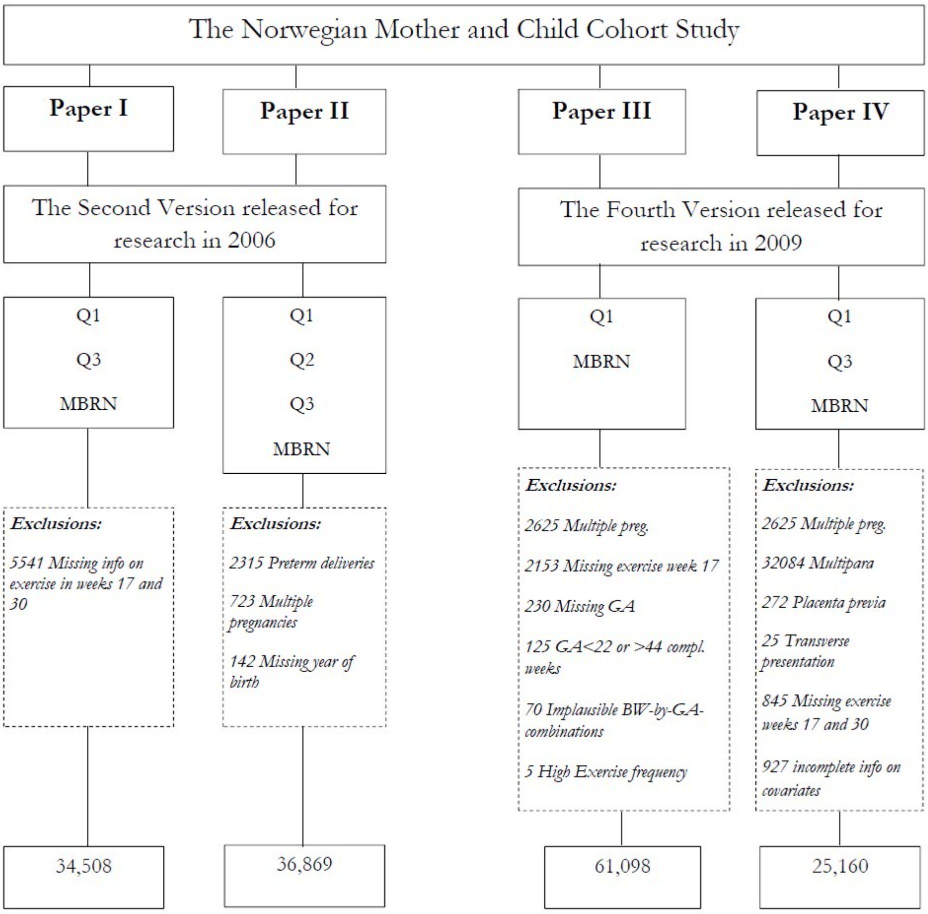


Figure 1: Overview of participants, which versions of MoBa data files were used, the number of questionnaires required, exclusion criteria, and the final study sample in papers I-IV. (MBRN = Medical Birth Registry of Norway. Q1 = Questionnaire 1. Q2 = Questionnaire 2. Q3 = Questionnaire 3.)

Outcome variables

Regular exercise (Paper I)

The main outcome variable in paper I was regular exercise during pregnancy, defined as participating in any combination of recreational activities at least 3 times a week [8;115]. The participants were asked to report how often they engaged in the following recreational activities during pregnancy weeks 17 and 30: strolling, brisk walking, running (jogging or orienteering), bicycling, fitness training in training centers, swimming, aerobic classes (low or high impact), prenatal aerobic classes, dancing, skiing, ball games, horseback riding and other. Frequency had five categories: “never”, “1-3 times per month”, “once a week”, “twice a week”, and “≥3 times a week”. We merged aerobic classes (high and low impact aerobics) and prenatal aerobic classes into “aerobic dancing”. Furthermore, the level of exercise was defined in terms of frequency and categorized as non-exercisers, irregular or regular exercisers. Women who answered “never” or “1-3 times a month” were referred to as non-exercisers. A frequency of 1-2 times a week was defined as irregular exercisers and ≥3 times a week was defined as regular exercisers. Strolling was not defined as a recreational activity due to its very low intensity [10], and therefore was excluded before estimating exercise levels before and during pregnancy.

We assessed the following reproductive outcomes in papers II-IV, obtained from the Medical Birth Registry of Norway:

Excessive newborn birth weight (Paper II)

The main outcome measure in the second paper was excessive newborn birth weight. To account for the increasing birth weight with increasing parity, we defined birth weight to be excessive if it was equal to or above the 90th percentile by parity (i.e. 4170 g and 4362 g for nulliparous and multiparous women, respectively).

Gestational age at birth (Paper III)

Gestational age was determined based on expected date of delivery according to ultrasound examination, or if ultrasound data were missing, estimated from the date of the last menstrual period (LMP) [116]. Delivery (both live- and stillbirth) was defined as a terminated pregnancy after 22 and before 45 completed weeks. We estimated gestational age in completed weeks. Pregnancies completed before 37 weeks (259 days) were defined as preterm, and those above 42 weeks gestation (294 days) were defined as post-term.

Cesarean delivery (Paper IV)

Cesarean delivery (CD) was indicated as acute, elective or unspecified CD. Acute CD was defined as a CD where the decision was made within 6 hours of delivery. The validity of mode of delivery in the MBRN is considered to be high with a 3% error rate [117].

Main exposure variable

Recreational exercise was the main exposure in this dissertation, except for paper I, in which regular exercise (≥ 3 times per week) was the main outcome.

Recreational exercise (papers II-IV)

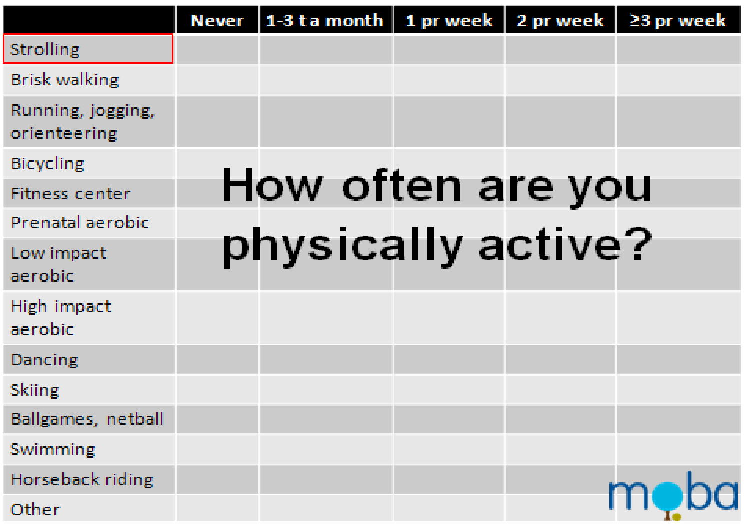
Recreational exercise was defined in terms of frequency per week. In both questionnaires Q1 and Q3, the participants were asked how often they participated in the following 14 different types of exercise: strolling, brisk walking, running (jogging or orienteering), bicycling, fitness training in training centers, swimming, aerobic classes (low or high impact), prenatal aerobic classes, dancing (swing, rock, folkdance), skiing (cross-country skiing), ball games, horseback riding and other. For all exercises, the frequency of exercise was categorized as: "never", "1-3 times per month", "once a week", "twice a week", and "≥3 times a week". We merged "once a week" and "twice a week" into "1-2 times a week". "Non-exercisers" were defined as those who responded "never" to all exercises. Strolling was excluded from the analysis due to its very low energy expenditure [10] and to avoid overestimating exercise levels.

Regular exercise participation before pregnancy was collected retrospectively in pregnancy week 17 (Q1). The respondents were asked to recall the type and frequency of exercises performed during the last three months before the present pregnancy. Thus, exactly the same questions were used to assess recreational exercise before and during pregnancy weeks 17 and 30. Figure 2 shows an unauthorized English translation of the questions used to assess recreational exercise in the present dissertation.

In papers III and IV, the highest frequency category (i.e. "≥3 times a week") was divided into two exclusive categories: "3-5 times per week" (e.g. one or two exercises three times a week or more often) and "≥6 times a week" (e.g. three or more exercises at least three times a week), by summing up the number of exercises performed per week. This was done as an attempt to capture the highly active women and to explore if the association between exercise and two different reproductive outcomes (gestational age and Cesarean delivery) changed with further increases in frequency of exercise.

Types of exercise

In papers III and IV, we also grouped exercises based on type: non-exercisers (strolling and never), brisk walking, non-weight bearing (cycling and swimming), low impact exercises (prenatal aerobics, low impact aerobics, dancing, cross-country skiing, and fitness training), high impact exercises (running, jogging, orienteering, ballgames), and horseback riding (horseback riding and other). A mixed exercise group included those who did not have a single dominant exercise mode (e.g. one session of jogging and one session of swimming per week). Based on the definition of exercise by Caspersen et al [1], strolling was categorized as non-exercise.



How often are you physically active?

	Never	1-3 t a month	1 pr week	2 pr week	≥3 pr week
Strolling					
Brisk walking					
Running, jogging, orienteering					
Bicycling					
Fitness center					
Prenatal aerobic					
Low impact aerobic					
High impact aerobic					
Dancing					
Skiing					
Ballgames, netball					
Swimming					
Horseback riding					
Other					

Figure 2. Types and frequencies of recreational exercise in MoBa.

In a preliminary version of questionnaire 1 (version 1A), information on *duration* of recreational exercise was collected in 2555 women, in addition to frequency and type. Unfortunately, due to extensive revisions of the MoBa questionnaires, the question on *duration* was removed in the following revised versions. Hence, we excluded the 2555 women who had answered the first version of questionnaire 1.

Comparison with objectively measured PA

The questions used to assess recreational exercise in this dissertation have been compared with objectively measured (ActiReg®) physical activity in a sub-sample of 112 MoBa participants [118]. As part of a validation study of the MoBa FFQ (Q2), accelerometers worn for 4 consecutive days provided objectively assessed energy expenditure, which was used to evaluate the probable range in energy intakes by the same women [119;120]. Women had to complete Q1 and Q2 by gestational weeks 17-18 and receive a routine ultrasound examination at Bærum Hospital in Oslo in order to be eligible for the validation study. Exclusion criteria were hyperemesis and anorexia nervosa. Out of 119 included women, 112 completed the ActiReg® assessment. Based on recordings from two sensors attached to the chest and the front of the right thigh, the ActiReg® measures PAL (physical activity level). The ActiReg® was worn at all times except during water- based activities or at night while sleeping. If the accelerometer was not in use for a period of 15 minutes or more during the daytime, the participants were instructed to record the type of activity performed during that time. Seven women reported swimming, but VPA_{AR} (vigorous physical activity measured by accelerometer) could not be approximated and swimming was thus excluded from reported exercise activities for comparison with VPA_{AR}. The ActiReg has been used to validate physical activity questions and questionnaires in different populations, but not in pregnant women [121;122].

The Pearson's correlation coefficient comparing self-reported weekly exercise and the objectively assessed variables ranged from r=0.17 for total energy expenditure (TEE) to r=0.32 for vigorous physical activity (VPA). All partial correlation coefficients remained unchanged after adjustment except for TEE for which r increased to 0.27 ($p<0.01$). We concluded that the questions used to assess recreational exercise in MoBa (frequency and type) may be useful for ranking women according to their level of recreational exercise [118].

Correlates

Socio-demographic and pregnancy related factors associated with regular exercise during pregnancy were the independent variables under study in paper I. These variables are referred to as *correlates* of regular exercise in the paper.

Socio-demographic and pregnancy related variables (paper I)

We included the following socio-demographic variables from questionnaire 1 (Q1) distributed in pregnancy week 17: maternal age, maternal education, marital status, prepregnancy body mass index (BMI), and smoking status. Maternal education was defined as the highest completed education at enrollment and was categorized as "primary school (9 years)", "secondary school (12 years)", college/university (≥ 15 years)", and "other". Prepregnancy BMI (kg/m^2) was calculated from self-reported body weight and height in Q1 and was categorized according to WHO's definitions for underweight (<18.5), normal weight (18.5-24.9), overweight (25.0-29.9), obese (30.0-34.9), and morbidly obese (≥ 35). Pregnancy-related health problems obtained from Q1 and Q3 were: pelvic girdle pain, urinary incontinence, nausea (with or without vomiting), severe fatigue, musculoskeletal pain (i.e. lower back pain and neck/shoulder pain), and pregnancy induced high blood pressure. Information on uterine contractions (after week 13) was collected from Questionnaire 3 in pregnancy week 30. From the MBRN we obtained information on parity and whether or not it was a multiple pregnancy (i.e. more than one fetus).

2.3 Statistical methods

In papers I and II, the outcome variables were binary and the effect estimates were obtained by logistic regression models. We reported crude and adjusted odds ratios (OR) with 95% Confidence Intervals (95% CI) from the models. Three models were used to estimate the association between regular exercise before (Model A) and during pregnancy (Model B and C) and excessive newborn birth weight (paper II). A Wald test was also used to test for trend across categories of exercise frequency. To investigate which types of exercise were associated with excessive birth weight, we performed a stepwise logistic regression. The possible interaction between maternal height and regular exercise was estimated by stratification and multiplicative interaction term. In order to determine if the adjusted ORs differed for pregnancy weeks 17 and 30, the following equation was used: $Z = \frac{b1 - b2}{\sqrt{(SEb1)2} + \sqrt{(SEb2)2}}$. If Z > 1.96 the adjusted ORs were significantly different ($p < 0.05$).

To compare mean gestational age by exercise levels during pregnancy in paper III, a one-way ANOVA with Bonferroni test was conducted separately for pregnancy weeks 17 and 30. We estimated the adjusted association between recreational exercise and gestational age at birth using a general linear model. Different models were then fitted with exercise frequency or types of exercise in pregnancy weeks 17 and 30, respectively, as the independent variable. We estimated the adjusted cross-sectional association between exercise and mean gestational age at birth using general linear model for pregnancy weeks 17 and 30. To estimate the risks of preterm and post-term birth by exercise levels, we used logistic regression analysis. To fully understand the effect of exercise at different time points during pregnancy, a model was then fitted by adding interaction terms combining all values of exercise in gestational weeks 17 and 30. We also combined all values of exercise three months prepregnancy with exercise in pregnancy week 17, to investigate if the association between exercise in week 17 and gestational age was independent of prepregnancy exercise level.

In an additional set of analyses we excluded pregnancies complicated by preeclampsia, pregnancy induced hypertension, persistent vaginal bleeding, at least two previous spontaneous abortions, assisted reproduction (present pregnancy), and those terminated by a Cesarean section (n=17,572). These analyses were performed to adjust for confounding by indication [123]. The effect of such an exclusion will be strong for complications with high recurrence risk and a high risk of preterm delivery, i.e. complications that are strongly associated with both the exposure (exercise) and the outcome (gestational age at delivery). Preeclampsia, pregnancy induced hypertension, persistent vaginal bleedings and having at least two previous spontaneous abortions are all contraindications for participating in regular exercise during pregnancy [22].

Due to a high incidence of the outcome of interest in paper IV (Cesarean delivery, 15.6%), we used the generalized linear model with identity link function and binominal distribution to estimate the association between antenatal exercise (both frequency and types of exercise) and CD, both acute and elective CD. Maternal age, prepregnancy BMI, educational level, marital status, assisted reproduction prior to this pregnancy, pelvic girdle pain and fear of childbirth were included as covariates in the models. From the models we reported the risk differences (RD) with 95% Confidence Intervals (Wald) using vaginal delivery as the reference category. When estimating the association between exercise and acute CD, pregnancies terminated by an elective or unspecified CD were excluded. Likewise, acute and unspecified CDs were excluded when elective CD was the dependent variable.

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 14 (paper I), version 15 (paper II), and PASW version 18 (papers III and IV).

Covariates and confounding

A covariate was included as a confounder in the regression models if it was associated with both the exposure and the outcome (figure 3). Potential confounders were considered based on the existing literature and knowledge on possible associations between maternal exercise and reproductive outcomes. In papers III and IV we used direct acyclic graphs (DAGs) [124] to assess covariates and confounding based on the review of previous studies and an assumed possible underlying causal mechanism. A more detailed description of covariates, mediators and possible confounders are written in the methods section in papers I-IV

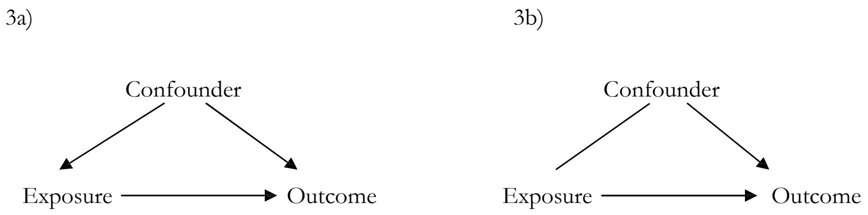


Figure 3. DAG (directed acyclic graph) of the assumed possible underlying causal mechanism. Arrows indicate causal directions of effects and lines indicate an association, but not necessarily a causal effect.

Missing

In papers I and II, missing values on covariates and exposure, respectively, were replaced by dummy variables and included in the multivariable analysis. Rates of missing data ranged from 0.2-0.7% and up to 2.7% for prepregnancy BMI (paper I). The multivariable regression analysis was run both with and without these dummy variables and these did not change the effect estimates substantially (data not shown). In paper III, missing values on exposure and outcome were excluded from the analytic sample. In paper IV, the final sample did only include participants with complete information on exposure, outcome and selected covariates in the models.

2.4 Ethical issues

Informed consent was obtained from each participant before inclusion into the MoBa study. The study has received approval from the Regional Committees for Medical Research Ethics (S-95113) and The Norwegian Social Science Data Services (01/4325-6), and guidelines and specific requirements for this study are being followed.

3. RESULTS

3.1 Summary of papers

Paper I

Owe KM, Nystad W, Bø K. Correlates of regular exercise during pregnancy: the Norwegian Mother and Child Cohort Study.

Objective: To describe the level of exercise during pregnancy and to assess factors associated with regular exercise.

Methods: Using data from the Norwegian Mother and Child Cohort study (MoBa) conducted by the Norwegian Institute of Public Health, 34,508 pregnancies were included in the present study. Data were collected by self-completed questionnaires in gestational weeks 17 and 30, and analyzed by logistic regression analysis. The results are presented as adjusted odds ratios (aOR) with 95% confidence interval (95% CI).

Results: The proportion of women exercising regularly was 46.4% before pregnancy and decreased to 28.0% and 20.4% in weeks 17 and 30, respectively. Walking and bicycling were the most frequently reported activities before and during pregnancy. The prevalence of swimming tended to increase from prepregnancy to week 30. Exercising regularly prepregnancy was highly related to regular exercise in week 17, aOR=18.4 (17.1-19.7) and 30, aOR 4.3 (4.1-4.6). Low gestational weight gain was positively associated with regular exercise in week 30, aOR=1.2 (1.1-1.4), whereas being overweight before pregnancy was inversely associated with regular exercise in week 17, aOR=0.8 (0.7-0.8) and 30, aOR=0.7 (0.6-0.7). Also, women experiencing a multiple pregnancy, pelvic girdle pain or nausea were less likely to exercise regularly.

Paper II

Owe KM, Nystad W, Bø K. Association between regular exercise during pregnancy and excessive newborn birth weight.

Objective: To estimate the association between regular exercise before and during pregnancy, and excessive infant birth weight.

Methods: Using data from the Norwegian Mother and Child Cohort Study (MoBa), 36,869 singleton pregnancies lasting at least 37 weeks were included. Information on regular exercise was based on answers from two questionnaires distributed in pregnancy weeks 17 and 30. Linkage to the Medical Birth Registry of Norway (MBRN) provided data on infant birth weight. The main outcome measure was excessive infant birth weight, defined as birth weight at or above the 90th percentile. Logistic regression analyses were used to estimate the associations separately for nulliparous (n=16,064) and multiparous (n=20,805) women, and the results are presented as adjusted odds ratios (aOR) with 95% confidence intervals (95% CI).

Results: Excessive infant birth weight was observed in 4033 (10.9%) infants, 56.1% (n=2263) of whom were born to multiparous women. An inverse association between regular exercise (≥3 times per week) and excessive infant birth weight in pregnancy weeks 17 and 30 was observed in nulliparous women, aOR=0.72 (95% CI 0.56-0.93) and aOR=0.77 (95% CI 0.61-0.96), respectively. Regular exercise performed before pregnancy did not affect the probability of delivering newborns with an excessive birth weight in nulliparous or multiparous women.

Conclusion: Regular exercise during pregnancy reduces the odds of giving birth to newborns with excessive birth weight by 23-28%.

Paper III

Owe KM, Nystad W, Skjærven R, Stigun H, Bø K. Exercise during pregnancy and the gestational age distribution: A cohort study.

Objective: To examine the associations between exercise performed at different time points during pregnancy and gestational age in a population based cohort study.

Methods: Data were included from 61,098 singleton pregnancies enrolled between 2000 and 2006 in the Norwegian Mother and Child Cohort Study (MoBa), conducted by the Norwegian Institute of Public Health. Self-reported exercise was collected from two questionnaires in pregnancy weeks 17 and 30. Gestational age was determined based on expected date of delivery according to ultrasound, as registered in the Medical Birth Registry of Norway. We used logistic regression to analyze preterm (<37 completed weeks) and post-term birth (≥42 weeks). Comparison of mean gestational age (GA) by exercise levels were estimated by general linear model.

Results: Mean GA for women exercising 3-5 times a week in week 17 was 39.51 (95% CI 39.48-39.54) compared to 39.34 (39.30-39.37) completed weeks for non-exercisers (p<0.001). Mean differences remained for all categories of exercise after adjusting for confounding with the greatest mean difference between exercising 3-5 times per week in week 17 and non-exercisers (equals 1 day). Similar mean differences in GA were observed by exercise levels in week 30. The greatest protective effects of preterm birth were observed for women exercising 3-5 times a week in weeks 17 or 30 (aOR=0.82; 95% CI 0.73-0.91; and 0.74; 0.65-0.83, respectively). Whereas, women exercising 1-2 or 3-5 times per week in week 17, were slightly more likely to have a post-term birth (aOR=1.14;1.04-1.24; aOR=1.15;1.04-1.26, respectively). Mean GA did not differ by type of exercise performed during pregnancy.

Conclusion: Exercise performed during pregnancy does not influence mean gestational age but is associated with a protective effect of preterm delivery.

Paper IV

Owe KM, Nystad W, Vangen S, Stigum H, Bø K. Antenatal exercise decreases Cesarean delivery rate in nulliparous women.

Objective: To investigate the association between exercise during pregnancy and CD, both acute and elective, in nulliparous women.

Methods: A total of 25,160 nulliparous women with a singleton pregnancy enrolled in the Norwegian Mother and Child Cohort Study (MoBa) between 2000 and 2006, were included. We performed a generalized linear model with identity link function and binominal distribution. From the models we reported the risk differences (RD) with 95% Confidence Intervals (Wald).

Results: The total CD rate was 15.6% (n=3928), whereas 67.8% (n=2663) of these were acute CDs. CD rates, both acute and elective type, were reduced in women exercising during pregnancy. The greatest risk reduction (-3.8 and -4.5 percent), was observed for acute CD among women reporting a high weekly frequency of exercise during pregnancy weeks 17 and 30, respectively. Compared to non-exercisers, participation in high impact exercises in weeks 17 and 30, such as jogging, running, orienteering, ballgames, or high-impact exercises, was associated with the largest reductions in risk (-5.1 and -6.2 percent, respectively).

Conclusion: Compared to non-exercisers we found a substantially reduced risk of having a CD among women exercising during pregnancy. A possible link between recreational exercise and reduced risk of CD provides new perspective on possible interventions to increase vaginal delivery rates for first time mothers

4. DISCUSSION

This dissertation presents data from one of the largest population based pregnancy cohorts to date, assessing exercise levels during pregnancy, its correlates and association with reproductive outcomes such as excessive birth weight, gestational age and cesarean delivery. In the following discussion, I will focus on the main results and the study's strengths and limitations.

4.1 General discussion

4.1.1 Regular exercise during pregnancy (Paper I)

In MoBa we observed a decline in regular exercise wherein the proportion of non-exercising women increased from three months before pregnancy and throughout pregnancy. Brisk walking and bicycling were the two most commonly reported activities both before and during pregnancy, whereas a higher proportion of women were swimming in late pregnancy compared to prepregnancy. These results are in line with other observational studies, regardless of study design, definition of physical activity and exercise used, and study populations in previous studies [39;40;42;125-130]. Another popular exercise was aerobic dancing, which included both high- and low impact aerobic and prenatal aerobic classes, as it was ranked among the five most common activities at all times. We also observed a higher proportion of women exercising during pregnancy compared with women in the Danish National Birth Cohort (DNBC) [131] (59% versus 37% in early pregnancy, respectively), even though we categorized strolling as non-exercise. A possible explanation may be that Juhl and co-workers assessed exercise levels by interviewing women and asking "Now that you are pregnant, do you engage in any kind of exercise". In case of uncertainty about which activities to report as exercise in the DNBC, the activity should make the women sweaty or short of breath [131]. We did not have the opportunity to clarify this in the questionnaires; hence our measure of recreational exercise may be over-reported compared to the DNBC. However, other aspects such as preferred type of exercise and changes in exercise levels during pregnancy were similar in the two cohorts.

Based on our observations, pregnancy did not seem to influence the choice of recreational exercises when it came to walking and bicycling, as these activities were the most frequently reported activities both before and during pregnancy.

To our knowledge, this is the first study to report that swimming increased from prepregnancy to gestational week 30. Swimming is widely recognized as one of the safest forms of exercise for pregnant women due to maintained thermoregulation by preventing overheating, the buoyancy, and the redistribution of blood flow from the periphery to the internal viscera [24]. Even light to moderate intensity swimming may improve fitness in sedentary pregnant women [132;133]. Women who exercise in water also seem to continue their exercise regime throughout pregnancy rather than having to stop in the last 4 to 6 weeks [24]. The type of exercise performed during pregnancy probably depends on the type of exercise the woman performed before she became pregnant and is a personal choice. However, for previously sedentary women, swimming and other forms of aquatic exercise may be the safest and most beneficial exercise and should be a recommended activity.

Women who exercised regularly prepregnancy were almost 10 times more likely to continue to exercise regularly during pregnancy in our study. Regular exercisers were also older, primiparous and had higher education. Also, prepregnancy overweight and gestational weight gain were independently associated with regular exercise during pregnancy. Pregnancy-related factors such as pelvic girdle pain, multiple pregnancy, nausea, uterine contractions, sick leave and musculoskeletal pain were all inversely associated with regular exercise during pregnancy.

Although other researchers have reported that pregnant women are less likely to engage in regular exercise compared to their non-pregnant counterparts [39;43;51], none of these studies have repeatedly assessed exercise level in the same population of women. To determine whether a decline in exercise level is caused by pregnancy or whether it was low before pregnancy, one needs to assess the same women at least twice. Unfortunately, we are left with retrospectively recalled prepregnancy exercise levels, but the alternative would not be possible to carry out in such a large cohort as MoBa. However, Treuth et al [134] examined pregnancy-related changes in physical activity, fitness and strength in 63 women with varying BMI. They found that both maximal oxygen consumption and leg strength decreased from prepregnancy to 6 weeks postpartum, but total self-reported PA did not change during the study period. However, conditioning and occupational activities decreased significantly postpartum, whereas walking and home activities increased [134]. In paper I we observed that pregnant women seemed to shift from high-impact aerobic classes to low-impact and prenatal aerobic classes in late pregnancy, and from high intensity exercise (i.e. running, ballgames, fitness training) to low and moderate intensity exercises such as swimming and bicycling between prepregnancy and late pregnancy. These adaptations are expected and may reflect that pregnancy-related bodily changes such as increased body weight and increased musculoskeletal discomforts [21] represent a huge challenge for pregnant women in maintaining their activity levels as pregnancy progresses.

Our results are consistent with previous studies which state that smokers and women with secondary school education only were significantly less likely to exercise regularly than non-smokers and women with a college/university degree [39;51;135]. In the present study, a positive association between age and regular exercise in pregnancy weeks 17 and 30 was observed. Other studies on pregnant women have reported both a positive [135] and negative [51] association between age and exercise frequency. A negative association between age and physical activity in non-pregnant populations has repeatedly been documented [46].

4.1.2 Regular exercise during pregnancy and Excessive newborn birth weight (Paper II)

Nulliparous women with a high level of exercise during pregnancy were less likely to give birth to newborns with an excessive birth weight. There seemed to be an increasing trend of a protective effect with increasing frequency of regular exercise during pregnancy, and this trend was independent of parity. Excluding women with preexisting diabetes, gestational diabetes or preeclampsia from the analysis did not change the estimates substantially, whereas prepregnancy exercise level did not seem to influence the upper extreme of the birth weight distribution. Nonetheless, from Paper I we observed that women exercising regularly before pregnancy also were more likely to continue their exercise programs during pregnancy. Hence, we cannot rule out that exercising regularly before pregnancy may also affect the probability of excessive newborn birth weight.

In agreement with our study, both Juhl et al [136] and Alderman et al. [137] observed a protective effect of regular exercise during pregnancy on risk of LGA. On the contrary, Voldner et at. (2008) observed an association between LTPA performed prepregnancy but not during pregnancy, and macrosomia risk [138]. Differences between study populations, design and size of study population in addition to different methods in defining type, intensity and frequency of regular exercise performed at different points in time during pregnancy may explain the different results. Nonetheless, the study by Juhl and co-workers [136], which included more than 79,000 pregnancies from the Danish National Birth Cohort (DNBC), is similar to the MoBa study in design, data collection, sample size and overall aims, and found a slightly decreased risk of LGA in the offspring of exercising women (HR=0.93; 95% CI 0.89-0.98) [131]. Underlying differences in the birth weight distribution between the two cohorts, with the highest prevalence of excessive newborn birth weight in MoBa, may explain the greater protective effect of regular exercise reported in paper II.

A possible mechanism behind our findings is the effect of aerobic exercise on glucose tolerance [139]. Our observation that running, walking, dancing and low impact aerobics were negatively associated with excessive infant birth weight supports this hypothesis. Both RCTs [140;141] and a prospective observational study [142] have shown that light-to-moderate physical activity during pregnancy may reduce glucose levels both in women with GDM and in non-diabetic pregnant women. Given the adverse maternal and prenatal complications associated with excessive newborn birth weight, regular exercise should be promoted during pregnancy for the purpose of prevention.

1.4.3 Exercise during pregnancy and Gestational age (Paper III)

Mean gestational age among women exercising during pregnancy was longer compared to non-exercising pregnant women, but the difference equals one day at the most and must therefore be considered of very limited clinical importance. The protective effect of exercise on preterm and the slightly increased risk of post-term birth, adds to the same conclusion; namely that engaging in regular exercise during pregnancy shifts the GA distribution slightly to the right resulting in moderately reduced risk of preterm births and a slightly increased risk of post-term birth. Other smaller observational studies that have assessed mean gestational age [94;97;143;144] as well as two randomized controlled trials [36;72] support our finding, even though different types and domains of physical activity have been used.

What this study adds is that we estimated the combined and separate effects of exercising in the second and/or third trimester of pregnancy. We also explored the possible influence of prepregnancy exercise on the gestational age distribution by exercise level in week 17 but these results did not change the conclusion.

A possible explanation for a reduced risk of preterm delivery may be reduced maternal stress in exercising pregnant women, assuming that stress in pregnancy predicts shorter gestations and that exercise reduces maternal stress [145]. However, this has not been investigated in pregnant women and needs further attention before drawing any conclusions.

1.4.4 Antenatal exercise and Cesarean delivery (Paper IV)

The results in Paper IV provide novel information from the first large, prospective population based study on the association between exercise during pregnancy and the risk of having a Cesarean delivery. Women exercising during pregnancy had substantially lower risks for both elective and acute CD compared to women not exercising during pregnancy. These risk reductions were present at both pregnancy weeks 17 and 30 and remained robust after adjusting for confounding factors. For acute CD, the greatest risk reduction was observed in frequent exercisers and women participating in high impact exercises during pregnancy. Exercise was associated with smaller, though still significant, risk reduction for elective CD.

Two small retrospective studies (n= 137 and n=173, respectively) [109;111] and one prospective study of 131 well-conditioned pregnant women [110], also reported lower prevalence of CD among exercising women. However, only Bungum and co-workers [109] provided adjusted risk estimates with a 4.5 greater odds of having a CD among sedentary compared to women doing aerobic exercise in the first two trimesters of pregnancy. However, in contrast to our study, most studies have failed to report an association between physical activity and exercise during pregnancy and CD [108;146;147], probably due to the varied definitions of physical activity and exercise used and the inclusion of clinical or highly selected study populations in these studies. In view of the possible causal explanation through increased concentrations of cholesterol and its effect on uterine contractility, it is also worth mentioning that only studies assessing aerobic exercise [109;110] observed an association with CD.

Given that previous studies have not looked at different types of CD or have provided adjusted risk estimates, it is difficult to compare our results. One explanation for the weaker association between exercise and elective type in our study may be that non-medical factors, such as fear of childbirth and maternal request without co-existing medical indications [148], contribute more to the rising rate of elective CD, compared to non-elective CD. In Norway, the most common indications for elective CDs are previous CD, breech presentation (≥ 34 weeks) and maternal request [106]. However, we included only nulliparous women in our study and adjusting for maternal request and fear of childbirth did not change the risk differences.

4.2 Methodological strengths and limitations

MoBa is a large population based pregnancy cohort study with a comprehensive data collection which includes detailed information on health history, social- and characteristics, illnesses and complaints, and a variety of different exposures collected before the development of disease. A large sample size makes it possible to examine rare exposures and outcomes, and to explore subgroups of women with unusual or rare patterns of exposure in relation to presence or absence of symptoms of disease. In Paper III, we took advantage of this opportunity to estimate the separate and combined effects of exercise at different time points in pregnancy, and gestational age at birth. The prospective design, extensive enrollment of participants, high follow-up rate and linkage to the MBRN make bias and other methodological challenges less likely. The large study size and narrow confidence intervals is thought to provide precise estimates for many associations.

Exercise is assessed twice during pregnancy and includes information on both frequency and type of exercise performed. We also have retrospective information on exercise level the last three months before pregnancy.

Bias and systematic error

Two broad types of error in epidemiological studies include random error and systematic error. Confounding, special characteristics of study participants (selection bias), and patterns of reporting and other information biases are called systematic errors. Associations obtained from data in an observational study may be biased in either direction due to systematic underlying mechanisms. Only some of these issues can be handled by statistical methods.

Selection bias

Selection bias occurs if the association between exposure and outcome differs between study participants and eligible participants, including those who were invited but refused to participate [123].

The response rate of eligible women invited to participate is approximately 44% in the second and fourth version of the data file, but in later version it has decreased to 38% [112]. Differences between participating and non-participating women would be expected due to the low participation rate, and when comparing demographic and reproductive variables between MoBa participants with the total number of births in Norway during the same period, some differences exist. Participating women seem to be older and have lower parity, they smoke less and the incidence of preterm birth is lower compared to the national preterm rate in the MBRN. Thus, it seems likely that the prevalence estimates are influenced by a socioeconomic gradient due to the observation that non-participants had a lower socioeconomic status compared to participating women [112]. There is also an underrepresentation of immigrants participating in MoBa [149], which may have influenced the associations estimated in paper II (toward greater differences between exercising and non-exercising women and risk of excessive newborn birth weight).

Hence, we cannot rule out the possibility that selection bias has influenced the prevalence estimates in paper I, leading to higher prevalence of regular exercise than in the target population. The observation that MoBa participants who did not respond to the questions on recreational exercise were more likely to smoke, have less education, experience pregnancy complications, and be overweight prepregnancy add to the same assumption.

Using an example from paper IV, we will graphically illustrate how we attempted to adjust for selection bias in paper II-IV.

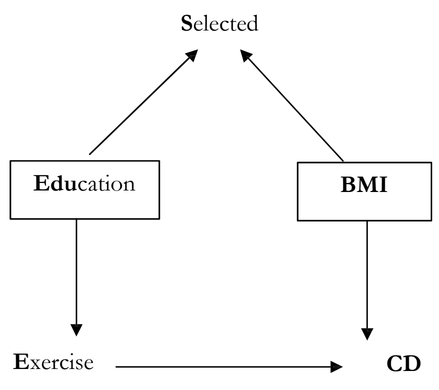


Figure 4. A proposed causal model for the relationship between selection bias (S), education (Edu), BMI and the association between exercise (E) during pregnancy and cesarean delivery (CD).

When exploring the association between exercise and Cesarean delivery (paper IV), as one of the reproductive outcomes, we wanted to assess to what extend the association was influenced by selection of participants in MoBa. Figure 4 is a graphical model that may explain the relationship between selection bias, education, maternal BMI, antenatal exercise and cesarean delivery. It shows that there is a non-causal open path between selection into the study (S), maternal exercise (E) and cesarean delivery (CD) through education and BMI:

E ← Edu → S ← BMI → C : non-causal, open path

By adjusting for education and BMI in a multivariable model, the path through selection bias is closed and may not influence the association between exercise and CD:

E ← [Edu] → S ← [BMI] → C : non-causal, closed path

Even if this model adjusts for the effect of being selected into the study on education and prepregnancy BMI, other unmeasured plausible mechanisms may still be present and thus influence the results.

Furthermore, women who were excluded from the study population due to missing information on exercise in Q1 also differed from the study population regarding educational level, smoking, marital status, prepregnancy BMI, parity, shift work, and exertion at work. Though, mean gestational age was not significantly shorter compared to women who had answered the questions on recreational exercise, and the proportions of both preterm and post-term deliveries were equal. Including these pregnancies in the analysis, assuming they were equal to the non-exercising group, did not change the estimates. Nevertheless, it is less likely that selection into the study is caused by exercise and the low response rate will therefore have little or no influence on the associations estimated in papers II-IV [150].

Information bias

Inaccuracies may occur when obtaining information on plausible exposures and outcomes. Non-differential bias is bias that affects each exposure (or treatment) group in such a way that the exposure effect measure remains unbiased. A non-differential error process may induce non-differential bias with respect to the measure of exposure effect but not another.

Misclassification

The reproductive outcomes reported in this dissertation were all obtained from an external source, namely the MBRN [150]. Any misclassification due to imprecise measurements of birth weight and Cesarean delivery is considered unlikely to have influenced the results in paper II and IV. In paper III, gestation age based on ultrasound was the outcome of interest, which is associated with some important limitations.

In this study, gestational age was estimated based on ultrasound-dating (UL). All methods of gestational age assessment have strengths and weaknesses, and the primary limitation of this method is that gestational age estimates of symmetrically large or small fetuses will be biased. Furthermore, ultrasound references were developed using pregnancies that were dated according to reliable LMP dates. Hence, UL-based dating is potentially biased in the same direction as dates estimated based on LMP [116]. Given that records from the MBRN include both ultrasound-based and menstrual-based dating of gestational age, we repeated the analysis using the LMP method as well. Using the LMP method, the gestational age distribution shifted slightly to the right (mean gestational age changed from 39.45 to 39.71 completed weeks) and it yielded a higher number of both preterm- (5.2% versus 4.7%) and post-term deliveries (13% versus 7.9%) compared to UL-based gestational age. In addition, more pregnancies were excluded according to the selection criteria using the LMP method, and 2476 pregnancies did not have their LMP recorded in the MBRN. Nonetheless, the effect estimates of exercise did not differ substantially between the two methods. Other studies on maternal physical exercise and gestational length have often used a combination of both UL and LMP based gestational age, and there is no consensus on which method to use. Finally, higher incidence of menstrual irregularities such as secondary amenorrhea and shortened luteal phases has frequently been reported among exercising women [151]. Even though menstrual irregularities are not caused by exercise alone, it does influence the regularity of the menstrual cycle [152] and most likely the LMP-based gestational age. Hence, we believe that the estimated association between exercise and UL-based gestational age is not biased due to misclassifications of GA.

Recreational exercise

Exercise was assessed indirectly by two self-administered questionnaires during pregnancy. Because of the prospective data collection, misclassification of regular exercise in our study is most likely to be non-differential and would most likely have biased the associations towards the null. Measurement of exercise and physical activity needs to be accurate to minimize the possibility that an effect will not be detected because of measurement error. This is crucial when estimating the association between exercise and excessive birth weight in paper II, and exercise and gestational age in Paper III, because the association is likely to be modest, as for other birth outcomes [153].

Even though questionnaires inadequately capture light to moderate physical activities and therefore tend to underestimate total physical activity in women in general [130;154], questionnaire-based studies are common and still the most feasible approach to measure general physical activity and exercise levels in large-scale epidemiological studies [6]. To date, there is no consensus on how to measure LTPA and exercise in pregnant women.

In contrast to other observational studies, the questions used to assess regular exercise in our study have recently been compared with objective measurements of physical activity by accelerometer (ActiReg®) in a subsample within the MoBa study [118], showing a positive correlation between self-reported frequency of recreational exercise and objectively measured physical activity was observed. However, the two methods do not measure the same construct of PA, as reflected in the partial correlations provided by Brantsaeter et al [118]. Moreover, the ActiReg® has not been validated in pregnant women. Another way of assessing the quality of the MoBa questions could be to do a test of reliability in a test-retest situation. Others have found similar correlations between questionnaire and objectively measured PA [155;156].

We defined strolling as a non-exercise and thus the true differences in outcome measures between exercising and non-exercising women may be larger than the differences reported here since strolling was a very common activity (reported by 87% in week 17 and increased weekly PA level by 1.5) [118]. It is also important to emphasize that even though half of the women were non-exercisers in week 30, we cannot conclude that these were sedentary or physically inactive. Among the 112 women in the study by Brantsaeter et al, 12 women, who reported exercising at least five times a week in the questionnaire, were classified in the lowest quartile of any of the objective measures. Interestingly, these women over-reported strolling and brisk walking from the questionnaire [118].

The weak association between exercise and GA observed in paper III may reflect the self-reported assessment of exercise and the fact that we did not assess other dimensions of exercise such as duration and intensity, or other domains of PA. However, in a case-control study by

Mottola and Campell [42] a high frequency of exercise, but not intensity, was association with increased risk of SGA. Even though we have tried to adjust for occupational PA, we cannot rule out the possibility that women may have reported OPA as exercise in our study. When we included strolling as a type of activity in the analysis with GA, non-exercisers had a significantly shorter gestational age compared to women who reported strolling (data not shown).

Prepregnancy Body mass index

Prepregnancy body mass index was calculated based on self-reported body weight and height from the first questionnaire in week 17 (Q1). This information is therefore prone to misclassification. Self-reported data on body weight tends to be slightly underestimated and height overestimated in the adult population [157], especially for well-educated and pregnant women [158], but with large individual variability in the reporting of these measures [157]. In MoBa, women were specifically asked to use their pregnancy card, which is a standard form completed for all pregnant women in Norway at the first routine examination in the first trimester, when filling in the questions on body weight and height in Q1. By using the standard form, may have lessens the probability of misclassification due to self-report of prepregnancy BMI.

Confounding

Consideration of confounding is fundamental to design, analysis, and interpretation of studies intended to estimate associations based on underlying causal mechanisms, and is a source of bias in the estimation of causal effects [159]. By definition, a confounding factor is associated with the outcome of interest and randomly distributed for all categories of exposure.

In Paper II, well known predictors of excessive birth weight such as gestational diabetes and smoking did not change the estimates substantially. Only a few women with preexisting or gestational diabetes mellitus were identified in our study, and excluding these women, did not change the observed association between regular exercise and excessive newborn birth weight. We therefore consider it unlikely that the effect estimates are confounded by these factors in our study.

Confounding by indication is a term which is used when a variable is a risk factor for a disease among non-exposed individuals and is associated with the exposure of interest in the population from which the cases derive, without being an intermediate step in the causal pathway between the exposure and the disease [160]. We assessed confounding by indication in Paper III by excluding pregnant women who previously experienced persistent vaginal bleedings and developed pregnancy induced hypertension or preeclampsia, or who had more than two spontaneous abortions because these women may choose not to exercise during this pregnancy, or may be advised not to do so by their midwife or general practitioner. We assumed that confounding by the indication for not exercising could have influenced our results. But after restricting the analysis to a subsample of normal pregnancies, the mean differences did not change substantially, suggesting that exercise in weeks 17 and/or 30 did not influence the gestational age distribution. However, no adjustment method fully manages to control confounding by indication in observational studies [161].

In all papers, we attempted to control for identifiable confounders obtained from questionnaires and the MBRN, which included a wide range of potential confounding factors such as differences in maternal demographics, obstetric and medical history, and lifestyle factors. All potential confounders were included based on review of the literature, cross-tabulations, and an extensive evaluation using DAGs [162]. However, regardless of these attempts to address confounding properly, we cannot rule out the possibility of residual confounding factors that have not been assessed. For example, the lack of adjusting for history of preterm births and miscarriages in paper III may have influenced the association between exercise and gestational age at birth. However, we did adjust for previous spontaneous abortions, which may be a risk factor for preterm delivery in subsequent pregnancies.

4.3 Future perspectives

In future studies it may be interesting to pursue some of the following ideas:

As a follow up of the first paper, it would be of great interesting to track exercise and LTPA from early pregnancy to when the child is 3 years old, taking subsequent pregnancies into account.

In all papers, except for paper I, I excluded multiple gestations from the analyses. Given the open gap in the literature regarding these pregnancies, to describe patterns of LTPA and exercise in this population, and how it relates to pregnancy and birth outcomes, would be of most interest.

To further explore the plausible causal link between exercise and preterm birth, and given its complex etiology, a new approach could be to estimate the association in spontaneous preterm, excluding preterm births that are not spontaneous due to pathological causes.

Going from research ideas to implementation of results, it is a need for studies that assess midwifes' and obstetricians' current knowledge of physical activity guidelines and how it affects their attitudes towards LTPA for pregnant women.

5. CONCLUSIONS

The main findings in this dissertation were:

Participation in regular exercise declined from prepregnancy to pregnancy week 30. Walking and bicycling were the most common exercises before and during pregnancy. The proportion of women, who swam increased from prepregnancy to pregnancy week 30. Regular exercise prepregnancy was strongly correlated with regular exercise during pregnancy. Women with low-gestational weight gain, with a higher educational level, first-time mothers, and non-smokers, were more likely to exercise regularly during pregnancy, whereas being overweight/obese, carrying twins/triplets, experiencing nausea, pelvic girdle pain were inversely associated with regular exercise during pregnancy.

Excessive birth weight

A protective effect of giving birth to a newborn with excessive birth weight was observed among regular exercising first time mothers only.

Gestational age

Gestational age was slightly longer among exercising women compared to non-exercisers. A reduced risk of preterm birth and a slightly increased risk of post-term birth were observed.

Mode of delivery

In this large population based cohort, women exercising during pregnancy had substantially lower risks for both elective and acute CD compared to women not exercising during pregnancy. These risk reductions were present at both weeks 17 and 30 and remained robust after adjusting for confounding factors. For acute CD, the risk reduction was especially pronounced in frequent exercisers and in women participating in high impact exercises. Exercise was associated with smaller, though still significant, risk reductions for elective CD.

Together with results from other studies and what we know about exercise epidemiology, it can be concluded that exercise during pregnancy seem beneficial for both mother and child when it comes to excessive birth weight, length of gestation, and risk of Cesarean delivery.

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Errata

Paper III

Since submission to the doctoral committee, Paper III has been accepted for publication in Medicine and Science in Sports and Exercise. During the review process, changes have been made to all chapter of the paper.

The following changes have been made:

Page 12: "The possible link between exercise performed at different time points during pregnancy across the entire distribution of gestational age, including both preterm and post-term birth, *has not been studied*."

Page 37: "The *weak* association between exercise and GA observed in paper III may reflect the self-reported assessment of exercise and the fact that we did not assess other dimensions of exercise such as duration and intensity, or other domains of PA."

Page 40: "Going from research ideas to implementation of results, *it is a need for studies* that assess midwifes' and obstetricians' current knowledge of physical activity guidelines and how it affects their attitudes towards LTPA for pregnant women."

Page 41: "Women with low- gestational weight gain, with a higher educational level, first-time mothers, and non-smokers, were more likely to exercise regularly during pregnancy, whereas *being overweight/obese, carrying twins/triplets, experiencing nausea, pelvic girdle pain were inversely associated with regular exercise during pregnancy*."

Page 41: "Gestational age was *slightly longer among exercising women compared to non-exercisers. A reduced risk of preterm birth and a slightly increased risk of post-term birth were observed*."

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Paper I

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Correlates of regular exercise during pregnancy: the Norwegian Mother and Child Cohort Study

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The aims of this study were to describe the level of exercise during pregnancy and to assess factors associated with regular exercise. Using data from the Norwegian Mother and Child Cohort Study conducted by the Norwegian Institute of Public Health, 34 508 pregnancies were included in the present study. Data were collected by self-completed questionnaires in gestational weeks 17 and 30, and analyzed by logistic regression analysis. The results are presented as adjusted odds ratios (aOR) with a 95% confidence interval. The proportion of women exercising regularly was 46.4% before pregnancy and decreased to 28.0 and 20.4% in weeks 17 and 30, respectively. Walking and bicycling were the most frequently reported activities before and during pregnancy. The prevalence of swimming tended to increase from prepregnancy to week 30. Exercising regularly prepregnancy was highly related to regular exercise in week 17, aOR 5 18.4 (17.1–19.7) and 30, aOR 4.3 (4.1–4.6). Low gestational weight gain was positively associated with regular exercise in week 30, aOR 5 1.2 (1.1–1.4), whereas being overweight before pregnancy was inversely associated with regular exercise in week 17, aOR 5 0.8 (0.7–0.8) and 30, aOR 5 0.7 (0.6–0.7). Also, women experiencing a multiple pregnancy, pelvic girdle pain, or nausea were less likely to exercise regularly.

Physical activity (PA) during pregnancy has previously been discouraged primarily due to the fear of fetal hypoxia, fetal growth restriction, and hyperthermia, which may lead to potential fetal teratogenic effects (Wolfe & Davies, 2003). However, recent reports have shown that exercise of moderate intensity during pregnancy may be beneficial in reducing the risk of complications and illnesses for both the mother and the fetus (Clapp et al., 2000; Dempsey et al., 2004), and is associated with overall health benefits for pregnant women (Brown, 2002).

Although the American College of Obstetricians and Gynecologists (ACOG) now recommends that virtually all pregnant women should exercise regularly, barring the presence of adverse complications (ACOG, 2002; Davies et al., 2003), pregnancy may be a time period when the level of PA declines (King, 1994; Mottola & Campbell, 2003). The prevalence of any PA during pregnancy varies widely and has been reported to be as high as 66% (Ning et al., 2003; Evenson et al., 2004). Understanding activity patterns during pregnancy and their correlates has significant public health implications. However, few longitudinal population-based studies have been conducted to investigate what kind of activities pregnant women do (Hatch et al., 1998), and how exercise levels change during pregnancy. Furthermore, information on pregnancy-related factors and other correlates of recreational exercise is currently sparse and equivocal with respect to pregnancy (Petersen et al., 2005).

Considering the insufficient data in this area, the aims of this study are (a) to describe the level of exercise during pregnancy in relation to frequency and type of activities and (b) to assess factors associated with regular exercise during pregnancy.

Presented in part at the annual meeting of the American College of Sports Medicine, New Orleans, May 30-June 2, 2007.

Material and methods

This study is based on the Norwegian Mother and Child Cohort Study (MoBa) conducted by the Norwegian Institute of Public Health (Magnus et al., 2006). MoBa is a pregnancy cohort that aims to include 100 000 pregnancies by 2008, and was designed to explore the associations between some of the lifestyle variables to which pregnant women and their fetuses are exposed in addition to diseases (MoBa, 2008).

Study population and inclusion criteria

The present study included pregnancies enrolled between June 1, 2001 and May 31, 2005. Of those invited in the MoBa study (116 224 pregnancies), 42% (n 5 48 700) gave their informed consent. The overall participation rate was 45% (Magnus et al., 2006). The follow-up rate in gestational week 30 was 92% (n 5 43 938).

The second version of the quality-assured data-file made available for research in April 2006 provided all data that were used for the statistical analysis in the present study. Both Questionnaires 1 and 3 (Q1 and Q3) had to be answered in order for the women to be included (n 5 40 049). Additionally, pregnancies with missing data on all 13 items of the recreational exercise questions in week 17 (9.3%) and 30 (6.0%) were omitted from the analyses (n 5 5541). Thus, the study population includes 34 508 pregnancies. The study has received approval from the Regional Committees for Medical Research Ethics and The Norwegian Social Science Data Services. Informed consent was obtained from each participant before inclusion.

The target population for MoBa consisted of all pregnant women in Norway who could read and write Norwegian. Pregnant women were recruited into the study through a postal invitation 2 weeks before their routine ultrasound examination, which usually takes place at their local hospital in gestational week 17. The invitation contained Q1 and Questionnaire 2 (Q2), a questionnaire for the father, and an informed consent form. All participants received written and oral information about the MoBa study. If the questionnaires had not been returned within 2 weeks, one reminder was sent by mail. In gestational week 30, the women received Q3.

The Questionnaires

Q1 provided data on various maternal behaviors and characteristics (e.g. body weight and height, marital status, education), diseases (e.g. depression, heart disease, pelvic girdle pain), and exposures before and during pregnancy. Q3 focused on health outcomes during pregnancy and included follow-up questions from Q1. Q2 was a food frequency questionnaire and was not relevant to this paper. Additional questionnaires were administered when the child was 6 months, 18 months, and 3 years of age. Data were obtained from 51 maternity units in Norway, all with more than 100 births annually. Linkage to the Medical Birth Registry of Norway (MBRN) was also provided.

Non-respondents

When comparing the MoBa participants and their births with the total number of births in Norway (approximately 55 000 births annually) using MBRN, enrolled women were largely similar for characteristics such as parity, maternal age, pre-eclampsia, gestational diabetes, and mean birth weight. However, enrolled women tended to have lower rates of preterm birth and low-birth-weight infants than women from the source population (Magnus et al., 2006).

When comparing the demographic characteristics of women with (n 5 34 508) and without (n 5 5541) information on recreational exercise, women whose information was missing were significantly more likely to smoke daily at enrollment (P 5 0.00), to have primary school only (P 5 0.00), to be sick-listed in pregnancy week 17 or 30 (P 5 0.00), and to have a body mass index (BMI) 424.9 kg/m^2 prepregnancy (P 5 0.02). These differences with the study population are also true for non-exercisers.

Main outcome

The main outcome variable was regular exercise during pregnancy, defined as participating in any combination of recreational activities at least three times a week (Bouchard et al., 1994). The participants were asked to report how often they engaged in the following recreational activities during pregnancy weeks 17 and 30: strolling, brisk walking, running (jogging or orienteering), bicycling, fitness training in training centers, swimming, aerobic classes (low or high impact), prenatal aerobic classes, dancing, skiing, ball games, horse back riding, and other. Frequency had five categories: ''never,'' ''one to three times per month,'' ''once a week,'' ''twice a week,'' and '' ::: 3 times a week.'' We merged aerobic classes (high- and low-impact aerobics) and prenatal aerobic classes into ''aerobic dancing.'' Further, the level of exercise was defined in terms of frequency and categorized as non-exercisers, irregular, or regular exercisers. Women who answered ''never'' or ''one to three times per month'' were referred to as non-exercisers. A frequency of one to two times a week was defined as irregular exercisers and ::: 3 times a week was defined as regular exercisers. Strolling was not defined as a recreational activity due to its very low intensity (Ainsworth et al., 2000), and therefore was excluded before estimating exercise levels before and during pregnancy.

In week 17, women were asked to recall the type and frequency of recreational exercise participated in during the last 3 months before the present pregnancy (Q1). The questions on recreational exercise before pregnancy, in pregnancy weeks 17 and 30, were identical (Q1 and Q3).

Sociodemographic covariates

The following sociodemographic covariates were included: age, maternal education, marital status, parity, prepregnancy BMI, and smoking status. Maternal age was treated as a continuous variable. Education was defined as the highest completed education at baseline and was categorized as ''primary school (9 years)'', ''secondary school (12 years)'', ''college/university (::: 15 years), and ''other''. Marital status included four categories: ''married'', ''cohabitant'', ''single'', and ''other''. Parity was collected from NMBR, and was defined in terms of earlier pregnancies lasting more than 20 weeks (Venes & Taber, 2005). BMI was calculated from self-reported body weight (Q1) and height (Q1), and was divided into five categories: ''O18.5'', ''18.5–24.9'', ''25–29.9'', ''30–34.9'', and ''351''. A BMI between 18.5 and 24.9 kg/m^2 was defined as the reference category. To control for prepregnancy BMI, the participants were asked to report their body weight when they became pregnant. Hence, we used prepregnancy BMI as an independent covariate in the analysis. To calculate weight change throughout pregnancy, the differences between body weight when pregnancy started, in weeks 17 and 30, were used. Smoking status was categorized as ''non-smoker'', ''occasional smoker'', and ''daily smoker''. Being short of breath/sweating at work at least once a week was used to assess PA at work during pregnancy, and was also included as a covariate.

Pregnancy-related variables

Pregnancy-related health problems in the current pregnancy that were included in the statistical analysis were: pelvic girdle pain, urinary incontinence, nausea (with or without vomiting), severe fatigue, musculo-skeletal pain (i.e. lower back pain and neck/shoulder pain), and pregnancy-induced high blood pressure. Information on uterine contractions (after week 13) was collected from Q3, while information on whether or not it was

Table 1. Demographic characteristics by level of exercise at baseline (n 5 34 508)

Variables	Non-exerciser, n 5 14 159 (%)	Irregular exerciser, n 5 10 691 (%)	Regular exerciser, n 5 9658 (%)	Total, n 5 34 508 (%)
BMI prepregnancy				
o18.5	2.8	2.6	3.2	2.8
18.5–24.9	56.7	62.5	68.0	61.7
25–29.9	25.1	23.4	18.9	22.8
30–34.9	9.1	6.7	5.4	7.3
35 1	3.7	2.1	1.7	2.7
Missing	2.6	2.7	2.9	2.7
Parity				
0	39.1	45.0	54.1	45.1
1	40.2	35.5	29.6	35.7
::: 2	20.8	19.5	16.4	19.2
Primary school (9 years)	4.7	2.8	3.0	3.6
Secondary school (12 years)	39.4	33.0	29.7	34.7
College/university (::: 15 years)	53.7	62.2	65.0	59.5
Other	1.8	1.7	1.9	1.8
Missing	0.3	0.2	0.4	0.3
Non-smoker	87.5	91.4	91.9	90.0
Occasional smoker	3.3	3.1	3.1	3.2
Daily smoker	8.6	5.0	4.3	6.3
Missing	0.6	0.5	0.7	0.6
Married	50.0	51.5	48.2	49.9
Single	2.2	2.1	2.4	2.2
Cohabitant	46.6	45.2	47.7	46.4
Other	0.9	0.8	1.3	1.0
Missing	0.4	0.4	0.5	0.4
Regular exercise prepregnancy				
No	79.0	57.3	10.8	53.2
Yes	20.7	42.0	89.0	46.4
Missing	0.3	0.7	0.3	0.4

BMI, body mass index.

a multiple pregnancy (i.e. more than one fetus) was collected from NMBR.

Statistical analysis

All analysis was performed using the statistical software program, SPSS, version 14.0 (SPSS, Chicago, Illinois, USA). First, we described the women by level of exercise at baseline. Then we estimated the association between regular exercise (::: 3 times a week) during pregnancy and sociodemographic characteristics of the women in pregnancy weeks 17 and 30, separately. The following maternal factors were included: age, prepregnancy BMI, parity, education, marital status, and smoking. The final model also included PA at work and regular exercise prepregnancy.

Furthermore, we examined the association between regular exercise in weeks 17 and 30 and the following pregnancy-related health problems: pelvic girdle pain, musculo-skeletal pain, nausea, urinary leakage, uterine contractions, multiple pregnancy, severe fatigue, and sick-leave, adjusting for socio-demographic variables. The associations were estimated by logistic regression analysis, and the results are presented in terms of crude (cOR) and adjusted odds ratios (aOR) with 95% confidence intervals (95% CI). The choice of covariates was based on previous review of the literature and frequency tabulation. The final multivariable logistic regression analysis was performed including all covariates significantly associated with regular exercise in week 17 or 30.

Missing data on covariates were replaced by dummy variables and included in the analysis. Rates of missing data ranged from 0.2–0.7% up to 2.7% (for prepregnancy BMI only).

Results

A total of 34 508 pregnancies were included in the analyses. At enrollment in gestational week 17, the mean age was 29.4 years (SD 4.5), ranging from 14 to 47 years, and the mean BMI was 25.2 (SD 4.2), ranging from 13.3 to 61.7 kg/m^2. Table 1 displays the demographic characteristics of the study population by level of exercise when entering the study. Forty-one percent of the women (n 5 14 159) were non-exercisers, whereas 31.0% (n 5 10 691) were irregular exercisers, and 28.0% (n 5 9658) were regular exercisers at enrollment. The latter group was more educated, cohabitant, smoked less, primiparous, and was also more likely to exercise regularly before pregnancy (Table 1).

The proportion of regular exercisers before pregnancy was 46.4% and declined to 28% and 20% by gestational weeks 17 and 30, respectively. The OR of exercising regularly in gestational week 30 equals 6.9 (95% CI 6.48–7.26) if the woman also participated in regular exercise in week 17. Before pregnancy, 25% (n 5 8485) were non-exercisers compared with 41% (n 5 14 159) and 53% (n 5 18 221) in pregnancy weeks 17 and 30, respectively.

Brisk walking and bicycling were the two most frequently reported activities both prepregnancy

(47.7% and 24.9%) and during pregnancy weeks 17 (39.0% and 14.6%) and 30 (27.4% and 8.5%) (Table 2). Before pregnancy, fitness training, aerobic dancing, and running were among the five most common activities. The pattern of recreational exercise changed from prepregnancy to weeks 17 and 30, showing that fewer women were running and reporting fitness training compared with aerobic dancing (Table 2). Participation in all types of activities decreased during pregnancy, except for swimming, in which participation increased from prepregnancy (7.3%) to week 30 (8.2%).

Regular exercise prepregnancy was strongly associated with regular exercise during pregnancy weeks 17 and 30 (Table 3). The corresponding relative risks (RRs) equal 9.42 and 3.48, respectively. In week 17, PA at work (RR 5 2.11) was strongly related to regular exercise, whereas gaining 10 kg or less was positively associated with regular exercise in week 30 (Table 4).

A positive association was observed between maternal age and regular exercise during pregnancy, with a 2% increase per year in the odds of being regular exercisers (Table 3). Sociodemographic characteristics inversely associated with regular exercise in weeks 17 and 30 had a BMI ::: 25, parity (::: 1), and secondary school education only. The cOR showed that daily smoking was also inversely associated with regular exercise in both weeks 17 and 30, but after adjusting for age and regular exercise prepregnancy the association was only significant in week 30 (Table 2).

In exploring how pregnancy-related health problems influenced level of exercise, it was found that women experiencing a multiple pregnancy and women experiencing pelvic girdle pain, nausea (week 17), musculo-skeletal pain (week 30), uterine contractions (week 30), and sick-leave were less likely to exercise regularly. Although pregnancy-related health problems in weeks 17 and 30 were included

Table 2. Proportion of women participating in different exercise activities at least once a week before and during pregnancy (%)*

Activity	Prepregnancy (%)	Week 17 (%)	Week 30 (%)
Walking	47.7	39.0	27.4
Bicycling	24.9	14.6	8.5
Fitness training	17.2	7.5	4.2
Aerobic dancing[w]	16.5	8.6	7.1
Running	9.1	2.3	0.5
Swimming	7.3	7.4	8.2
Ballgames/netball	6.2	1.8	0.3
Cross-country skiing	4.4	2.8	1.4
Dancing (swing, rock, folk)	3.1	1.5	0.8
Horseback riding	2.1	1.0	0.3
Other	5.1	4.3	7.2

*Multiple answers were possible.

[w]Including prenatal aerobic classes, high-, and low-impact aerobic classes.

Table 3. Association between regular exercise during pregnancy and sociodemographic characteristics of pregnant Norwegian women (n 5 34 508)

	Week 17			Week 30		
	%[w]	cOR	aOR (95% CI)*	%[w]	cOR	aOR (95% CI)*
Age		1.00	1.01 (1.00–1.02)		1.00	1.02 (1.01–1.02)
BMI prepregnancy						
O18.5	31.1	1.01	1.29 (1.09–1.53)	22.3	0.94	1.05 (0.89–1.24)
18.5–24.9	30.8	1.00	1.00	23.5	1.00	1.00
25–29.9	23.2	0.68	0.74 (0.69–0.79)	15.4	0.59	0.64 (0.60–0.69)
30–34.9	20.6	0.58	0.76 (0.68–0.86)	12.3	0.46	0.56 (0.49–0.64)
351	18.1	0.50	0.77 (0.63–0.94)	10.3	0.37	0.50 (0.40–0.63)
Missing	29.7	0.95	0.97 (0.82–1.15)	23.0	0.98	0.98 (0.83–1.16)
Parity						
0	33.5	1.00	1.00	25.4	1.00	1.00
::: 1	23.4	0.61	0.76 (0.72–0.81)	16.4	0.58	0.65 (0.61–0.69)
Secondary school (12 years)	23.9	0.71	0.90 (0.84–0.96)	16.7	0.68	0.85 (0.79–0.90)
Non-smokers	28.6	1.00	1.00	20.9	1.00	1.00
Occasional smoker	27.2	0.93	1.09 (0.93–1.29)	20.7	0.99	1.16 (0.97–1.38)
Daily smoker	19.2	0.59	0.92 (0.80–1.05)	13.4	0.59	0.83 (0.73–0.96)
Missing	32.1	1.18	1.11 (0.77–1.58)	18.9	0.88	0.86 (0.59–1.24)
Regular exercise prepregnancy						
No	5.7	1.00	1.00	9.5	1.00	1.00
Yes	53.7	19.27	18.39 (17.15–19.74)	33.1	4.74	4.34 (4.08–4.61)
Missing	17.3	3.49	3.45 (2.25–5.30)	10.7	1.14	1.11 (0.66–1.88)

Data are presented as cOR and aOR with 95% CI.

*Adjusted for maternal education and marital status.

[w]The proportion of regular exercisers within each response category.

aOR, adjusted odds ratio; cOR, crude odds ratio; CI, confidence interval; BMI, body mass index.

Table 4. Association between regular exercise during pregnancy and pregnancy-related factors adjusted for sociodemographic characteristics of pregnant Norwegian women (n = 34 508)

	Week 17			Week 30		
	%[w]	cOR	aOR (95% CI)*	%[w]	cOR	aOR (95% CI)*
Sick-leave						
No	29.8	1.00	1.00	23.6	1.00	1.00
Yes	20.7	0.62	0.68 (0.63–0.74)	15.7	0.60	0.75 (0.71–0.80)
PA at work						
No	27.2	1.00	1.00	19.5	1.00	1.00
Yes	31.2	1.21	1.31 (1.23–1.40)	24.4	1.33	1.22 (1.14–1.30)
Missing	17.1	0.55	0.49 (0.39–0.60)	13.0	0.62	0.61 (0.37–1.00)
Pelvic girdle pain						
No	29.1	1.00	1.00	23.6	1.00	1.00
Yes	21.3	0.66	0.83 (0.76–0.91)	14.8	0.56	0.73 (0.69–0.78)
Musculoskeletal pain						
No	28.8	1.00	1.00	21.9	1.00	1.00
Yes	26.5	0.89	0.96 (0.90–1.02)	18.6	0.82	0.94 (0.88–0.99)
Nausea						
No	32.0	1.00	1.00	21.3	1.00	1.00
Yes	26.5	0.77	0.78 (0.73–0.83)	18.7	0.85	1.02 (0.96–1.09)
Uterine contractions						
No	28.9	1.00	1.00	22.5	1.00	1.00
Yes	27.1	0.92	1.00 (0.94–1.06)	18.8	0.80	0.91 (0.86–0.97)
Missing	30.9	1.10	1.12 (0.97–1.29)	21.1	0.92	0.95 (0.83–1.10)
Multiple pregnancy						
No	28.1	1.00	1.00	20.7	1.00	1.00
Yes	20.9	0.68	0.64 (0.51–0.81)	7.9	0.33	0.38 (0.28–0.51)
Weight change (kg)						
>10	25.2	1.00	1.00	16.4	1.00	1.00
6–10	27.1	1.11	1.06 (0.81–1.40)	20.4	1.31	1.23 (1.11–1.38)
1–5	29.5	1.24	1.19 (0.92–1.55)	21.6	1.40	1.40 (1.26–1.57)
0	25.7	1.03	1.08 (0.82–1.43)	21.6	1.40	1.66 (1.11–2.47)
<0	21.9	0.83	1.02 (0.77–1.35)	17.5	1.08	1.55 (1.09–2.19)
Missing	27.4	1.12	1.12 (0.81–1.53)	21.5	1.39	1.31 (1.14–1.50)

Data are presented as cOR and aOR with 95% CI.

*Adjusted for maternal age, parity, prepregnancy BMI, education, marital status, smoking, regular exercise prepregnancy, urinary leakage, and severe fatigue.

[w]The proportion of regular exercisers within each response category.

aOR, adjusted odds ratio; cOR, crude odds ratio; CI, confidence interval; BMI, body mass index; PA, physical activity.

in the model, the association between regular exercise and sociodemographic characteristics remained unchanged (data not shown).

Discussion

In this longitudinal cohort study, we observed a decline in regular exercise wherein the proportion of non-exercising women increased from 3 months before pregnancy and throughout pregnancy. Brisk walking was the most commonly reported activity both before and during pregnancy, whereas swimming was the only activity that increased during pregnancy. Established regular exercise routines prepregnancy was the strongest correlate of regular exercise during pregnancy. Regular exercisers were also older, primiparous, and had higher education. Prepregnancy overweight and gestational weight gain were independently associated with regular exercise during pregnancy. Pregnancy-related factors such as pelvic girdle pain, multiple pregnancy, nausea, uterine contractions, sick-leave, and musculo-skeletal pain were all inversely associated with regular exercise during pregnancy.

Brisk walking was the most common type of PA at all time points, which is in line with findings in previous studies (Mottola & Campbell, 2003; Ning et al., 2003; Evenson et al., 2004). Increased focus has been placed on the health benefits of walking in the adult population, and epidemiological studies suggest that they are substantial (Andersen, 2007). Compared with other recreational activities often performed by women, such as aerobic dancing and bicycling, the intensity of walking is often low. However, according to the Compendium of Physical Activity (Ainsworth et al., 2000), walking at a moderate pace (i.e. 5 km/h) expends sufficient energy to meet the definition of moderate-intensity PA and may improve fitness in sedentary women (Hardman et al., 1992). In an attempt to capture walking of moderate intensity only, we therefore excluded strolling before estimating exercise level. Hence, by definition, one should be sweating and short of breath. On the other hand, intensity is the least valid component assessed by questionnaires (Sallis & Saelens, 2000), and we cannot eliminate a possible overestimation of regular exercisers due to a high prevalence of walking.

Based on our observations, pregnancy did not seem to influence the choice of recreational exercises when it came to walking and bicycling, as these activities were the most frequently reported activities both before and during pregnancy. Even though aerobic dancing decreased during pregnancy, it was ranked among the five most common activities at all times. However, women seemed to shift from high-impact aerobic classes to low-impact and prenatal aerobic classes in late pregnancy. There also seems to be a shift from high-intensity exercise (i.e. running, ballgames, fitness training) to low- and moderate-intensity exercises such as swimming and bicycling from prepregnancy to late pregnancy, which corresponds well with the guidelines for exercise during pregnancy and the postpartum period published by ACOG (2002). To our knowledge, this is the first study to report that swimming increased from prepregnancy to gestational week 30. Swimming is widely recognized as one of the safest forms of exercise for pregnant women due to maintained thermoregulation by preventing overheating, the buoyancy, and the redistribution of blood flow from the periphery to the internal viscera (Katz, 2003). Even light- to moderate-intensity swimming may improve fitness in sedentary pregnant women (Lynch et al., 2003; Lynch et al., 2007). Women who exercise in water also seem to continue their exercise regime throughout pregnancy rather than having to stop in the last 4–6 weeks (Katz, 2003). The type of exercise performed during pregnancy probably depends on the type of exercise the woman performed before she became pregnant, and is a personal choice. However, for previously sedentary women, swimming and other forms of aquatic exercise may be the safest and most beneficial exercise and should be a targeted activity.

Women who exercised regularly prepregnancy were almost 10 times more likely to continue to exercise regularly during pregnancy. Although other researchers have reported that pregnant women are less likely to engage in regular exercise compared with their non-pregnant counterparts (Zhang & Savitz, 1996; Evenson et al., 2004; Petersen et al., 2005), none of these studies have repeatedly assessed exercise level in the same population of women and this therefore makes it difficult to determine whether exercise level declines as a consequence of pregnancy or whether it was low also before pregnancy.

We observed a substantial increase in the proportion of non-exercisers from 25% prepregnancy to 53% in late pregnancy, which is in agreement with the study by Pereira et al. (2007). The prevalence of an insufficiently active lifestyle (i.e. fewer than 150 min/week of total leisure-time PA) in their study increased from 12.6% prepregnancy to 21.6% in the second trimester. Because pregnancy is a time period characterized by progressively physiological, psychological, and metabolic changes, a decline in regular exercise may be expected as pregnancy progresses. However, the proportion of non-exercisers is high among pregnant women in our study, considering that walking was included in the definition of regular exercise.

Pereira et al. (2007) reported that 34% of the women in their study were overweight or obese prepregnancy (BMI $\geq$ 24 kg/m^2), compared with 32.8% in our study. Considering that self-reported weight tends to be underestimated, especially in overweight individuals (Gorber et al., 2007), this is an alarming observation. There is growing evidence that overweight and obesity before pregnancy is a significant risk factor for maternal and fetal complications including pregnancy-induced hypertension, preterm delivery, gestational diabetes, and macrosomia (Cnattingius et al., 1998; Baeten et al., 2001; Ehrenberg et al., 2004). Additional weight gain during pregnancy increases the risk for both the mother and the fetus (Kiel et al., 2007). We observed that women with a prepregnancy BMI $\geq$ 24.9 kg/m^2 were less likely to participate in regular exercise in pregnancy weeks 17 and 30, and gaining more than 10 kg was inversely associated with regular exercise in week 30. These results are of particular concern because both overweight, excessive gestational weight gain and inactivity are independently associated with adverse health outcomes in both the woman and the fetus.

Women who reported being short of breath/sweating from PA at work at least once a week were more likely to participate in regular exercise during pregnancy. This could possibly be explained by type of occupation, but we do not have this information. On the other hand, being short of breath or sweating during pregnancy is not a valid indicator of the intensity of PA, as the interaction of an increased body weight, core temperature, and the respiratory changes could affect this matter.

Our results are consistent with previous studies that state that smokers and women with secondary school education only were significantly less likely to exercise regularly than non-smokers and women with a college/university degree (Hinton & Olson, 2001; Evenson et al., 2004; Petersen et al., 2005). In the present study, a positive association between age and regular exercise in pregnancy weeks 17 and 30 was observed. Other studies on pregnant women have reported both a positive (Hinton & Olson, 2001) and a negative (Petersen et al., 2005) association between age and exercise frequency. According to the review article by Trost et al. (2002), a negative association between age and PA in non-pregnant populations has repeatedly been documented.

We have not been able to find comparable studies that have investigated pregnancy-related (weight gain, pelvic girdle pain, nausea, uterine contractions), social (sick-leave, PA at work), and maternal health-related variables (smoking, musculo-skeletal pain, chronic diseases) that may influence exercise levels during pregnancy. Hence, our study provides new information on correlates of an active lifestyle during pregnancy, as well as an insight into potential risk factors for pregnant women that become inactive.

There are some limitations to be considered when interpreting the results from the present study. First, because the response rate was 42% we cannot rule out the possibility of selection bias. Hence, we should interpret the prevalence of regular exercise in pregnancy with caution. However, the follow-up rate in gestational week 30 is high (92%) and the response rate in comparable studies varies between 41% and 74% (Zhang & Savitz, 1996; Hinton & Olson, 2001; Ning et al., 2003). When comparing demographic and reproductive variables between the MoBa participants and their births with the total number of births in Norway during the same period, there were only minor differences. However, it is likely that a socioeconomic gradient influenced the prevalence estimates, as women with a lower socioeconomic status were underrepresented in the study population (Magnus et al., 2006). Demographic variables such as BMI, education, parity, and smoking are distributed differently among low-income compared with high-income pregnant women. This may have introduced a bias, most likely toward a higher prevalence of regular exercise than in the target population. The observation that women without information on recreational exercise were more likely to smoke, have less education, and be overweight prepregnancy adds to the same assumption.

Another limitation is that maternal exercise frequency was self-reported and thus prone to potential measurement errors (Sallis & Saelens, 2000). Assessing PA patterns in women in general and during pregnancy in particular is further complicated by the difficulty of assessing and quantifying PA in this population (Ainsworth, 2000a). Jakicic et al. (1998) found that overweight women who were enrolled in a behavioral weight loss program tended to over-report their exercise level when assessed by self-reporting compared with an accelerometer. The questions chosen in our study have been evaluated as having higher validity because they aim to capture structured exercise activities of moderate to high intensity (Ainsworth et al., 1993), while pregnant women may differ from overweight women in many ways. Even though questionnaires inadequately capture light to moderate PAs and therefore tend to underestimate total PA in women (Ainsworth, 2000b; Schmidt et al., 2006), questionnaire-based studies are common and still the most feasible approach to measure general PA and exercise levels in large-scale epidemiological studies (LaPorte et al., 1985).

The strengths of the present study include the large sample size, population-based, comprehensive longitudinal data collection, and linkage to the NMBR that provided compulsory pregnancy and birth records filled in by midwives. These records are included in the MoBa database and provide information on pregnancy complications, pregnancy outcomes, and the neonatal period, as well as data on non-respondents (Magnus et al., 2006). In contradiction to other studies (Mottola & Campbell, 2003; Ning et al., 2003; Evenson et al., 2004; Petersen et al., 2005), we also collected longitudinal data from the same women from gestational weeks 17 and 30, measuring recreational exercise twice during pregnancy.

Perspectives

Given the adverse health effects of inactivity, overweight, and excessive gestational weight gain, interventions for encouraging pregnant women to become physically active should be implemented. Considering that aerobic dancing is common among both non-pregnant and pregnant women, one strategy to increase participation in recreational exercise could be to develop exercise classes designed especially for pregnant women. Fitness trainers and instructors as well as health care providers should be educated on the benefits of regular exercise during pregnancy and on how pregnant women can exercise safely. Hence, the promotion of swimming and aquatic exercise should be emphasized. Multiparous women are less likely to exercise regularly compared with primiparous women. Given that child care appears to be a major factor for women of childbearing age being able to perform PA (Booth et al., 1997), we suggest that fitness centers, sport clubs, and public swimming pools provide child care in order to increase accessibility for more pregnant women. However, further research is needed on how different exercise regimes affect pregnancy and the offspring.

Key words: prospective, population-based, recreational exercise, pregnancy, correlates.

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Paper II

Association Between Regular Exercise and Excessive Newborn Birth Weight

Katrine Mari Owe, MSci, Wenche Nystad, PhD, and Kari Bø, Prof, PhD

OBJECTIVE: To estimate the association between regular exercise before and during pregnancy and excessive newborn birth weight.

METHODS: Using data from the Norwegian Mother and Child Cohort Study, 36,869 singleton pregnancies lasting at least 37 weeks were included. Information on regular exercise was based on answers from two questionnaires distributed in pregnancy weeks 17 and 30. Linkage to the Medical Birth Registry of Norway provided data on newborn birth weight. The main outcome measure was excessive newborn birth weight, defined as birth weight at or above the 90th percentile. Logistic regression analyses were used to estimate the associations separately for nulliparous (n=16,064) and multiparous (n=20,805) women, and the results are presented as adjusted odds ratios (aORs) with 95% confidence intervals (95% CIs).

RESULTS: Excessive newborn birth weight was observed in 4,033 (10.9%) newborns, 56.1% (n=2,263) of whom were born to multiparous women. An inverse association between regular exercise (at least three times per week) and excessive newborn birth weight in pregnancy weeks 17 and 30 was observed in nulliparous women, aOR 0.72 (95% CI 0.56–0.93) and aOR 0.77 (95% CI 0.61–0.96), respectively. Regular exercise performed before pregnancy did not affect the probability of delivering newborns with an excessive birth weight in nulliparous or multiparous women.

CONCLUSION: Regular exercise during pregnancy reduces the odds of giving birth to newborns with excessive birth weight by 23–28%.

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Fetal macrosomia, often defined as birth weight above 4,000 or 4,500 g regardless of gestational length,[1] is associated with both maternal and perinatal complications. When birth weight exceeds 4,000 g, both mother and newborn are at greater risk of morbidity including perineal lacerations, postpartum hemorrhage, caesarean delivery, shoulder dystocia, low Apgar score, birth trauma, and obesity.[2-4] Several studies show that both mean birth weight and the proportion of newborns weighing more than 4,000 g and 4,500 g have increased during the past decades.[5,6]

Evidence-based guidelines indicate that regular exercise is an important component of a healthy pregnancy.[7] However, recent studies show a decreasing trend of regular exercise during pregnancy.[8,9] Both frequency and the intensity of exercise seem to decrease as pregnancy progresses,[10,11] and most pregnant women shift from weight-bearing to non-weight-bearing exercises such as swimming and bicycling.[12] Despite extensive literature on the relationship between regular exercise during pregnancy and mean birth weight, the results are ambiguous and lack consistency. Both a positive[13-15] and negative association with newborn birth weight have been suggested.[16-18] A few studies also report no difference in birth weight of neonates born to exercising and non-exercising mothers.[19,20]

The aim of the present study was to estimate, in a prospective cohort of pregnant women, the association of regular exercise, performed before and during pregnancy, with excessive newborn birth weight.

METHODS AND MATERIALS

The data used for this study are derived from the Norwegian Mother and Child Cohort Study (MoBa) conducted by the Norwegian Institute of Public

Health.[21] The Norwegian Mother and Child Cohort Study is a nationwide pregnancy cohort that aimed to include 100,000 pregnancies by 2008 and was designed to estimate the associations between some of the lifestyle variables to which pregnant women and their fetuses are exposed in addition to diseases.[22] Pregnant women are recruited into the study through a postal invitation 2 weeks ahead of their routine ultrasound examination at gestational week 17 at their local hospital. Data are obtained from 50 of 52 maternity units in Norway.[21] The overall participation rate for the present data file is 45%. However, the follow-up rate from inclusion to questionnaire 3 is 92%. The present study includes pregnancies enrolled between June 1, 2001, and May 31, 2005.

Participants receive three questionnaires during pregnancy weeks 17 and 30 (questionnaire 1, 2, and 3). Questionnaire 1 includes items of maternal health status, lifestyle behaviors, previous diseases, and medication covering both prepregnancy and the first weeks of pregnancy. Questionnaire 2 is a Food Frequency Questionnaire and is mailed with the invitation and questionnaire 1 in gestational week 17. Questionnaire 3, which is sent out in gestational week 30, focuses mainly on health outcomes during pregnancy and follows up some of the items from questionnaire 1. One reminder is sent by mail if the questionnaires have not been returned within 2 weeks. Linkage to the Medical Birth Registry of Norway was also provided. The questionnaires are available at www.fhi.no/morogbarn. Informed consent was obtained from each participant before inclusion. The study has received approval from the Regional Committees for Medical Research Ethics (S-95113) and The Norwegian Social Science Data Services (01/4325-6).

The second version of the quality-assured data file released for research in April 2006 provided data that were used in the present study. Both questionnaires 1 and 3 had to be answered in order for the women to be included (n=40,049). The record in the Medical Birth Registry of Norway[23] from the present pregnancy and energy intake (MJ/d) from questionnaire 2 were also linked to the Norwegian Mother and Child Cohort Study data set. Pregnancies with missing information on year of birth were omitted from the analyses (n=142). We also excluded multiple pregnancies (n=723) and pregnancies ending before 37 weeks of gestation (n=2,315), leaving 36,869 pregnancies that constitute the study population.

The main outcome measure was excessive newborn birth weight as registered in the Medical Birth Registry of Norway. There is no widely agreed upon definition of fetal macrosomia or excessive newborn birth weight. To account for the increasing birth weight with increasing parity, we defined birth weight to be excessive if it was equal to or above the 90th percentile (ie, 4,170 g and 4,362 g for nulliparous and multiparous women, respectively).

The main exposure was regular exercise before and during pregnancy weeks 17 and 30, defined in terms of frequency. In both questionnaires 1 and 3, the participants were asked how often they engaged in the following exercises: strolling, brisk walking, running (jogging or orienteering), bicycling, fitness training in training centers, swimming, aerobic classes (low or high impact), prenatal aerobic classes, dancing (swing, rock, folkdance), skiing, ball games, horseback riding, and other. For all exercises, the respondents were asked to report frequency with the following categories: "never," "one to three times per month," "once a week," "twice a week," and "three or more times a week." Strolling was excluded from the analysis due to its very low energy expenditure.[24] Regular exercise participation before pregnancy was collected retrospectively in pregnancy week 17 (questionnaire 1). The respondents were asked to recall the type and frequency of exercises performed during the last 3 months before the present pregnancy. The questions on recreational exercise have shown moderate correlations with motion sensor measurements.[25]

Potential confounders of excessive birth weight were selected by cross-tabulations and literature review.[26] The following confounders of excessive birth weight were evaluated: maternal age, maternal education, parity, hypertension, diabetes, gestational weight gain, body mass index (BMI) prepregnancy (both as a continuous and categorical variable), preeclampsia, smoking habits, and maternal height.[5,27,28] Diabetes was defined as either preexisting diabetes or gestational diabetes of any kind. Hypertension was defined as any pregestational or gestational hypertensive disorder complicating pregnancy. Preeclampsia was defined as any diagnosis of preeclampsia. All diagnoses were based on ICD-9 codes from the Medical Birth Registry of Norway records. Parity was collected from the Medical Birth Registry of Norway and was defined in terms of earlier pregnancies lasting more than 20 weeks.[29] Gestational length was also retrieved from the Medical Birth Registry of Norway and was based on a combination of ultrasound scanning and last menstrual period. Body mass index was calculated from self-reported body weight (questionnaire 1) and height (questionnaire 1) and categorized according to the World Health Organization: less than 18.5, 18.5–24.9, 25–29.9, 30–34.9, and 35 or higher. Total gestational weight change was calculated as the difference between the last pregnancy weight before 30 weeks of gestation and the self-reported weight when pregnancy started. Energy intake (MJ/d) was assessed using a Food Frequency Questionnaire (questionnaire 2), and the cutoff intervals for energy intake presented by Meltzer et al[30] were used.

All analysis was carried out in the statistical software program, SPSS 15.0 for Windows (SPSS, Chicago, IL). Three logistic regression models were used to investigate the association between regular exercise before (Model A) and during pregnancy (Model B and C) and excessive newborn birth weight. All models adjusted for maternal age, education, BMI prepregnancy, and current smoking habits. Model B, which assessed the association between regular exercise in week 17 and excessive newborn birth weight, additionally adjusted for exercise prepregnancy, gestational weight change, energy intake (MJ/d), and preexisting diabetes/gestational diabetes mellitus. Lastly, the association between regular exercise in week 30 and excessive newborn birth weight was assessed in Model C, additionally adjusting for exercise prepregnancy, exercise in week 17, total gestational weight change, energy intake (MJ/d), preeclampsia, and preexisting diabetes/gestational diabetes mellitus. Further, to investigate which types of exercises were associated with excessive newborn birth weight, we used stepwise logistic regression adjusting for the same covariates as in Models A through C.

To evaluate the hypothesis that the odds of giving birth to newborns with an excessive birth weight continues to increase with further increases in regular exercise (frequency), we conducted tests for trends by treating the category numbers of regular exercise as an interval-scale variable in the logistic regression models (Wald test).

The possible interaction between maternal height and regular exercise on excessive newborn birth weight was estimated using stratification and multiplicative interaction term. Maternal height was dichotomized at the population median of 1.68 m, and regular exercise was dichotomized at a frequency of three or more times per week, before estimating the association between regular exercise before and during pregnancy and excessive newborn birth weight. However, we did not detect an interaction between maternal height and regular exercise before or during pregnancy on excessive newborn birth weight. Furthermore, we explored whether parity might modify the association between regular exercise and excessive newborn birth weight using stratification. This was done due to the observation that nulliparous women exercise more frequently than their multiparous counterparts.[11,12] Hence, the results are presented separately for nulliparous and multiparous women.

RESULTS

Mean birth weight in this cohort was 3,682 g (standard deviation 488). Among the 36,869 pregnancies included, 4,033 (10.9%) newborns had a birth weight equal to or above the 90th percentile. A higher number of newborns with an excessive birth weight were born to multiparous women (n=2,263) compared with nulliparous women (n=1,770).

The distribution of maternal characteristics by parity is given in Table 1 and shows that nulliparous and multiparous women did not differ significantly in height, education, smoking habits, or diabetes. Nevertheless, nulliparous women were younger, had a lower energy intake (−0.23 MJ/d) ($P<.001$), gained more weight during pregnancy ($P<.001$), and their offspring had a lower mean birth weight compared with offspring of multiparous women ($P<.001$). The highest proportion of overweight women (BMI greater than 24.9), non-exercisers, and excessive newborn birth weight was seen in multiparous women.

Regular exercise performed 3 months before the present pregnancy did not affect the probability of delivering a high birth weight newborn in nulliparous or multiparous women (Table 2, Model A). A moderate protective effect of regular exercise during pregnancy was observed in nulliparous women, irrespective of time of exposure (gestational week 17 or 30) (Table 2, Models B and C).

Nulliparous women exercising at least three times a week in pregnancy week 17 were less likely to give birth to an newborn with an excessive birth weight (P for trend .008) (Table 2, Model B). Adjustment for hypertension and preeclampsia did not change the observed association between regular exercise in pregnancy week 17 and excessive newborn birth weight.

In week 30, nulliparous women exercising one to two times a week were less likely to deliver newborns with an excessive birth weight compared with nonexercisers, but this association was attenuated when we adjusted for gestational weight change independent of diabetes. The adjusted association reached significance only for nulliparous women exercising at least three times a week in pregnancy week 30 (Table 2, Model C).

Walking (adjusted odds ratio [aOR] 0.86, 95% confidence interval [CI] 0.75–0.99) and running (aOR 0.63, 95% CI 0.45–0.89) in pregnancy week 17 were negatively associated with excessive newborn birth weight in nulliparous women. Walking in pregnancy week 30

Table 1. Demographic and Medical Characteristics of Study Participants by Parity (N=36,869)

	Nulliparous (n=16,064)	Multiparous (n=20,805)
Maternal height [cm, mean (SD)]	168.2 (6.0)	168.1 (5.9)
Energy intake [MJ/d, mean (SD)]	9.500 (2.609)*	9.730 (9.393)
Total gestational weight gain [kg, mean (SD)]	9.463 (4.717)*	9.272 (4.500)
Birth weight [g, mean (SD)]	3,585 (472)*	3,758 (489)
Maternal age (y)		
Younger than 25	3,750 (23.3)	1,200 (5.8)
25–29	7,171 (44.6)	6,185 (29.7)
30–34	4,082 (25.4)	9,449 (45.4)
35 or older	1,061 (6.6)	3,971 (19.1)
Education		
Primary school (9 y)	634 (3.9)	691 (3.3)
Secondary school (12 y)	5,403 (33.6)	7,099 (34.1)
College/University (15 or more y)	8,668 (54.0)	11,245 (54.0)
Other	1,295 (8.1)	1,673 (8.0)
Prepregnancy BMI		
Less than 18.5	534 (3.3)	515 (2.5)
18.5–24.9	10,217 (63.6)	12,476 (60.0)
25–29	3,313 (20.6)	5,139 (24.7)
30–34	1,050 (6.5)	1,566 (7.5)
35 or higher	364 (2.3)	592 (2.8)
Smokers (wk 17)	1,613 (10.1)	2,088 (10.1)
Prepregnancy exercise		
Never	1,434 (8.9)	2,437 (11.7)
1–3 times per mo	2,654 (16.5)	4,279 (20.6)
1–2 times a wk	4,568 (28.4)	6,596 (31.7)
3 or more times a wk	6,961 (42.7)	6,589 (31.7)
Missing	547 (3.4)	904 (4.3)
Exercise in wk 17		
Never	2,126 (13.2)	3,544 (17.0)
1–3 times per mo	2,903 (18.1)	4,675 (22.5)
1–2 times a wk	4,719 (29.4)	5,990 (28.8)
3 or more times a wk	5,022 (31.3)	4,475 (21.5)
Missing	1,294 (8.1)	2,121 (10.2)
Exercise in wk 30		
Never	3,910 (24.3)	7,063 (33.9)
1–3 times per mo	3,042 (18.9)	4,349 (20.9)
1–2 times a wk	4,424 (27.5)	4,925 (23.7)
3 or more times a wk	3,844 (23.9)	3,135 (15.1)
Missing	844 (5.3)	1,333 (6.4)
Excessive newborn birth weight	1,120 (7.0)	2,719 (13.1)
High blood pressure (questionnaire 1)	103 (0.6)	227 (1.1)
Pregnancy induced hypertension	730 (4.5)	812 (3.9)
Total preeclampsia incidence	698 (4.3)	434 (2.1)
Preexisting diabetes	56 (0.3)	77 (0.4)
Total gestational diabetes	125 (0.8)	167 (0.8)
Preexisting/GDM	176 (1.1)	232 (1.1)

SD, standard deviation; BMI, body mass index; GDM, gesational diabetes mellitus.
Data are n (%) unless otherwise noted.
* $P<.001$.

was also negatively associated with the outcome (aOR 0.84, 95% CI 0.73–0.96) (data not shown).

Multiparous women who participated in dancing in pregnancy week 17 were less likely to deliver newborns with an excessive birth weight (aOR 0.75, 95% CI 0.63–0.90), whereas training in fitness centers in pregnancy week 17 was positively associated with excessive newborn birth weight (aOR 1.16, 95% CI 1.00–1.35). In pregnancy week 30, low impact aerobics (aOR 0.68, 95% CI 0.47–0.97) and dancing (aOR 0.69, 95% CI 0.53–0.88) were negatively associated with excessive newborn birth weight. Multiparous women participating in swimming in pregnancy week 30 were more likely to give birth to an newborn with an excessive birth weight (aOR 1.16, 95% CI 1.04–1.30) compared with those who did not swim (data not shown).

DISCUSSION

In this large prospective pregnancy cohort study, nulliparous women performing a high level of exercise during pregnancy were less likely to give birth to newborns with an excessive birth weight. The highest number of newborns with excessive birth weight was observed in multiparous women. Interestingly, independent of parity, there seems to be an increasing trend of a protective effect with increasing frequency of regular exercise during pregnancy.

The results indicate that regular exercise during pregnancy may have a protective effect on excessive newborn birth weight, and this association tends to be different with parity. Excluding women with preexisting diabetes/gestational diabetes or preeclampsia from the analysis did not change the estimates substantially. As expected, regular exercise performed during pregnancy seems to have a greater influence on the upper extreme of the birth weight distribution compared with regular exercise performed before pregnancy. Nonetheless, women exercising regularly before pregnancy are also more likely to continue their exercise programs during pregnancy. Based on this study, we cannot rule out that exercising regularly before pregnancy may also affect the upper extreme of the birth weight distribution.

The strengths of this study are the prospective design, study size and that the outcome was obtained from an external source, the Medical Birth Registry of Norway.[23] We therefore consider it unlikely that any misclassification due to imprecise measurements of the outcome influenced the results.

However, regular exercise was assessed indirectly by two self-administered questionnaires. Despite its limited accuracy and imprecision when it comes to

Table 2. Regular Exercise and Excessive Birth Weight (90th Percentile or Higher) Stratified by Parity (N=36,869)

	Nulliparous (n=16,064)			Multiparous (n=20,805)		
	% (Frequency)*	cOR (95% CI)	aOR (95% CI)†	% (Frequency)*	cOR (95% CI)	aOR (95% CI)
Model A: prepregnancy exercise						
Never	12.3 (176)	1.00	1.00	10.9 (265)	1.00	1.00
1–3 times per mo	12.8 (339)	1.05 (0.86–1.27)	0.96 (0.75–1.22)	11.0 (471)	1.01 (0.86–1.19)	1.02 (0.88–1.19)
1–2 times per wk	10.6 (484)	0.85 (0.70–1.02)	0.86 (0.68–1.08)	11.4 (752)	1.06 (0.91–1.22)	1.10 (0.95–1.26)
3 or more times per wk	10.3 (706)	0.82 (0.69–0.98)	0.85 (0.68–1.06)	10.6 (697)	0.97 (0.84–1.13)	1.05 (0.91–1.21)
Missing	11.9 (65)	0.96 (0.71–1.30)	1.10 (0.76–1.58)	8.6 (78)	0.77 (0.59–1.01)	0.86 (0.67–1.10)
Model B: exercise wk 17						
Never	12.7 (271)	1.00	1.00	11.2 (398)	1.00	1.00
1–3 times per mo	12.3 (357)	0.96 (0.81–1.14)	0.93 (0.74–1.18)	11.5 (536)	1.02 (0.89–1.18)	1.05 (0.91–1.22)
1–2 times per wk	11.2 (529)	0.86 (0.74–1.01)	0.91 (0.73–1.14)	10.8 (646)	0.96 (0.84–1.09)	0.95 (0.83–1.10)
3 or more times per wk	9.3 (465)	0.70 (0.60–0.82)	0.72 (0.56–0.93)	10.1 (450)	0.88 (0.77–1.02)	0.90 (0.76–1.07)
Missing	11.4 (148)	0.88 (0.71–1.09)	0.93 (0.68–1.28)	11.0 (233)	0.98 (0.82–1.16)	1.12 (0.93–1.37)
Model C: exercise wk 30						
Never	13.1 (511)	1.00	1.00	11.1 (786)	1.00	1.00
1–3 times per mo	11.5 (350)	0.87 (0.75–1.00)	1.04 (0.86–1.27)	11.1 (483)	1.00 (0.89–1.13)	1.02 (0.90–1.15)
1–2 times per wk	10.4 (462)	0.78 (0.68–0.89)	0.90 (0.75–1.09)	11.0 (542)	1.00 (0.88–1.11)	1.00 (0.89–1.13)
3 or more times per wk	8.5 (327)	0.62 (0.53–0.72)	0.77 (0.61–0.96)	9.4 (294)	0.83 (0.72–0.95)	0.96 (0.83–1.12)
Missing	14.2 (120)	1.10 (0.89–1.37)	1.17 (0.87–1.58)	11.9 (158)	1.07 (0.90–1.29)	1.09 (0.90–1.32)

cOR, crude odds ratio; aOR, adjusted odds ratio; CI, confidence interval.

* The proportion of newborns weighing above the 90th percentile within each response category.

† Model A: Adjusted for maternal age, education, body mass index (BMI) prepregnancy, and smoking status. Excluding women with preeclampsia or preexisting diabetes/gestational diabetes mellitus (GDM) did not change the effect estimates. Model B: Adjusted for maternal age, education, BMI prepregnancy, smoking status week 17, prepregnancy exercise, gestational weight change, energy intake (MJ), preexisting diabetes/GDM. Model C: Adjusted for maternal age, BMI prepregnancy, smoking status week 30, exercise week 17, prepregnancy exercise, energy intake (MJ), preeclampsia, preexisting diabetes/GDM, total gestational weight change.

assessing exercise duration and intensity, postal questionnaires are considered the most feasible method for assessing frequency of physical activity in large epidemiological studies.[31] Because of the prospective data collection, misclassification of regular exercise in our study is most likely to be nondifferential and would most likely have biased the association toward the null. The questions used to assess regular exercise in our study have recently been compared with position and motion sensor measurements of physical activity. A positive association between self-reported frequency of recreational exercise and objectively measured physical activity was observed, indicating that the questions used in the Norwegian Mother and Child Cohort Study can be useful for ranking pregnant women according to their exercise level.[25]

Another limitation is the low response rate in the Norwegian Mother and Child Cohort Study. When comparing participants with nonparticipants using the Medical Birth Registry of Norway, some differences are indicated.[21] Participating women seem to have a slightly different age distribution and to have a lower parity than nonparticipating women. They also smoke less and tend to have lower rates of preterm birth and low birth weight newborns compared with women from the source population.[21] However, not all characteristics or exposures differ between participants and nonparticipants. And even though women in lower socioeconomic classes were underrepresented and may have influenced the prevalence estimates, we believe that estimates of associations will not necessarily be biased as long as reporting of outcomes and exposures is nondifferential and confounding is handled properly. This study estimates the association between regular exercise both before and during pregnancy and excessive newborn birth weight, which is believed to be an effect dependent on biological mechanisms, and therefore valid for participants as well as nonparticipants.

In the adjusted analysis, we strived to control adequately for possible confounding factors. Well-known predictors of birth weight, such as gestational diabetes and smoking, did not change the estimates substantially. Only a few women with preexisting or gestational diabetes mellitus were identified in our study, and excluding these women did not change the observed association between regular exercise and excessive newborn birth weight. We therefore consider it unlikely that the effect estimates are confounded by these factors.

The literature available on the relationship between physical activity during pregnancy and mean birth weight has been inconsistent.[13,16,17,32,33] Nevertheless, a shift in mean birth weight may be of little relevance to the practicing obstetrician, whose main concern is directed toward the two extremes of the birth weight range where maternal and perinatal complications are increasing. If, for instance, a shift in mean birth weight is due to a factor exerting more, or all, of its influence at one extreme and little or none at the other, extrapolation from effects on mean values to other parts of the distribution can be misleading. Furthermore, a factor which only affects the spread of the birth weight distribution will make no difference to the mean but would increase (or decrease) the proportion at both extremes.[34] Regular exercise may be an example of such a factor, rendering physical inactivity a risk factor for excessive newborn birth weight. To date, data relating regular exercise before and during pregnancy to the risk of excessive newborn birth weight are sparse. A moderate protective effect of regular exercise during pregnancy on excessive birth weight was observed in our study, which is in agreement with a case-control study by Alderman et al (1998),[18] albeit a stronger protective effect was observed in their study. On the contrary, a recent study by Voldner et al[35] in 2008 did not observe an association between level of physical activity during pregnancy and macrosomia risk. However, in contrast to these studies, our study is large and population based with a comprehensive prospective data collection. The discrepancy in findings between studies may be due to study design and size of study population in addition to different methods in defining type, intensity and frequency of regular exercise performed during pregnancy.

A possible mechanism behind our findings is the effect of aerobic exercise on glucose tolerance.[36] Our observation that running, walking, dancing, and low-impact aerobics were negatively associated with excessive newborn birth weight supports this hypothesis. Both randomized trials[37,38] and a prospective observational study[39] have shown that light-to-moderate physical activity during pregnancy may reduce glucose levels both in women with gestational diabetes mellitus and in nondiabetic pregnant women. Given the adverse maternal and prenatal complications associated with excessive newborn birth weight, clinicians should promote regular exercise during pregnancy for the purpose of prevention.[7] Nevertheless, neither a Cochrane review[40] nor search on PubMed revealed randomized controlled trials evaluating the effect of regular exercise during pregnancy on excessive newborn birth weight. Although our results indicate a protective effect of regular exercise during pregnancy, there seems to be an urgent need for randomized controlled trials with high methodological and interventional quality to be carried out to study the causal relationship between regular exercise in pregnancy and excessive newborn birth weight.

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Paper III

EXERCISE DURING PREGNANCY AND THE GESTATIONAL AGE DISTRIBUTION: A COHORT STUDY

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ABSTRACT

Purpose: To examine the associations between exercise performed at different time points during pregnancy and gestational age in a population based cohort study. **Methods:** Data included 61,098 singleton pregnancies enrolled between 2000 and 2006 in the Norwegian Mother and Child Cohort Study (MoBa), conducted by the Norwegian Institute of Public Health. Self-reported exercise was collected from two questionnaires in pregnancy weeks 17 and 30. Gestational age was determined based on expected date of delivery according to ultrasound, as registered in the Medical Birth Registry of Norway. We used logistic regression to analyze preterm (<37 completed weeks) and post-term birth (≥42 weeks). Comparison of mean gestational age (GA) by exercise levels were estimated by general linear model. **Results:** Mean GA for women exercising 3-5 times a week in week 17 was 39.51 (95% CI 39.48-39.54) compared to 39.34 (39.30-39.37) completed weeks for non-exercisers (p<0.001). Mean differences remained for all categories of exercise after adjusting for confounding with the greatest mean difference between exercising 3-5 times per week in week 17 and non-exercisers (equals 1 day). Similar mean differences in GA were observed by exercise levels in week 30. The greatest protective effect on risk of preterm birth were observed for women exercising 3-5 times a week in weeks 17 or 30 (aOR=0.82; 95% CI 0.73-0.91; and 0.74; 0.65-0.83, respectively) compared to non-exercisers. Whereas, women exercising 1-2 or 3-5 times per week in week 17, were slightly more likely to have a post-term birth (aOR=1.14;1.04-1.24; aOR=1.15;1.04-1.26, respectively). Mean GA did not differ by type of exercise performed during pregnancy. **Conclusion:** Exercise performed during pregnancy shifted the gestational age distribution slightly upwards resulting in reduced preterm births and slightly increased post-term births.

Key words: birth, gestation**,** longitudinal, pregnancy outcome, self-report, physical activity

INTRODUCTION

Paragraph Number 1 To date, several studies document various health benefits of regular exercise performed during pregnancy, such as reduced risk of developing gestational diabetes mellitus, pregnancy induced hypertension and preeclampsia, urinary incontinence, and reduced postpartum depression (28, 36). Consequently, current guidelines for exercise during pregnancy are now proactive and recommend aerobic exercise of moderate intensity on most, if not all, days of the week for women with normal pregnancies (1, 40) , in addition to strength-conditioning exercise (3,13, 39).

Paragraph Number 2 However, a question still to be answered is the possibility of whether exercise, especially high levels of exercise in the third trimester of pregnancy, might affect gestational age negatively and thereby influence the risk of preterm delivery (<37 weeks gestation), which is the leading cause of neonatal morbidity and mortality worldwide (7). Optimally, exercise during pregnancy, independent of trimester in which exercise is performed, would have no effect on gestational age and the risk of preterm or post-term delivery (>42 weeks gestation). On the contrary, exercising women may have either shorter or prolonged gestations and hence an increased risk of preterm or post-term delivery. Furthermore, exercise patterns seem to change as pregnancy progresses (35), and this change may also affect gestational age differently. Therefore, when one studies the potential effect of exercise on gestational age, it is important to consider the timing of exercise.

Paragraph Number 3 Kramer and McDonald (21) concluded in a recently published Cochrane review that increasing exercise during pregnancy for previously sedentary women does not result in a clinically important shortening of gestation. However, these conclusions are based on few and small studies. Previous observational studies have primarily focused on preterm birth as an outcome (15, 17, 20, 27), and have found physical activity (PA) or exercise to be associated with a decreased risk of preterm birth regardless of study design and definition of PA used. In a large cohort including more than 90,000 pregnant women enrolled in the Danish National Birth Cohort, Madsen et al (24) reported an increased risk of miscarriage by amount of exercise before week 18. Based on the same cohort, Juhl et al (20) reported a decreased risk of preterm birth. Nonetheless, existing studies have not assessed the possible influence of exercise performed at different time points during pregnancy across the entire distribution of gestational age including preterm and post-term birth in addition to mean gestational age.

Paragraph Number 4 The Norwegian Mother and Child Cohort Study (MoBa) is a large prospective study in which data on various health issues and exposures are collected twice during pregnancy via questionnaires (25). Additional information on pregnancy- and birth outcomes from the Medical Birth Registry of Norway (MBRN) provides the opportunity to investigate how exercise performed during pregnancy affect gestational age. The aim of the present study is to examine the association between exercise performed at different time points during pregnancy and gestational age at birth.

MATERIALS AND METHODS

Paragraph Number 5 This study is based on the MoBa study conducted by the Norwegian Institute of Public Health (25). MoBa is a population-based prospective study that has included more than 100,000 pregnancies between 1999 and 2008. The study's primary aim is to identify environmental and genetic factors or interactions of these, for prevention of diseases in pregnancy and childhood and is described elsewhere (25). The fourth version of the quality assured data file released for research in January 2009 provides data for the preset study.

Paragraph Number 6 The majority of all pregnant women in Norway were invited to participate in MoBa and the participation rate is around 44%. In pregnancy week 30, the follow-up rate was 93.6%. Two weeks before the routine ultrasound examination offered to all pregnant women in Norway in gestational weeks 17-18, women are recruited through a mailed invitation. Participants complete two questionnaires during weeks 15-17 (Q1) and 30 of gestation (Q3), respectively. Q1 includes items of maternal health, demographics, lifestyle behaviors, and medical history. Q3 focuses mainly on health outcomes during pregnancy and contains some of the same questions from Q1 for follow-up. All questionnaires are available at www.fhi.no/morogbarn .

Paragraph Number 7 We first included all singleton pregnancies enrolled between 2000 and 2006 for which questionnaire 1 (Q1) was obtained (n=63,681). Pregnancies with missing information on both gestational age from the MBRN (n=230, 0.4%) and exercise in week 17 (n=2153, 3.4%) were excluded. We then omitted pregnancies ended before 22 completed weeks (n=107), and after 44 completed weeks (n=18). Also, those with implausible birth-weight-by-gestational-age combinations (i.e. z-score for gestational age above 4 or less than -4) (n=70) and weekly exercise frequencies above 25 (n=5) were excluded. Thus, the sample size comprises 61,098 pregnancies. In pregnancy week 30, 93.1% (56,853) of the pregnancies had information on exercise level. Through the personal identification number, the record from the Medical Birth Registry of Norway (MBRN) was linked to the MoBa data set. Since 1967, all live- and stillbirths from 16 weeks of gestation in Norway have been compulsory registered in the MBRN (19).

Paragraph Number 8 Informed consent was obtained from each participant before inclusion. The study has received approval from the Regional Committees for Medical Research Ethics (S-95113) and The Norwegian Social Science Data Services (01/4325-6).

Main outcome

Paragraph Number 9 Gestational age was determined based on predicted date of delivery according to ultrasound, or on the date of the last menstrual period in cases where ultrasound data were missing (23), as registered in the Medical Birth Registry of Norway (MBRN). Delivery (both live- and stillbirth) was defined as a terminated pregnancy after 22 completed weeks. Preliminary analysis of the birth weight distribution by each gestational week showed extremely low gestational ages for normal birth weights (e.g. 18 completed weeks and 3320 grams) for some cases, whereas other records contained high gestational ages for low birth weights (e.g. 47 completed weeks and 2150 grams). Furthermore, in order to exclude extreme outliers and potential errors in gestational age, we screened for implausible birth-weight-by-gestational-age combinations by sex (38).

Main exposure variable

Paragraph Number 10 The main exposure was exercise before and during pregnancy weeks 17 and 30, defined in terms of frequency. In both questionnaires Q1 and Q3, the participants were asked how often they performed the following exercises: strolling, brisk walking, running (jogging or orienteering), bicycling, fitness training in training centers, swimming, aerobic classes (low or high impact), prenatal aerobic classes, dancing (swing, rock, folkdance), skiing (cross-country skiing), ball games, horseback riding and other exercises. For all exercises, the frequency of exercise was categorized as: “never”, “1-3 times per month”, “once a week”, “twice a week”, and “≥3 times a week”. To capture the highly active women we divided the responses in the latter category into two exclusive categories by summing up the number of exercises performed per week: “3-5 times a week” (one or two exercises three times a week or more often) and “≥6 times a week” (three or more exercises at least three times a week). We also merged “once a week” and “twice a week” into “1-2 times a week”. “Non-exercisers” were defined as those who responded “never” to all exercises. We then grouped exercises based on type: non-exercisers (strolling and never), brisk walking, non-weight bearing (cycling and swimming), low impact exercises (prenatal aerobics, low impact aerobics, fitness training, dancing, cross-country skiing), high impact exercises (running, jogging, orienteering, ball games), and horseback riding (horseback riding and other). A mixed exercise group included those who did not have a single dominant exercise mode (e.g. one session of jogging and one session of swimming per week). According to the definition of exercise by Caspersen et al (8), strolling was categorized as non-exercise. Exercising before pregnancy was collected retrospectively in pregnancy week 17 (Q1). The respondents were asked to recall the type and frequency of exercises performed during the last three months before the present pregnancy. The questions used on recreational exercise have shown positive correlations with motion sensor measurements (ActiReg®) in a sub-sample within the MoBa study (6). The questions are available in English at the *Journal's* web site (see Table 4, Supplemental Digital Content 1, Questions used to assess recreational exercise in MoBa).

Covariates

Paragraph Number 11 We assessed the following covariates from the MoBa questionnaires (Q1 and Q3): prepregnancy Body Mass Index (BMI) (Q1), educational level (Q1), marital status (Q1), smoking habits (Q1), working hours (i.e. shift work, permanent or non-permanent work) (Q1), predominantly standing or walking at work (Q1), physical exertion at work (Q1), high blood pressure (Q1), pregnancy induced hypertension (Q3), time to pregnancy (Q1), vaginal bleedings in pregnancy (Q1 and Q3), and uterine contractions (Q3). In addition, maternal age, parity, spontaneous abortions, assisted reproduction (present pregnancy), Cesarean section (CS), and preeclampsia were obtained from the Medical Birth Registry of Norway (MBRN).

Statistical Analysis

Paragraph Number 12 Data were analyzed using the PASW Statistics Version 18.0 for Windows (SPSS Inc, Chicago, IL). The distribution of maternal characteristics by exercise level at enrollment was examined by cross-tabulation (Table 5, Supplemental Digital Content 2, Maternal characteristics by exercise level in week 17). To compare mean gestational age by exercise levels during pregnancy, one-way ANOVA was conducted separately for pregnancy weeks 17 and 30. For multiple comparisons, the Bonferroni test was used to determine which means differed significantly from each other (Tables 1 and 3). We estimated the adjusted association between exercise (frequency and types) and mean gestational age at birth using general linear model for pregnancy weeks 17 and 30 (Tables 1 and 3, respectively). The following covariates were added into the final models based on review of previous studies and directed acyclic graphs (DAGs) (37): maternal age, educational level, prepregnancy BMI, smoking and parity. To estimate the risks of preterm and post-term birth by exercise levels, we used logistic regression analysis (Table 2). First, we adjusted for maternal age, educational level, prepregnancy BMI, smoking and parity. Then we included variables such as working hours (unemployed, evening/night, day, non-permanent, rotating shifts, night shifts), spontaneous abortions (both dichotomized and with cut off at or above two previous spontaneous abortions), vaginal bleedings (before or after week 20), assisted reproduction (present pregnancy), and high blood pressure. In week 30, predominantly standing/walking at work and vaginal bleedings after week 20 were added as covariates.

Paragraph number 13 To fully understand the effect of exercise at different time points during pregnancy, a model was then fitted by adding interaction terms combining all values of exercise in gestational weeks 17 and 30. We also combined all values of exercise three months prepregnancy with exercise in pregnancy week 17, to investigate if the association between exercise in week 17 and gestational age was independent of prepregnancy exercise level.

Paragraph Number 14 In an additional set of analyses we excluded pregnancies complicated by preeclampsia, pregnancy induced hypertension, persistent vaginal bleedings, at least two previous spontaneous abortions, assisted reproduction (present pregnancy), and those terminated by a Cesarean section (n=17,572). These analyses were performed to adjust for confounding by indication (34). The effect of such an exclusion will be strong for complications with high recurrence risk and a high risk of preterm delivery, i.e. complications that are strongly associated with both the exposure (exercise) and the outcome (gestational age at delivery). Preeclampsia, pregnancy induced hypertension, persistent vaginal bleedings and having at least two previous spontaneous abortions are all contraindications for participating in regular exercise during pregnancy (1).

RESULTS

Paragraph Number 15 Mean gestational age at birth was 39.45 (SD 1.94) completed weeks. Among the 61,098 pregnancies in this cohort, 5.2% (n=3181) ended before 37 completed weeks and 7.9% (n=4842) ended at or beyond gestational week 42, indicating a skewed distribution. The median was 40 weeks gestation ranging from 22 to 44 completed weeks. Thirteen percent (n=7578) of the pregnancies with information from both questionnaires, did not participate in any kind of exercise during pregnancy weeks 17 and 30, while 12.6% (n=7168) were exercising regularly at least three times a week at both weeks 17 and 30.

Paragraph Number 16 The distribution of maternal characteristics by exercise level showed that women exercising at least six times a week at enrolment were more likely to be non-smokers, nulliparous, and had a higher educational level compared to those who were less physically active (see Table 5, SDC 2, Maternal characteristics by exercise level in week 17).

They also reported a history of fewer spontaneous abortions. Among women exercising less than once a week, 37.2% were overweight or obese according to their prepregnancy BMI (≥ 25 kg/m^2), compared to 20.5% of those exercising at least six times a week. Higher proportions of women reporting predominantly standing or walking at work, working evening/nights, and with non-permanent work were observed among those exercising at least six times per week. There were no differences across levels of exercise in the reporting of maternal age or vaginal bleedings after week 20 (Table 5 is available on the *Journal's* web site).

Paragraph Number 17 Women never exercising in week 17 had a significantly shorter mean gestational age (39.34 weeks, p<.0001) compared to women exercising 1-3 times per month (39.45 weeks), 1-2 times per week (39.48 weeks) and 3-5 times per week (39.51 weeks) (Table 1, Model 1). In contrast, mean gestational age for women who exercised at least six times a week did not differ from the non-exercisers. In the adjusted model, mean differences in GA remained for all categories of exercise with the greatest mean difference between women exercising 3-5 times per week and the non-exercisers (equals 1 day) (Table 1, Model 1). When we excluded pregnancies with obstetrical or medical complications (n=17,572), mean differences in GA were slightly reduced (Table 1).

Paragraph Number 18 Tabel 2 shows the crude and adjusted risk of preterm birth by exercise level. Women exercising 1-2 or 3-5 times per week in week 17 or 30 were associated with a reduced risk of preterm delivery, even though the confidence intervals for all exercise categories overlapped. Adjusting for maternal age, prepregnancy BMI, parity, education and smoking did not attenuate these associations. Neither did adjusting for reproductive history and work-related factors (Table 2). In addition, women exercising 1-2 or 3-5 times a week in week 15 had slightly increased risk of post-term birth (aOR=1.14; 95% CI 1.04-1.24 and aOR=1.15; 1.04-1.26, respectively). In week 30, exercising 1-2 times per week was also associated with an increased risk of post-term birth (aOR=1.11; 1.02-1.20) (data not shown).

Paragraph Number 19 Combining prepregnancy and pregnancy exercise levels in week 17 showed that 1.4% of the women started to exercise in gestational week 17 (n=857), whereas 13.4% previously exercising women stopped before reaching week 17 (n=8215). Compared to women who didn't exercise prepregnancy nor week 17 (n=5185), women who increased their exercise frequency from 1-3 times per month prepregnancy to 3-5 times per week in week 17 (n=252) had on average 2.45 days longer gestations (p <.0001) after adjusting for maternal age, prepregnancy BMI, education, smoking and parity. Smaller mean differences in GA, both crude and adjusted were revealed for other combinations of exercise. Women who started exercising in week 17 and reported at least six sessions per week (n=14), had an increased risk of preterm birth but adjusting for prepregnancy BMI, maternal age, parity and education diluted the association (data not shown).

Paragraph Number 20 We also compared maternal- and social characteristics and obstetric history for women with and without information on exercise at enrolment in week 17 (data not shown). Among women who did not answer the questions on exercise in week 17 (n=2153), it was more common to be single (p<0.001), multiparous (p<0.001), smokers (p<0.001), without a permanent job (p<0.001), to work evening/night shifts (p<0.001), to have primary school only (p<0.001), and a prepregnancy BMI between 30-34 kg/m^2 (p<0.001). Mean gestational age for these pregnancies was slightly shorter (39.37 completed weeks) compared to the study population (p=.09), but the proportions of pre- and post-term births were equal. Hence, selected characteristics in these women were similar to those observed in the non-exercisers. We then repeated the regression analysis including the non-responders in the non-exercise group. However, the mean differences in GA by level of exercise did not change (data not shown).

Paragraph Number 21 In pregnancy week 30, we observed mean differences in the range 0.42 – 1.05 days between exercisers and non-exercisers (Table 1, Model 2), with the smallest mean difference for exercising at least six times per week. Adjusting for confounding factors did not change the mean differences of gestational age (Table 1, Model 2). In pregnancies without obstetrical or medical complications (n=40,424), small mean differences in GA, equal to half a day, were observed between exercisers and non-exercisers (Table 1).

Paragraph Number 22 Twenty percent of the women stopped exercising after pregnancy week 17 (11,703 out of 56,853), whereas eight percent (n=4648) exercised only in week 30. Women exercising 3-5 times a week in both pregnancy weeks 17 and 30 (n=4816) had on average 1.61 days (0.23 weeks) longer gestations compared to women neither exercising in pregnancy week 17 nor 30 ($p<0.001$). Adjusting for possible confounding factors didn'tchange the estimates substantially. Smaller mean differences in gestational age were observed for other combinations of exercise in week 17 and 30 (data not shown).

Paragraph Number 23 Table 3 displays the associations between different types of exercise performed during pregnancy and gestational age at birth. In week 17, women participating in high impact exercises (HIE) had on average 1.33 days longer gestations compared to the non-exercisers ($p<.0001$) but did not differ from the other exercisers (Table 3). The adjusted model did not change the estimates substantially. Likewise, in week 30, women exercising had on average 0.77 – 1.19 days longer gestations compared to the non-exercisers. Mean gestational age did not differ between the different types of exercise and adjusting for maternal age, prepregnancy BMI, education, smoking and parity did not influence the associations.

Paragraph Number 24 Given that records from the MBRN include both ultrasound-based and menstrual-based dating of gestational age, we repeated the analysis using the LMP method as well. Using the LMP method, the gestational age distribution shifted slightly to the right (mean gestational age changed from 39.45 to 39.71 completed weeks) and it yielded a higher number of both preterm- (5.2% versus 4.7%) and post-term deliveries (13% versus 7.9%) compared to UL-based gestational age. In addition, more pregnancies were excluded according to the selection criteria using the LMP method, and 2476 pregnancies did not have their LMP recorded in the MBRN. Nonetheless, the effect estimates of exercise did not differ substantially between the two methods.

DISCUSSION

Paragraph Number 25 This study indicates that mean gestational age among women exercising during pregnancy was longer compared to non-exercising women, but the difference equals one day and must be considered of very limited clinical importance. The protective effect of exercise on preterm and the slightly increased risk of post-term birth, adds to the same conclusion; namely that engaging in regular exercise during pregnancy shift the gestational age distribution slightly upwards resulting in a moderately reduced risk of preterm births and a few more post-term births. This finding is consistent with other smaller observational studies that have assessed mean gestational age (5, 15, 22, 42) as well as two randomized controlled trials (2, 26). A reduced risk of preterm birth have also been reported by others (4, 15-17, 20, 27, 32), whereas few have assessed post-term birth in relation to exercise (15, 16, 22). In contrast to these studies, we observed an increased likelihood of post-term birth for exercising women. What this study adds is that we estimated the possible influence of exercise frequencies and types performed at different time points during pregnancy across the entire gestational age distribution, including both preterm- and post-term births.

Paragraph Number 26 Strengths of our study are that it is population based and includes a large number of pregnancies, with a prospective data collection and a high follow-up rate.

Exercise is assessed twice during pregnancy and includes information on both frequency and type of exercise performed. We also have retrospective information on exercise level the last three months before pregnancy. In addition, linkage to the MBRN, from where the outcome variable was obtained, and two questionnaires in pregnancy provide information on possible confounding variables. We attempted to control for identifiable confounders such as differences in maternal demographics, obstetric and medical history, and lifestyle factors. However, regardless of these attempts to address confounding, we cannot ignore possible bias from unmeasured confounding factors such as for example history of preterm birth.

Paragraph Number 27 In this study, gestational age was estimated based on ultrasound-dating (UL). All methods of gestational age assessment have strengths and weaknesses, and the primary limitation of this method is that gestational age estimates of symmetrically large or small fetuses will be biased. Furthermore, ultrasound references were developed using pregnancies that were dated according to reliable LMP dates. Hence, UL-based dating is potentially biased in the same direction as dates estimated based on LMP (23). Other studies on maternal exercise and gestational length have often used a combination of both UL and LMP based gestational age, and there is no consensus on which method to use. Finally, higher incidence of menstrual irregularities such as secondary amenorrhea and shortened luteal phases has frequently been reported among exercising women (14). Even though menstrual irregularities are not caused by exercise alone, it does influence the regularity of the menstrual cycle (41) and most likely the LMP-based gestational age. Hence, we decided to estimate gestational age based on UL.

Paragraph Number 28 There are several methodological challenges when studying how exercising at different time points during pregnancy may affect gestational age. First, measurement of exercise and physical activity needs to be accurate to minimize the possibility that an effect will not be detected because of measurement error. This is crucial when estimating the association between exercise and gestational age because the association is likely to be modest, as for other birth outcomes (10). The self-reported assessment of exercise and the fact that we did not assess all four dimensions (i.e. type, frequency, duration, and intensity) or domains (i.e. exercise, transportation, occupation, gardening, and care giving) of exercise may have influenced the results and unable us to estimate a dose-response relationship if there is one. We defined strolling as a non-exercise and the true differences in gestational age between exercising and non-exercising women may therefore be larger than the difference reported here. Adjusting for working hours, physical exertion at work or predominantly standing or walking at work did not, however, influence the gestational age distribution by exercise level in our study. This is in contrast to other observational studies reporting an increased risk of preterm delivery or miscarriage among shift-workers and women doing physically demanding work (12, 18, 33, 43). However, our results are in line with Zhu and coworkers (2004), who did not find any significant difference in gestational age between any type of shift work and daytime work in the Danish national birth cohort (44). This may be explained by the high levels of education in the Norwegian and Danish population, and that shift-work is common among highly educated women (e.g. medical doctors working shift at hospitals). In MoBa, a high proportion of shift-workers were exercising during pregnancy. In contrast to other observational studies on the association between recreational exercise and gestational age, the questions used to assess exercise in our study have been validated against a position motion sensor (ActiReg®) in a subsample within the MoBa study (6). Significant positive associations between self-reported exercise and the motion sensor were observed, indicating their usefulness as assessment of recreational exercise in MoBa. Besides, the present study used information from a prospective cohort of more than 60,000 pregnancies which produced small statistically significant estimated effects. Likewise, the fact that the adjusted distribution of gestational did not differ substantially from the crude distribution, further strengthens our results.

Paragraph Number 29 Second, pregnant women who previously experienced persistent vaginal bleedings and developed pregnancy induced hypertension or preeclampsia, or who had more than two spontaneous abortions may choose not to exercise during this pregnancy, or may be advised not to do so by their midwife or general practitioner. We assumed that confounding by the indication for not exercising could have influenced our results. Hence, we restricted the analysis to a subsample of normal pregnancies showing that exercise in weeks 17 and/or 30 did not influence the gestational age distribution.

Paragraph Number 30 Third, a low response rate makes it difficult to generalize the results from this study to the target population. Women participating in the Norwegian Mother & Child Cohort Study differ from the target population in relation to premature delivery rates, and the proportion of newborns with low birth weight are lower among MoBa participants compared with the target population in the MBRN (25). Given that MoBa participants also have a slightly higher educational level, we may assume that they are more physically active compared to the target population. Consequently, the differences in GA between exercisers and non-exercisers may be larger than reported in the present study. Furthermore, women who were excluded from the study population due to missing information on exercise at enrolment also differed from the study population regarding educational level, smoking, marital status, prepregnancy BMI, parity, shift work, and exertion at work. Though, mean gestational age was not significantly shorter compared to women who had answered the questions on recreational exercise, and the proportions of both preterm and post-term deliveries were equal. Including these pregnancies in the analysis, assuming they were equal to the non-exercising group, did not change the estimates. Nevertheless, is it not likely that selection into the study is caused by exercise and the low response rate will therefore have little or no influence on the associations estimated in our study (29).

Paragraph Number 31 Physically active women who become pregnant are more likely to continue their exercise routines during pregnancy (30). Furthermore, women who exercise in late pregnancy are most likely to be different from women not exercising and women quitting exercise in the latter part of pregnancy. If pregnancy is normal without complications, women are also more likely to exercise during pregnancy until childbirth (31). Even though the mechanisms that initiate spontaneous delivery are far from understood (9), it seems that other factors than recreational exercise affect mean gestational age. Despite the limitations of our study, we believe that exercise, whether performed in the second and/or third trimester of pregnancy, shift the distribution of gestational age slightly upwards resulting in a reduced proportion of preterm births and a slightly increased proportion of post-term births.

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Conflict of Interest

None

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Supplemental Digital Content 1. Table 4

Supplement al Digital Content 2. Table 5

Table 1: Binary and multivariate associations between exercise during pregnancy and gestational age at birth (UL-based GA).

	N	Mean (SD)	95% CI	*p-value*		B	95% CI	*p-value*
MODEL 1								
Week 17	61,098	39.45 (1.94)	39.43 – 39.46		*Intercept*	39.28	39.17-39.39	
Exercise frequency (Q1)								
Never	13378	39.34 (2.03)	39.30 – 39.37			Ref.		
1-3 pr month	12656	39.45 (1.94)	39.42 – 39.49	*<.0001*		0.11	0.06 – 0.15	*<.0001*
1-2 a week	18260	39.48 (1.94)	39.45 – 39.50	*<.0001*		0.13	0.08 – 0.17	*<.0001*
3-5 pr week	14030	39.51 (1.86)	39.48 – 39.54	*<.0001*		0.16	0.10 – 0.20	*<.0001*
≥6 pr week	2774	39.44 (1.92)	39.37 – 39.51	*.097*		0.09	0.01 – 0.17	*.038*
Uncomplicated Pregnancies‡	*3,526*				*Intercept*	39.56	39.51-39.60	
Never	9090	39.58 (1.75)	39.46 – 39.54			Ref.		
1-3 pr month	9046	39.66 (1.68)	39.58 – 39.64	*<.0001*		0.09	0.04 – 0.14	*.001*
1-2 a week	13124	39.65 (1.69)	39.58 – 39.63	*<.0001*		0.08	0.03 – 0.12	*.001*
3-5 pr week	10188	39.65 (1.67)	39.59 – 39.65	*<.0001*		0.08	0.03 – 0.13	*.002*
≥6 pr week	2078	39.61 (1.69)	39.52 – 39.65	*.242*		0.04	-0.05 – 0.12	*.395*
MODEL 2								
Week 30	56,851	39.53 (1.72)	39.50 – 39.53		*Intercept*	39.34	39.23 – 39.44	
Exercise frequency (Q3)								
Never	19281	39.42 (1.81)	39.40 – 39.45			Ref.		
1-3 pr month	11217	39.53 (1.70)	39.50 – 39.56	*<.0001*		0.11	0.06 – 0.15	*<.0001*
1-2 a week	14799	39.57 (1.67)	39.55 – 39.60	*<.0001*		0.14	0.11 – 0.18	*<.0001*
3-5 pr week	10116	39.57 (1.72)	39.54 – 39.60	*<.0001*		0.14	0.09 – 0.18	*<.0001*
≥6 pr week	1440	39.48 (1.67)	39.39 – 39.56	*.258*		0.05	-0.05 – 0.14	*.354*
Uncomplicated pregnancies‡	*40,424*				*Intercept*	39.24	39.13 – 39.34	
Never	13178	39.65 (1.52)	39.63 – 39.68			Ref.		
1-3 pr month	8050	39.69 (1.49)	39.66 – 39.72	*.590*		0.05	0.00 – 0.09	*.039*
1-2 a week	10713	39.70 (1.51)	39.67 – 39.73	*.194*		0.05	0.01 – 0.09	*.012*
3-5 pr week	7381	39.71 (1.51)	39.68 – 39.75	*.064*		0.06	0.02 – 0.11	*.005*
≥6 pr week	1102	39.60 (1.53)	39.51 – 39.69	*1.000*		-0.04	-0.14 – 0.05	*.372*

*Adjusted for: maternal age, prepregnancy BMI, educational level, and parity.

‡ Uncomplicated pregnancies: excluding pregnancies complicated by preeclampsia, pregnancy induced hypertension, assisted reproduction (present pregnancy), persistent vaginal bleedings, at least two previous spontaneous abortions, and those terminated by a Caesarean section (n=17,572). Adjusted for: maternal age, prepregnancy BMI, education, smoking and working hours.

Table 2: Crude and adjusted Risk of Preterm Birth by level of Exercise during pregnancy.

	PRETERM BIRTH (<37 completed weeks)			
	% (Frequency)	**cOR* (95% CI)**	**aOR* (95% CI)**	**aOR# (95% CI)**
Exercise frequency week 17 (n=61,098)				
Never	5.9 (789)	Ref.	Ref.	Ref.
1-3 times per month	5.2 (661)	0.88 (0.79-0.98)	0.92 (0.82-1.02)	0.91 (0.82-1.02)
1-2 times a week	5.1 (923)	0.85 (0.77-0.94)	0.87 (0.79-0.97)	0.89 (0.80-0.98)
3-5 times per week	4.8 (670)	0.80 (0.72-0.89)	0.82 (0.73-0.91)	0.84 (0.75-0.93)
≥6 times per week	5.0 (138)	0.84 (0.69-1.01)	0.83 (0.68-1.00)	0.86 (0.73-1.07)
Exercise frequency week 30 (n=56,853)				
Never	5.3 (1028)	Ref.	Ref.	Ref.
1-3 times per month	4.8 (534)	0.89 (0.80-0.99)	0.88 (0.79-0.99)	0.90 (0.81-1.01)
1-2 times a week	4.3 (631	0.79 (0.71-0.88)	0.77 (0.69-0.86)	0.81 (0.73-0.89)
3-5 times per week	4.1 (412)	0.75 (0.67-0.85)	0.74 (0.65-0.83)	0.76 (0.68-0.86)
≥6 times per week	4.3 (62)	0.80 (0.62-1.04)	0.75 (0.57-0.99)	0.81 (0.62-1.05)

* Adjusted for: maternal age, prepregnancy BMI, education, smoking and parity.

Adjusted for: working hours, spontaneous abortions, assisted reproduction, vaginal bleeding < 20th week (week 17), preexisting high blood pressure (week 17), vaginal bleeding >20th week (week 30) and predominantly standing/ walking at work (week 30).

Table 3: Binary and multivariate associations between different types of exercise performed during pregnancy and gestational age at birth (UL-based GA).

	N	Mean (SD)	95% CI	*p-value*		B[#]	95% CI	*p-value*
WEEK 17 (Q1)								
	61,098	39.45 (1.94)	39.43 – 39.46		*Intercept*	39.39	39.23-39.55	
Type of Exercise								
Non-exercisers	13378	39.34 (2.03)	39.30 – 39.37			Ref.		
Brisk walking	12886	39.47 (1.94)	39.43 – 39.50	*<.0001*		0.12	0.07 – 0.16	*<.0001*
Non-weight bearing [1]	7318	39.50 (1.85)	39.46 – 39.54	*<.0001*		0.14	0.08 – 0.20	*<.0001*
LIE [2]	7617	39.49 (1.89)	39.44 – 39.53	*<.0001*		0.13	0.07 – 0.19	*<.0001*
HIE [3]	3336	39.53 (1.83)	39.47 – 39.59	*<.0001*		0.17	0.09 – 0.24	*<.0001*
Horseback riding [4]	3087	39.48 (1.85)	39.41 – 39.54	*.007*		0.13	0.05 – 0.20	*<.0001*
Mixed exercisers	13476	39.46 (1.96)	39.42 – 39.49	*<.0001*		0.11	0.06 – 0.15	*<.0001*
WEEK 30 (Q3)								
	56,853	39.51 (1.73)	39.50 – 39.53		*Intercept*	39.35	39.20 – 39.50	
Type of Exercise								
Non-exercisers	19281	39.42 (1.81)	39.40 – 39.45			Ref.		
Brisk walking	9400	39.58 (1.72)	39.55 – 39.62	*<.0001*		0.16	0.12 – 0.20	*<.0001*
Non-weight bearing [1]	5760	39.55 (1.71)	39.51 – 39.60	*<.0001*		0.13	0.07 – 0.18	*<.0001*
LIE [2]	5694	39.58 (1.67)	39.53 – 39.62	*<.0001*		0.14	0.09 – 0.20	*<.0001*
HIE [3]	607	39.59 (1.71)	39.45 – 39.72	*.470*		0.16	0.02 – 0.31	*.027*
Horseback riding [4]	4121	39.53 (1.64)	39.48 – 39.58	*.010*		0.10	0.04 – 0.16	*.001*
Mixed exercisers	11990	39.54 (1.69)	39.50 – 39.57	*<.0001*		0.11	0.07 – 0.15	*<.0001*

[1] Includes swimming and cycling.

[2] LIE = Low Impact Exercises
[3] HIE = High Impact Exercises
[4] Horseback riding and a non-classifiable category

[#] Adjusted for: maternal age, prepregnancy BMI, educational level, and parity.

Table 4: How often do you exercise? (Fill in each line for both before and during this pregnancy.)

	Never	1-3 times a month	Once a week	2 times a week	≥ 3 times a week
1. Strolling					
2. Brisk walk					
3. Running/ jogging, orienteering					
4. Bicycling					
5. Fitness center					
6. Prenatal aerobic					
7. Low Impact Aerobic					
8. High Impact Aerobic					
9. Dancing (folk, rock, swing)					
10. Skiing*					
11. Ballgames/ netball					
12. Swimming					
13. Horseback riding					
14. Other					

* Cross-country skiing.

Table 5: Maternal characteristics by exercise level at enrollment in gestational week 17 for singleton pregnancies lasting more than 21 weeks (n=61,098).

		Exercise Level				
	No. of pregnancies (%)	**Non-exerciser n=13,378 (21.9%)**	**1-3 per month n=12,656 (20.7%)**	**1-2 t a week n=18,260 (29.9%)**	**3-5 t per week n=14,030 (23.0%)**	**≥6 t per week n=2774 (4.5%)**
Age (yrs) (mean, 95% CI)	61098	29.6 (29.5-29.7)	29.6 (29.5-29.7)	29.7 (29.6-29.8)	29.6 (29.6-29.7)	29.4 (29.3-29.6)
		N (%)	N (%)	N (%)	N (%)	N (%)
Education						
Primary school (9 yrs)	2309 (3.8)	826 (6.2)	453 (3.6)	531 (2.9)	409 (2.9)	90 (3.3)
Secondary school (12 yrs)	21850 (35.9)	5817 (43.8)	4572 (36.1)	6099 (33.5)	4490 (32.1)	872 (31.5)
College/ Univer (≥15 yrs)	34633 (56.9)	6177 (46.5)	7174 (56.7)	11002 (60.4)	8552 (61.2)	1728 (62.4)
Other	2066 (3.4)	476 (3.6)	415 (3.3)	571 (3.1)	526 (3.8)	78 (2.8)
P-value< .001						
BMI						
<18.5	1842 (3.1)	437 (3.4)	346 (2.8)	499 (2.8)	436 (3.2)	124 (4.6)
18.5-24.9	37860 (63.7)	7502 (57.9)	7418 (60.0)	11435 (64.3)	9488 (69.6)	2017 (75.0)
25-29.9	13809 (23.2)	3326 (25.6)	3126 (25.3)	4213 (23.7)	2722 (20.0)	422 (15.7)
30-34.9	4290 (7.2)	1208 (9.3)	1037 (8.4)	1205 (6.8)	747 (5.5)	93 (3.5)
35+	1620 (2.7)	494 (3.8)	430 (3.5)	419 (2.4)	243 (1.8)	34(1.3)

P-value< .001						
Parity						
0	28120 (46.0)	5266 (39.4)	5114 (40.4)	8419 (46.1)	7558 (53.9)	1763 (63.6)
≥1	32978 (54.0)	8112 (60.6)	7542 (59.6)	9841 (53.9)	6472 (46.1)	1011 (36.4)
P-value< .001						
Smoking in pregnancy						
Non-smokers	55123 (90.9)	11460 (86.5)	11368 (90.4)	16767 (92.4)	12953 (93.0)	2575 (93.7)
Smokers	5514 (9.1)	1782 (13.5)	1211 (9.6)	1370 (7.6)	979 (7.0)	172 (6.3)
P-value< .001						
Working hours						
Day	33418 (54.7)	6947 (51.9)	7169 (56.6)	10355 (56.7)	7554 (53.8)	1393 (50.2)
Evening/night	2960 (4.8)	673 (5.0)	566 (4.5)	858 (4.7)	666 (4.7)	197 (7.1)
Night	1089 (1.8)	253 (1.9)	236 (1.9)	328 (1.8)	226 (1.6)	46 (1.7)
Rotating shifts	11038 (18.1)	2326 (17.4)	2260 (17.9)	3243 (17.8)	2683 (19.1)	526 (19.0)
Non-permanent	4182 (6.8)	882 (6.6)	882 (7.0)	1198 (6.6)	986 (7.0)	234 (8.4)
Other	4087 (6.7)	900 (6.7)	756 (6.0)	1193 (6.5)	1012 (7.2)	226 (8.1)
Out of work	4324 (7.1)	1397 (10.4)	787 (6.2)	1085 (5.9)	903 (6.4)	152 (5.5)
P-value< .001						
Predominantly standing/ walking at work						
No	37050 (60.6)	7984 (59.7)	7710 (60.9)	11277 (61.8)	8508 (60.6)	1571 (56.6)

Yes	24048 (39.4)	5394 (40.3)	4946 (39.1)	6983 (38.2)	5522 (39.4)	1203 (43.4)
P-value< .001						
Physical exertion at work						
No	43452 (71.1)	9292 (69.5)	9035 (71.4)	13257 (72.6)	9982 (71.1)	1886 (68.0)
Yes	17646 (28.9)	4086 (30.5)	3621 (28.6)	5003 (27.4)	4048 (28.9)	888 (32.0)
P-value< .001						
Vaginal bleeding < wk 20						
No	48372 (80.1)	10262 (77.6)	10074 (80.3)	14586 (80.8)	11229 (80.9)	2221 (81.1)
Yes	12050 (19.9)	2960 (22.4)	2467 (19.7)	3462 (19.2)	2645 (19.1)	516 (18.9)
P-value< .001						
Vaginal bleeding > wk 20[2]						
No	54268 (94.9)	11653 (94.6)	11313 (95.2)	16310 (95.0)	12521 (95.0)	2471 (94.7)
Yes	2897 (5.1)	659 (5.4)	572 (4.8)	865 (5.0)	663 (5.0)	138 (5.3)
P-value> .05						
Assisted reproduction						
No	58099 (95.1)	12606 (94.2)	12070 (95.4)	17379 (95.2)	13389 (95.4)	2655 (95.7)
Yes	2999 (4.9)	772 (5.8)	586 (4.6)	881 (4.8)	641 (4.6)	119 (4.3)
P-value= .001						
Spontaneous abortion(s)						
0	47529 (77.8)	9897 (74.0)	9704 (76.7)	14372 (78.7)	11229 (80.0)	2327 (83.9)
1	10352 (16.9)	2550 (19.1)	2268 (17.9)	2998 (16.4)	2175 (15.5)	361 (13.0)

≥ 2	3217 (5.3)	931 (7.0)	684 (5.4)	890 (4.9)	626 (4.5)	86 (3.1)
P-value< .001						
High blood pressure						
No	60507 (99.0)	13214 (98.8)	12538 (99.1)	18072 (99.0)	13920 (99.2)	2763 (99.6)
Yes	591 (1.0)	164 (1.2)	118 (0.9)	188 (1.0)	110 (0.8)	11 (0.4)
P-value< .001						
Prepregnancy exercise						
Non-exerciser	4162 (6.8)	3492 (26.1)	285 (2.3)	257 (1.4)	115 (0.8)	13 (0.5)
1-3 pr month	8943 (14.6)	2458 (18.4)	5177 (40.9)	1039 (5.7)	252 (1.8)	17 (0.6)
1-2 pr week	17554 (28.7)	3129 (23.4)	4250 (33.6)	8846 (48.4)	1280 (9.1)	49 (1.8)
3-5 pr week	20555 (33.6)	2129 (15.9)	2398 (18.9)	6544 (35.8)	9053 (64.5)	431 (15.5)
≥6 pr week	8005 (13.1)	477 (3.6)	492 (3.9)	1465 (8.0)	3308 (23.6)	2263 (81.6)
Missing	1879 (3.1)	1693 (12.7)	54 (0.4)	109 (0.6)	22 (0.2)	1 (0.0)
P-value< .001						

[1] Prepregnancy Body Mass Index (kg/m^2).

[2] Information on uterine contractions, vaginal bleeding after week 20, and pregnancy induced hypertension was obtained from Questionnaire 3; hence the total number of pregnancies was 57,165.

Paper IV

ANTENATAL EXERCISE DECREASES CESAREAN DELIVERY RATE IN NULLIPAROUS WOMEN

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ABSTRACT

Context Given the worldwide rising cesarean delivery (CD) rates over the past decades, the search for modifiable factors associated with CD is needed**.**

Objective To investigate the association between exercise during pregnancy and CD, both acute and elective, in nulliparous women.

Design, Setting, and Population Population based pregnancy cohort study, involving 25,160 nulliparous women with a singleton pregnancy who were enrolled in the Norwegian Mother and Child Cohort Study (MoBa) between 2000 and 2006.

Main outcome measures Acute and elective Cesarean delivery obtained from the Medical Birth Registry of Norway. From the generalized linear model, risk differences (RD) with 95% CI for different frequencies and types of exercise during pregnancy were reported.

Results The total (Cesarean delivery) CD rate was 15.6% (n=3928), whereas 67.8% (n=2663) was acute CD. CD rates, both acute and elective type, were reduced in women exercising during pregnancy. The greatest risk reduction (-3.8 and -4.5 percent) was observed for acute CD among women reporting a high weekly frequency of exercise during pregnancy weeks 17 and 30, respectively. Participation in high impact exercises in week 17 and 30 was associated with the largest reductions in risk (-5.1 and -6.2 percent, respectively) compared to non-exercisers.

Conclusions: Compared to non-exercisers, women exercising during pregnancy had a substantially reduced risk of having a CD. A possible link between recreational exercise and

reduced risk of CD provides a new perspective on possible interventions to increased vaginal delivery rates for first time mothers.

INTRODUCTION

The rising rate of cesarean delivery (CD) in developed countries has been partly attributed to broadened medical indications and maternal request [1;2]. Given the adverse effects of repeated cesarean deliveries [3;4], understanding factors associated with the decision to perform the first cesarean is vital [5].

Exercise during pregnancy may influence the course of labor and mode of delivery by affecting metabolic and hormonal changes, uterine contractility, endurance, and muscle strength [6]. Some suggest that women who exercise are more likely to have a "can do" attitude towards labor, due to improved self-efficacy, and are therefore less likely to request a CD [7]. Given the many positive effects of exercise, high-quality research is needed to understand how exercise during pregnancy impacts the course of labor and delivery. The few studies evaluating the association between physical activity and exercise during pregnancy and mode of delivery either reported a protective effect [8;9] or no effect [7;10]. However, existing studies are small, generally not population-based, retrospective in nature, fail to properly adjust for potential confounders, do not assess actual exercise dosage, or are unable to distinguish between elective and acute CD.

The Norwegian Mother and Child Cohort Study (MoBa) is a large prospective study in which data on various health issues and exposures were collected through questionnaires twice during pregnancy [11]. The MoBa dataset was linked to records from the Medical Birth Registry of Norway (MBRN) [12] to provide information about pregnancy, delivery and birth outcomes.

Hence, the purpose of the present study was to investigate the association between exercise during pregnancy and CD, both acute and elective, in nulliparous women.

METHODS

We used data from the Norwegian Mother and Child Cohort Study (MoBa), initiated by the Norwegian Institute of Public Health [11]. MoBa is a population-based prospective study that included over 100,000 pregnancies between 1999 and 2008. The study's primary aim was to identify environmental and genetic factors associated with diseases in pregnancy and childhood. Methods and cohort characteristics have been reported elsewhere [11;13]. Data were collected from all parts of Norway, including both rural and urban areas. The present study was based on the fourth version of the quality assured data file released for research in January 2009. Informed consent was obtained from all participants before inclusion. The study was approved by the Regional Committees for Medical Research Ethics (S-95113) and The Norwegian Social Science Data Services (01/4325-6).

The majority of all pregnant women in Norway were invited to participate in MoBa and the participation rate is around 44%. The follow-up rate was 93.6% in pregnancy week 30. In the current analysis, we first included all women with singleton pregnancies enrolled between 2000 and 2006 with available records from the MBRN who completed questionnaires at 17 weeks (Q1) and 30 weeks (Q3) (n=59,313). We then excluded multiparous women (n=32,084), pregnancies complicated by placenta previa (n=272) and transverse fetal presentation (n=25), because these conditions are absolute indications for elective cesarean delivery, and women with missing information on exercise in weeks 17 and 30 (n=845). After omitting women with incomplete information on marital status, educational level and prepregnancy body mass index (n=927, 3.6%), the final analytic sample consisted of 25,160 singleton pregnancies. Women completed two questionnaires during weeks 15-17 (Q1) and week 30 of gestation (Q3), respectively. Questionnaires included items about maternal health, demographics, lifestyle behaviors, and medical history. All questionnaires are available at www.fhi.no/morogbarn.

Outcome

Cesarean delivery was the outcome of interest in the present study. Information about CD, indicated as acute, elective or unspecified was obtained from the MBRN. Acute CD is defined as a CD where the decision is made within 8 hours of delivery and includes both emergency and acute operations. The validity of mode of delivery in the MBRN is considered to be high with a 3% error rate [14].

Main Exposure

The main exposure was exercise performed during pregnancy weeks 17 and 30. In both questionnaires Q1 and Q3, the participants were asked how often they participated in the following exercises: strolling, brisk walking, running (jogging or orienteering), bicycling, fitness training in training centers, swimming, aerobic classes (low or high impact), prenatal aerobic classes, dancing (swing, rock, folkdance), skiing (cross-country skiing), ball games, horseback riding and other. For all exercises, the frequency of exercise was categorized as: "never", "1-3 times per month", "once a week", "twice a week", and "≥3 times a week". To capture the highly active women we divided responses in the latter category into two exclusive categories by summing up the number of exercises performed per week: "3-5 times a week" (e.g. one or two exercises at least three times a week) and "≥6 times a week" (e.g. three or more exercises at least three times a week). We also merged "once a week" and "twice a week" into "1-2 times a week". "Non-exercisers" were defined as those who responded "never" to all exercises. We then grouped exercises based on type: non-exercisers (strolling and never), brisk walking, non-weight bearing (cycling and swimming), low impact exercises (prenatal aerobics, low impact aerobics, dancing, cross-country skiing, and fitness training), high impact exercises (running, jogging, orienteering, ballgames), and horseback riding (horseback riding and other). A mixed exercise group included those who did not have a single dominant exercise mode (e.g. one session of jogging and one session of swimming per week). Based on the definition of exercise by Caspersen et al [15], strolling was categorized as non-exercise. The questions used to assess exercise in the present study have been compared with accelerometer measurements of physical activity in a sub-sample within the MoBa study, and have shown moderate correlations [16].

Covariates

Based on review of previous studies and an assumed possible underlying causal mechanism, we assessed covariates and confounding factors using directed acyclic graphs (DAGs) [17]. Figure 1 shows the possible association between antenatal exercise and CD. The following covariates were included in the final models : Maternal age (years), prepregnancy body mass index (BMI, kg/m^2), educational level (primary, secondary, college/university, and other), marital status (married, cohabitant, single, and other), fear of giving birth (no/yes), pelvic girdle pain (no/yes), and assisted reproduction prior to this pregnancy. Gestational weight gain, preeclampsia, pregnancy induced hypertension, and gestational diabetes were not included as covariates because they might be on the causal pathway.

Statistics

We explored the crude associations between a wide range of covariates and CD using cross-tabulations. In addition, the same covariates were explored for associations with the exposure variable (exercise). Due to the high incidence of the outcome of interest in our study (15.6%), we used the generalized linear model with identity link function and binominal distribution to estimate the association between exercise during pregnancy and CD (both acute and elective CD). Maternal age and prepregnancy BMI were entered as continuous variables in the models. From the models we report the risk differences (RD) with 95% Confidence Intervals (Wald) for different frequencies and types of exercise during pregnancy weeks 17 and 30. Vaginal delivery was the reference category in all models. In Models 1 and 2, we estimated the associations between frequency and types of exercise in week 17, respectively, and acute CD. The associations between frequency and types of exercise in week 30, and acute CD were estimated in Models 3 and 4, respectively. In all models estimating the associations with acute CD, pregnancies terminated by an elective or unspecified CD were excluded (n=1330). We also estimated the associations between frequency and types of exercise in weeks 17 and 30, and elective CD, excluding pregnancies terminated by an acute or unspecified CD (n=3219). The results were analyzed using PASW Statistics 18.0 for Windows (SPSS Inc, Chicago, IL).

Results

The mean maternal age at delivery was 28.3 (SD 4.4) years ranging from 15 to 46 years, and the mean prepregnancy BMI was 23.8 kg/m^2 (SD 4.2) with 30.1% (n=7623) of the women entering their pregnancy being overweight or obese (prepregnancy BMI at or above 25 kg/m^2). The mean gestational age was 39.5 (SD 1.9) completed weeks, and 6.9% (n=1748) of the pregnancies resulted from an assisted reproduction. At week 30, 17.5% (n=4407) reported fear of childbirth (Table 1). Breech presentation was observed in 5% (n=1254) of the pregnancies.

Among the 25,160 pregnancies in this cohort, 15.6% (n=3928) had a CD, approximately 2/3 (67.8%, n=2663) were acute CD (Table 1). Women 35 years or older had the highest proportion of both elective (6.9%) and acute CD (16.5%) compared to women between 25 and 29 years (2.9% and 9.6%, respectively) (p<.001). The proportion of acute CD was also higher among women who entered pregnancy as overweight or obese (15.8%) compared to having a prepregnancy BMI within the normal range (8.8%) or being underweight (7.5%) (p<.001). The highest proportion of non-exercisers was also observed among the youngest (<25 years) and women with a prepregnancy BMI at or above 30 (22.7% and 26.2%, respectively). The prevalence of CD did not differ by marital status or educational level (data not shown).

Table 2 displays the levels of exercise during pregnancy weeks 17 and 30 in relation to mode of delivery. The prevalence of acute CD decreased as frequency of exercise increased from 1-3 times per month to more than five times a week during both pregnancy weeks 17 and 30. Women who performed high impact exercises in week 17 had the lowest prevalence of acute

CD (8.4%) whereas mixed exercisers and non-exercisers had the highest prevalence of acute CD (11.5% and 13.0%, respectively). The differences in the prevalence of elective CD by frequency and types of exercise were small at all points in time, except for brisk walking (Table 2). A small proportion of the CD performed in this study was unspecified (1.7%). We did not observe any differences in the incidence of unspecified CD by frequency or type of exercise (data not shown).

The crude and adjusted RDs for having an acute CD in relation to frequency and type of exercise during pregnancy are summarized in Table 3. In comparison with non-exercisers, the negative risk differences of having an acute CD increased gradually from -2.2 to -3.8 percent with increasing frequency of exercise in week 17 (Model 1). High impact exercisers had the lowest prevalence of elective CD at both time points giving the largest RD. Also brisk walking, low impact exercises, non-weight bearing exercises and horseback riding (week 30) were associated with a reduced risk of having an acute CD (Models 2 and 4). Frequency of exercise in week 30 was negatively associated with having an acute CD, with the RDs ranging from -1.7 to -4.5 percent, compared to non-exercisers (Model 3). Including the confounding factors in the Models did not influence the estimates significantly, nor did adjusting for smoking status, prepregnancy hypertension or other plausible mediators (data not shown).

For elective CD, exercising 1-2 times per week showed the greatest RD compared to non-exercisers in week 17 (-2.2 percent), whereas women had to exercise at least six times a week in week 30 to reach a comparable risk reduction (Table 4). In week 17, brisk walking and high impact exercises had the largest risk reductions for elective CD (-2.6 and -2.3, respectively), compared to non-exercisers. In week 30, however, the risk reductions by types of exercise ranged from -0.6 to -1.8 percent. The crude and adjusted risk differences did not change significantly (Table 4). Overall, acute CD revealed the largest risk differences as compared to elective CS, at both time points during pregnancy (data not shown).

Discussion

In this large population based pregnancy cohort, women exercising during pregnancy had substantially lower risks for both acute and elective CD than women not exercising during pregnancy. For acute CD, the risk reduction was especially pronounced in frequent exercisers and women participating in high impact exercises. Exercise was associated with smaller, though still significant, risk reduction for elective CD.

Comparison with other studies

To our knowledge, this is the first large, prospective, population based study of pregnant women that assesses the association between exercise at different time points during pregnancy and different types of CD. However, studies that are based on clinical or highly selected study populations exist [7;18-22], but have failed to report an association between physical activity or exercise and mode of delivery. Few studies have also assessed physical activity or exercise more than once during pregnancy. The varied definitions of physical activity and exercise used in previous studies make it difficult to compare the results across studies. Our results are in line with two small retrospective studies [9;23] and one previous prospective study on well-conditioned recreational athletes [24]. none of these studies are population based and all but one is based on American women. Given the vast differences in CD rate by country of residence, it is important to study the possible association in women in other populations.

The most common indication for CD in nulliparous women is dystocia, which includes problems of uterine dysfunction, impaired cervical dilatation and/or fetal descent in the maternal pelvis [25]. Dystocia is generally thought to be due to insufficient uterine contractions

[26]. A recently published study found athletics and heavy gardening to be protective of dystocia in nulliparous women [27], which may further support a possible biological link. Anecdotally, some obstetricians express concern that strenuous exercise, by strengthening skeletal muscle including pelvic floor muscles, might lead to dystocia from muscle obstruction. Our results do not support this opinion.

A suggested underlying causal link between maternal obesity and inefficient uterine contractility during labor has previously been suggested [6;28]: increased concentrations of total cholesterol and low density lipoproteins (LDL) inhibit uterine contractions [6]. Similarly, regular aerobic exercise is associated with reduced levels of both cholesterol and LDL in non-pregnant women [29]. One study reported reduced total cholesterol in women with the highest levels of physical activity in early pregnancy [30]. MoBa did not measure lipoproteins or cholesterol, but along the same lines of this biologic plausibility, we found the greatest risk reduction for acute CD in the most frequent exercisers and those who performed high impact exercises compared to non-exercisers. Studies that have examined the effect of specific exercises such as pelvic floor exercises [31] and very light resistance exercises [10], have not found an association between exercise and mode of delivery.

Thus, one possible mechanistic explanation to our results is the fact that there is an association between exercise and body composition, here expressed as prepregnancy BMI. Women who enter their pregnancy with a normal BMI are more likely to exercise during pregnancy [32], gain less weight during pregnancy[33], and are less likely to develop pregnancy related diseases such as preeclampsia [34] and gestational diabetes [35], both of which predispose women to both elective and acute CD. Prepregnancy BMI is also associated with newborn birth weight [36], another important risk factor for CD (acute type). However, after adjusting for prepregnancy BMI in our models, the estimates did not change substantially, pointing towards an independent effect of exercise in this study.

We observed weaker associations for elective CD, compared to acute CD. Most of the elective CDs in Norway are performed on indications such as previous cesarean delivery, breech presentation (≥34 weeks) and maternal request [37]. However, a recently published study by Stjernholm et al. [38] reported that the increased rate of elective CD is due to increasing psychosocial indications defined as maternal request without any co-exiting medical indication. Women who experience medical complications are also less likely to exercise during pregnancy. Only nulliparous women were included in our study and both maternal request and a single question on fear of childbirth were included as covariates in an attempt to adjust for these factors but they did not change the risk differences.

Strengths and limitations

The major strengths of this study are its prospective design, large sample size, high follow-up rate and linkage to the MBRN. The mandatory nature of MBRN reported minimizes selection bias, and the validity of delivery type, including CD data, are considered to be of high quality [14].

Possible limitations include self-report of exercise, selection bias of women that chose to enroll in MoBa, and that even minor risk reductions become highly significant due to the large sample size. Similar to previous studies of the association between exercise and mode of delivery, information on the exposure variable was self-reported by questionnaires. Exercise levels may therefore be overestimated, with an underrated proportion of non-exercisers. Nevertheless, we defined strollers as non-exercisers and other physical activities such as household, gardening and childcare were not included. In addition, self-reported exercise was compared to objective measurements of PA by accelerometer in a subgroup of MoBa participants [16;16]. By providing detailed information on type of exercise, our study was the first to include types of exercise in the analysis, we were able to explore the possible association between different types of exercise and mode of delivery.

Conclusions and implications for clinicians

Our results suggest that exercising during pregnancy decreases the risk of both elective and acute CD. The risk reduction of CD was greatest (minus six percent for acute CD) among women performing high impact exercises such as running, jogging, orienteering, ballgames, and high impact aerobics during pregnancy. A possible link between recreational exercise and reduced risk of acute CD among first time mothers has far reaching implications. Our results provide a new perspective on birth performance and possible interventions to increase vaginal delivery rates for first time mothers. Hence, the results of the current study should stimulate to further research into possible causal mechanisms explaining the association between exercise and Cesarean delivery. Further knowledge of this issue would be helpful for midwifes and doctors who care for and counsel pregnant women. Vaginal delivery for the first birth is of great importance for further obstetric performance for the individual women. Therefore, reduction of CD in first time mothers would also have a substantial impact on the national CD rates.

Author contributions: Mrs. Owe had the full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concepts and design: Owe, Nystad, Vangen, Stigum and Bø.

Analysis and interpretation of data: Owe, Nystad, Stigum, Vangen and Bø.

Drafting of manuscript and critical revision of the manuscript for important intellectual content: Owe, Nystad, Vangen, Stigum and Bø.

Statistical analysis: Owe, Nystad, Stigum and Vangen.

Study supervision: Bø and Nystad

Conflict of interest disclosures: None conflicts of interests were reported.

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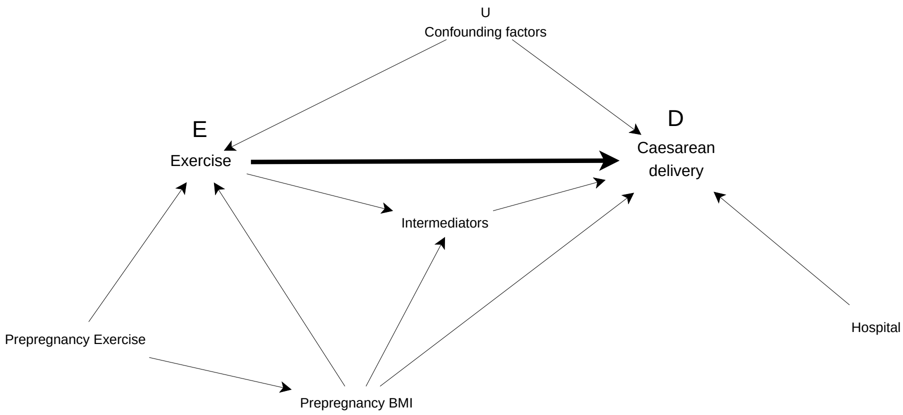
Figure 1. A plausible causal model for the association between exercise during pregnancy and Cesarean delivery.



U: Maternal age, education, marital status, pelvic girdle pain, fear of childbirth and IVF.
Intermediators: Gestational weight gain, high blood pressure, preeclampsia and gestational diabetes/preexisting diabetes.
Exercise and prepregnancy BMI share common cause (prepregnancy exercise).

Figure 1.

Table 1: Characteristics of study population (n=25,160).

	N (%)
Cesarean delivery	
No CD	21232 (84.4)
Elective	848 (3.4)
Acute	2663 (10.6)
Unspecified CD	417 (1.7)
Exercise week 17	
Never	4549 (18.1)
1-3 times per month	4610 (18.3)
1-2 times per week	7586 (30.2)
3-5 times per week	6831 (27.2)
≥6 times per week	1584 (6.3)
Age (years)	
<25	5480 (21.8)
25-29	11148 (44.3)
30-34	6726 (26.7)
≥35	1806 (7.2)
Prepregnancy BMI	
<18.5	866 (3.4)
18.5-24.9	16671 (66.3)
25.0-29.9	5369 (21.3)
30.0-34.9	1645 (6.5)
35+	609 (2.4)
Education	
Primary school	917 (3.6)
Secondary school	8840 (35.1)
College/ university	14465 (57.5)
Other	938 (3.7)
Marital status	
Married	8976 (35.7)
Cohabitant	15001 (59.6)
Single	774 (3.1)
Other	409 (1.6)
Fear of giving birth	
No	20753 (82.5)
Yes	4407 (17.5)
Smoking	
No	22892 (91.0)
Yes	2109 (8.4)
missing	159 (0.6)
Preexisting high BP	
No	24925 (99.1)
Yes	235 (0.9)
Preexisting Diabetes	
No	25021 (99.4)
Yes	139 (0.6)
Preeclampsia	
No	23834 (94.7)
Yes	1326 (5.3)
Pelvic girdle pain after week 13	
No	20079 (79.8)
Yes	5081 (20.2)
Assisted reproduction	
No	23412 (93.1)
Yes	1748 (6.9)

Table 2: The distribution of frequency and type of Exercise during pregnancy weeks 17 and 30 by Cesarean delivery in 25,160 nulliparous singleton pregnancies in the Norwegian Mother and Child Cohort Study (MoBa).

	Vaginal delivery* n=21,232 (84.4%)	Elective CD n=848 (3.4%)	Emergent CD n=2663 (10.6%)	Total CD† n=3928
	N (%)	N (%)	N (%)	N (%)
Frequency of Exercise				
Week 17				
Non-exerciser	3674 (80.8)	211 (4.6)	588 (12.9)	875 (19.2)
1-3 times per month	3872 (84.0)	158 (3.4)	508 (11.0)	738 (16.0)
1-2 times per week	6482 (85.4)	217 (2.9)	756 (10.0)	1104 (14.6)
3-5 times per week	5847 (85.6)	212 (3.1)	661 (9.7)	984 (14.4)
≥6 times per week	1357 (85.7)	50 (3.2)	150 (9.5)	227 (14.3)
Week 30				
Non-exerciser	5639 (81.6)	282 (4.1)	871 (12.6)	1269 (18.4)
1-3 times per month	3926 (83.9)	162 (3.5)	521 (11.1)	753 (16.1)
1-2 times per week	6092 (85.5)	204 (2.9)	692 (9.7)	1029 (14.5)
3-5 times per week	4767 (86.2)	178 (3.2)	500 (9.0)	763 (13.8)
≥6 times per week	808 (87.6)	22 (2.4)	79 (8.6)	114 (14.4)

Type of Exercise				
Week 17				
Non-exerciser	2629 (80.8)	156 (4.8)	416 (12.8)	625 (19.2)
Brisk walking	4632 (85.6)	144 (2.7)	535 (9.9)	781 (14.4)
Non-weight bearing [1]	2525 (85.3)	100 (3.4)	284 (9.6)	434 (14.7)
Low impact exercises [2]	3276 (85.1)	125 (3.2)	385 (10.0)	573 (14.9)
High impact exercises [3]	1441 (87.4)	49 (3.0)	135 (8.2)	207 (12.6)
Horseback riding [4]	1182 (84.5)	48 (3.4)	145 (10.4)	217 (15.5)
Mixed exercises [5]	5547 (83.6)	226 (3.4)	763 (11.5)	1091 (16.4)
Week 30				
Non-exerciser	4762 (81.6)	237 (4.1)	744 (12.7)	1076 (18.4)
Brisk walking	3284 (86.6)	110 (2.9)	333 (8.8)	507 (13.4)
Non-weight bearing [1]	1915 (85.1)	71 (3.2)	224 (10.0)	335 (14.9)
Low impact exercises [2]	2780 (86.4)	85 (2.6)	306 (9.5)	438 (13.6)
High impact exercises [3]	255 (87.9)	11 (3.8)	20 (6.9)	35 (12.1)
Horseback riding [4]	1642 (85.7)	61 (3.2)	175 (9.1)	275 (14.3)
Mixed exercises [5]	6594 (83.9)	273 (3.5)	861 (11.0)	1262 (16.1)

[#] Includes strolling and those who answered never.

† Includes unspecified CD (n=417).

[1] Swimming and cycling.

[2] Prenatal aerobic dancing, low impact aerobic dancing, dancing, cross-country skiing and fitness training.

[3] Running, jogging, orienteering, ballgames, netball games.

[4] Horseback riding and unclassifiable exercises (other).

[5] Includes those who did not perform a single exercise >50% of the total active time.

Table 3. Incidence, crude and adjusted risk differences (RD x100) for Acute Cesarean delivery (n=23,895) by exercise level during pregnancy weeks 17 and 30 in singleton nulliparous women.

	Acute CD				
	%	cRD	aRD[#]	95% CI†	*Sign.*
Week 17 (Q1)					
Model 1 – Exercise frequency					
Non-exerciser	13.8	Ref.	Ref.		
1-3 times per month	11.6	-2.2	-2.2	-3.6, -0.8	*.002*
1-2 times per week	10.4	-3.4	-3.4	-4.6, -2.1	*.000*
3-5 times per week	10.2	-3.6	-3.6	-4.9, -2.4	*.000*
≥6 times per week	10.0	-3.8	-3.8	-5.7, -2.0	*.000*
Model 2 – Type of Exercise					
Non-exerciser	13.7	Ref.	Ref.		
Brisk walking	10.4	-3.3	-3.3	-4.8, -1.8	*.000*
Non-weight bearing[1]	10.1	-3.6	-3.6	-5.2, -1.9	*.000*
LIE [2]	10.5	-3.1	-3.1	-4.7, -1.6	*.000*
HIE [3]	8.6	-5.1	-5.1	-6.9, -3.3	*.000*
Horseback riding [4]	10.9	-2.7	-2.7	-4.8, -0.7	*.010*
Mixed exercises	12.1	-1.6	-1.6	-3.0, -0.1	*.035*
Week 30 (Q3)					
Model 3 – Exercise frequency					
Non-exerciser	13.4	Ref.	Ref.		
1-3 pr m	11.7	-1.7	-1.7	-2.9, -0.4	*.009*
1-2 pr wk	10.2	-3.2	-3.2	-4.3, -2.1	*.000*
3-5 pr wk	9.5	-3.9	-3.9	-5.0, -2.7	*.000*
≥6 pr wk	8.9	-4.5	-4.5	-6.5, -2.4	*.000*
Model 4 – Type of Exercise					
Non-exerciser	13.5	Ref.	Ref.		
Brisk walking	9.2	-4.3	-4.3	-5.6, -3.0	*.000*
Non-weight bearing [1]	10.5	-3.0	-3.0	-4.6, -1.5	*.000*
LIE [2]	9.9	-3.6	-3.6	-5.0, -2.2	*.000*
HIE [3]	7.3	-6.2	-6.2	-9.4, -3.0	*.000*
Horseback riding [4]	9.6	-3.9	-3.9	-5.5, -2.3	*.000*
Mixed exercises	11.5	-2.0	-2.0	-3.1, -0.8	*.001*

[#] Adjusted for: Maternal age, marital status, prepregnancy BMI, educational level, assisted reproduction, pelvic girdle pain (PGP), and fear of childbirth.
† 95% Wald Confidence Intervals
[1] Swimming and cycling
[2] LIE = Low Impact Exercises
[3] HIE= High Impact Exercises
[4] Horseback riding and a non-classifiable category

Table 4. Incidence, crude and adjusted risk differences (RD x100) for Elective (n=22,080) Cesarean delivery by exercise level during pregnancy weeks 17 and 30 in singleton nulliparous women.

	Elective CD				
	%	cRD	aRD[#]	95% CI	*Sign.*
Week 17 (Q1)					
Model 1 – Exercise frequency					
Non-exerciser	5.4	Ref.	Ref.		
1-3 pr m	3.9	-1.5	-1.5	-2.4, -0.6	*.001*
1-2 pr wk	3.2	-2.2	-2.2	-3.0, -1.4	*.000*
3-5 pr wk	3.5	-1.9	-1.9	-2.8, -1.1	*.000*
≥6 pr wk	3.6	-1.9	-1.9	-3.1, -0.7	*.002*
Model 2 – Type of Exercise					
Non-exerciser	5.6	Ref.	Ref.		
Brisk walking	3.0	-2.6	-2.6	-3.6, -1.6	*.000*
Non-weight bearing[1]	3.8	-1.8	-1.8	-2.9, -0.7	*.002*
LIE [2]	3.7	-1.9	-1.9	-3.0, -0.9	*.000*
HIE [3]	3.3	-2.3	-2.3	-3.6, -1.1	*.000*
Horseback riding [4]	3.9	-1.7	-1.7	-3.1, -0.3	*.016*
Mixed exercises	3.9	-1.7	-1.7	-2.7, -0.7	*.001*
Week 30 (Q3)					
Model 3 – Exercise frequency					
Non-exerciser	4.8	Ref.	Ref.		
1-3 pr m	4.0	-0.8	-0.8	-1.6, 0.000	*.089*
1-2 pr wk	3.2	-1.5	-1.5	-2.2, -0.8	*.000*
3-5 pr wk	3.6	-1.2	-1.2	-1.9, -0.4	*.005*
≥6 pr wk	2.7	-2.1	-2.1	-3.3, -0.9	*.002*
Model 4 – Type of Exercise					
Non-exerciser	4.7	Ref.	Ref.		
Brisk walking	3.2	-1.5	-1.5	-2.3, -0.7	*.000*
Non-weight bearing [1]	3.6	-1.1	-1.2	-2.2, -0.2	*.023*
LIE [2]	3.0	-1.8	-1.8	-2.6, -0.9	*.000*
HIE [3]	4.1	-0.8	-0.6	-3.1, 1.9	*.630*
Horseback riding [4]	3.6	-1.2	-1.2	-2.2, -0.1	*.032*
Mixed exercises	4.0	-0.8	-0.8	-1.5, 0.00	*.045*

[#] Adjusted for: Maternal age, marital status, prepregnancy BMI, educational level, assisted reproduction, pelvic girdle pain (PGP), and fear of childbirth.

[1] Swimming and cycling

[2] LIE = Low Impact Exercises

[3] HIE= High Impact Exercises

[4] Horseback riding and a non-classifiable category