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Physical activity before and during pregnancy and size at birth

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Contents

Abstract. *Background:* Newborn macrosomia is related to a range of serious health outcomes for both the baby and the mother. Maternal lifestyle factors, including physical activity and body mass index, may influence the final birth weight of the baby; however, the existing literature shows inconsistent results. The objective of the present investigation was to assess the relation of physical activity measured either before or during pregnancy with birth weight, and more specifically, to examine the effect of physical activity on the risk of delivering a high birth weight infant. In addition, we will explore the combined effect of body mass index (BMI) and leisure time physical activity (LTPA) in relation to birth weight and risk of macrosomia (defined as birth weight ≥4,000 g). *Methods:* We used data from two large health surveys conducted in 1984-1986 (HUNT I) and 1995-1997 (HUNT 2) in Nord- Trøndelag county, Norway. The study included 2,277 women in HUNT 1 and 2,286 women in HUNT 2 aged 20-39 years, who gave birth to at least one child during a five year period after participation. LTPA was assessed by baseline questionnaires, maternal BMI was computed from measured height and weight, and a linkage to the Medical Birth Registry of Norway provided data on newborn birth weight. In linear regression, adjusted differences in mean birth weight were calculated, and logistic regression was used to compute odds ratios (ORs) with 95% confidence interval (CI) for macrosomia. *Results:* No clear association was found between the different measures of LTPA before or during pregnancy with birth weight in any of the surveys. However, women who were inactive before pregnancy in HUNT 1 had about 40% lower risk for having an offspring with macrosomia, compared with women who had a high level of LTPA (OR, 0.59; CI, 0.4-0.9). In additional analysis, the combined effect of maternal pre- pregnancy BMI and LTPA before pregnancy showed that overweight women (BMI ≥25.0 kg/m^2) who reported no or low LTPA in HUNT 1 gave birth to offspring with significantly higher birth weight (134 g, CI, 41.0-227.3 g) and had an OR for macrosomia of 1.87 (CI, 1.2-2.9) compared to women with BMI <25.0 kg/m^2 who were more active. In HUNT 2, overweight women, across all categories of LTPA, gave birth to offspring with significantly higher birth weight than women with BMI <25.0 kg/m^2, and they had also a higher odds ratio for macrosomia *Conclusion:* No clear association was found between the different measures of LTPA before or during pregnancy with birth weight. However, the result may indicate that inactive women may give birth to infants with lower birth weight and have decreased risk for delivering an infant with high birth weight. Maternal pre- pregnancy BMI may be a more important determinant of birth weight. The combined effect of maternal BMI and LTPA in relation to birth weight should be considered in future studies.

Introduction

Physical activity is an important contributor to a healthy lifestyle in pregnant women, as well as the general population (Bouckhard & Blair, 1999; Melzer et al., 2010; Warburton et al., 2006). It is recommended that healthy pregnant women should engage in moderate exercise of 30 minutes or more, preferably all days of the week (ACOG, 2002). Recent reviews suggests that there are potential health benefits of physical activity during a normal pregnancy, and these include improvement of fitness and maternal weight control, decreased musculoskeletal discomfort, mood stability, and decreased risk of gestational diabetes and hypertension (Hammer et al., 2000; Melzer et al., 2010).

Although most pregnant women may be aware of the benefits of physical activity, pregnancy may be a time period with less practice of physical activity (Haakstad et al., 2007; Haakstad et al., 2009; Owe et al., 2009b). Frequency, intensity and duration of leisure time exercise seem to decrease as pregnancy progresses (Haakstad et al., 2007). Some women may believe that rest and relaxation during pregnancy are more important than maintaining an active lifestyle, and others, that the limitations posed by pregnancy prevent them from participating in regular exercise (Clarke & Gross, 2004). Women who exercise regularly before pregnancy have been found more likely to continue to exercise during pregnancy (Hegaard et al., 2010a; Owe et al., 2009b). Haakstad et al. (2009) reported that pre- pregnancy inactivity was strongly related with decreased maternal exercise at late gestation.

Physical activity during an uncomplicated pregnancy may be considered a protective factor for the risk of complications and illnesses in pregnancy (Dempsey et al., 2004; Hegaard et al., 2007), as well as being related to the growth rate and final birth weight of the baby (Clapp et al., 2000; Leiferman & Evenson, 2003). Optimal birth weight is of high importance for both the mother and the infant. Whereas consequences of low birth weight may include infant mortality and morbidity (Kramer, 2003), high birth weight (i.e. macrosomia) has also been related to a range of serious health outcomes for both the mother and the baby (Henriksen, 2008). There is no generally accepted definition of macrosomia, and different studies have used various cut-offs (e.g. ≥4,000, ≥4,500, or ≥5,000 g, regardless of gestational age) and definitions (e.g. large for gestational age [LGA], or birth weight ≥90th percentile) (Alderman et al., 1998; Boulet et al., 2003; Jolly et al., 2003; Stotland et al., 2004).

Complications of high birth weight include caesarean section, chorioamnionitis, fourth degree perineal lacerations, postpartum hemorrhage, shoulder dystocia (Henriksen, 2008; Stotland et al., 2004; Voldner et al., 2009) and low Apgar- score (Jolly et al., 2003). Additionally, recent reviews have suggested long term consequences in infants born with high birth weight, such as higher risk of later obesity (McGuire et al., 2010) and type 2 diabetes (Harder et al., 2007). The proportion of women giving birth to large infants has increased around the world (Kramer et al., 2002; Ørskou et al., 2001), most likely because of the rising rates of maternal overweight and obesity (Bhattacharya et al., 2007; Ehrenberg et al., 2002; Galtier- Dereure et al., 2000; Nelson et al., 2010; WHO, 2011). In Norway, the percentage of newborns weighing more than 4,000 g and 4,500 g increased in the years 1990-2000. Unexpectedly, a decreasing trend in high birth weight was observed in the years 2000-2008. In 2008, the percentage of newborns weighing more than 4,000 g and 4,500g was 17.5% and 3.2%, respectively, compared with 21.9% and 4.7% in year 2000 (FHI, 2011).

Several modifiable and non-modifiable risk factors have been found to increase the risk of delivering a high birth weight infant; a low level of physical activity before or during pregnancy (Owe et al., 2009a; Voldner et al., 2008) maternal pre pregnancy overweight and high weight gain in pregnancy (Bhattacharya et al., 2007; Fleten et al., 2010; Frederick et al., 2008; Jolly et al., 2003; Mantakas & Farrell, 2010; Sheiner et al., 2004; Weiss et al., 2004), pre-gestational and gestational diabetes mellitus (Boulet et al., 2003; Ehrenberg et al., 2004; Jolly et al., 2003), being married, non-smoking (Alderman et al., 1998; Boulet et al., 2003; Shu- Kay et al., 2010), high maternal age, low educational level (Alderman et al., 1998; Boulet et al., 2003) multiparity (Owe et al., 2009a), post term delivery (Stotland et al., 2004) and previous macrosomic birth (Boulet et al., 2003).

Physical activity in pregnancy has been associated with a reduced risk of delivering a large infant (Alderman et al., 1998; Owe et al., 2009a). However, a recent study reported only a modest decreased risk of large infants related to exercise during pregnancy (Juhl et al., 2010), whereas others have reported no influence of physical activity during pregnancy on birth weight (Hegaard et al., 2007; Hegaard et al., 2010b; Voldner et al., 2008). Physical activity may have an impact on insulin resistance, decreasing the amount of glucose available for the fetus, which again could affect birth weight (Nelson et al., 2010). To date, there are few studies relating physical activity before pregnancy to the risk of excessive newborn weight, and the potential effect of maternal physical activity before pregnancy on birth weight is still debated (Löf et al., 2008; Owe et al., 2009a; Voldner et al., 2008).

To our knowledge, existing literature on the association between physical activity before or during pregnancy with birth weight in Norway is rather sparse, and the results from previous studies have been inconsistent; both a positive and negative association have been reported (Fleten et al., 2010; Owe et al., 2009a; Voldner et al., 2008).
Thus, we have utilized data on women participating in two large health surveys (HUNT 1 and HUNT 2) linked with information from the Medical Birth Registry to study the relation of physical activity measured either before or during pregnancy with birth weight. More specifically, we will examine the effect of physical activity on the risk of delivering a high birth weight infant.

Additionally, we will explore the combined effect of body mass index and physical activity in relation to birth weight and risk of macrosomia.

Materials and methods

The data used for the current study are derived from the Nord- Trøndelag Health study (HUNT), an ongoing population based cohort study in one of Norway's counties. The first health survey was conducted during 1984-1986 (HUNT 1), and the second follow- up survey was conducted during 1995-1997 (HUNT 2). All men and women aged ≥20 years were invited to participate. In HUNT 1, 87,285 were invited, and 77,216 (88.5%) individuals accepted the invitation and attended a clinical examination (37,826 men and 39,390 women). The participants filled in a questionnaire that was included with the invitation. At the examination, the participants received a second questionnaire with more detailed information on a range of lifestyle and health related factors, including questions regarding physical activity. Standardized measurements of body height and weight were included at the clinical examination. In HUNT 2, 94,187 were invited, and 65,215 (69.2%) individuals participated (30,562 men and 34,653 women). The methods and procedures were similar to those in HUNT 1, although the range of information collected on lifestyle and health were more comprehensive.

Due to the nature of the physical activity questionnaires used in the two surveys, association between physical activity during pregnancy and birth weight will be examined using data from HUNT 1, whereas the association between pre-pregnancy physical activity and birth weight will be studied using data from both surveys.

Study population

The current study included women aged 20-39 years at participation in HUNT 1 (1984-86) or HUNT 2 (1995-97) who gave birth to at least one child during a five year period after participation in either of the survey. Information on the offspring was obtained by a linkage to the Medical Birth registry of Norway.

In HUNT 1, we identified 13,470 women aged 20-39 years at invitation. Of these, 3,739 women gave birth to at least one child during a five year period after the survey (until year 1991). We excluded, 2,516, women who reported diagnoses or conditions known to affect birth weight, and women with missing information on relevant variables needed for classification, as summarized in Fig. 1. For the purpose of the analysis of physical activity *before* pregnancy, we also excluded 490 women who gave birth within 10 months, leaving a total of 2,026 women and their offspring available for analysis (Fig. 1). Further, of the 490 women who gave birth within 10 months, we selected the 251 women who gave birth within 6 months to ensure that analysis of physical activity *during* pregnancy was conducted only on women who were aware of their pregnancy at the time of participation (i.e. when they reported the physical activity level).

In HUNT 2, 10,833 women aged 20-39 years participated, and of these, 3,548 gave birth to at least one child during a five year period after the survey (until year 2002). Exclusion criteria are summarized in Fig. 1. Since the questions regarding physical activity in HUNT 2 focused on the whole year preceding participation in the study, women who gave birth within 10 months after participation (therefore most likely pregnant at HUNT 2 participation) were excluded, to ensure that they reported LTPA level before pregnancy (Fig. 2). After these exclusions, 2,286 women, and their offspring, were included in the analysis of physical activity before pregnancy.

The Medical Birth Registry of Norway

Variables obtained from the Medical Birth Registry of Norway included parity, gestational age (days and weeks), newborn length (cm), birth weight (g) multiple pregnancy (i.e. twins), sex, gestational diabetes, and preeclampsia. These data were obtained for the first child born during five years after participation in HUNT. The main outcome variable was newborn birth weight, measured in grams (g), first analyzed as a continuous variable and then as a dichotomized variable, grouped into <4,000 g and ≥4,000 g. Macrosomia was defined as birth weight at or above 4,000 g (Boulet et al., 2003). In addition, we computed ponderal index (PI) as birth weight divided by the cubed value of height in meters (kg/m^3) (Kramer, 2003; Nguyen & Wilcox, 2005), first analyzed as a continuous variable and then as a dichotomized variable. The 90th percentile of PI was used as a cut- off to classify the newborns into two categories; below- or above the 90th percentile.

Age 20-39 years in HUNT 1 and gave birth during a five year period after the survey N = 3,739	Age 20-39 years in HUNT 2 and gave birth during a five year period after the survey N = 3,548

↓ ↓

Exclusion of participants (n):		Exclusion of participants (n):	
Pre-term delivery (<37 weeks) or post-term delivery (≥44 weeks)	232	Pre-term delivery (<37 weeks) or post-term delivery (≥44 weeks)	217
Multiple pregnancies (i.e. twins etc)	32	Multiple pregnancies (i.e. twins etc)	31
Gestational diabetes	10	Gestational diabetes	9
Preeclampsia	118	Preeclampsia	39
Missing information on physical activity*	553	Missing information on physical activity*	54
Missing information on other relevant variables (gestational age, newborn length, and BMI)	278	Missing information on other relevant variables (gestational age, newborn length, and BMI)	327
Gave birth within 10 months after participation	490	Gave birth within 10 months after participation	585
Excluded from total	**1,713**	Excluded from total	**1,262**

↓ ↓

2,026 women and their offspring included in the study of physical activity before pregnancy	2,286 women and their offspring included in the study of physical activity before pregnancy

Figure 1 Flow-chart showing exclusions of participants in HUNT 1 and HUNT 2 in the study of physical activity and birth size. * No response to questions needed for classification.

Leisure time physical activity (LTPA)

At baseline in HUNT 1, LTPA was assessed using three questions on LTPA per week (e.g. walking, skiing, swimming or other sports). In the first question the participants was asked to report how many exercise sessions they had during a week, with five response options (0, <1, 1, 2-3, ≥4 times; coded 1-5). If the participants reported exercising at least once a week, they were also asked to report the average duration (<15, 15-30, 31-60 and >60 minutes; coded 1-4) and intensity (light, moderate and to exhaustion; coded 1-3) of the activity. Among participants who reported exercising at least once a week, a summary score of frequency, duration and intensity was calculated according to the following equation: 1/5 *frequency + 1/4 *duration + 1/3 *intensity. This procedure gave a maximum score of 1.0 for each of the three components of the summary score. The median score value of 1.97 (range, 1.2-3.0) was then used as a cut- off to classify women into two categories of score values, resulting in a total LTPA variable, defined as; no activity, low activity (<1 session per week), medium activity (<median score), and high activity (≥median score).

Due to a low number of participants who were pregnant at the time of participation in HUNT 1, the two latter categories of frequency and total LTPA during pregnancy were merged into one single category. Thus, four frequency levels (no activity, <1 per week, 1 per week, and ≥2 times per week) and three levels of total LTPA (no, low, and medium/high) was used in the analyses of pregnant women in HUNT 1.

In HUNT 2, the participants were asked to report their weekly average duration of LTPA the preceding year, either in terms of "light activity" (defined as no sweating or being out of breath) or as "hard activity" (defined as sweating/being out of breath). Both questions had four response options (0, <1, 1-2, and ≥3 hours; coded 1-4). The individual answers to these questions were then used to compute a summary score of total weekly LTPA, combining information on "light" and "hard" activity into the following categories: no activity, <3 hours light and no hard activity, ≥3 hours light and/or <1 hour hard activity, and any light and ≥1 hour hard activity.

Maternal body mass index

Body mass index (BMI) was computed from standardized measures as weight divided by the squared value of height (kg/m^2), and categorized into to two groups; BMI <25.0 kg/m^2 and BMI ≥25.0 kg/m^2 (i.e. overweight) (WHO, 2011).

Statistical Analyses

HUNT 1 and HUNT 2 data were analyzed separately. After reviewing the data, we calculated descriptive statistics with mean and percentages of the study population in HUNT 1 and HUNT 2 according to the total summary score of LTPA before and during pregnancy.

We used linear regression to analyze the association between the different measures of LTPA performed before (HUNT 1 and HUNT 2) and during (HUNT 1) pregnancy with mean birth weight. The odds ratio (OR) for delivering a macrosomic infant (≥4,000g) in relation to measures of LTPA before and during pregnancy was estimated using logistic regression. Precision of the estimates was assessed by 95% confidence interval (95% CI). The different levels of LTPA were compared with the reference group consisting of subjects who reported the highest activity level. We considered the following variables as potential confounders; age (20-24, 25-29, 30-34, and 35-39 years), smoking (never, former, and current), frequency of alcohol consumption during the 14 days prior to participation (HUNT 1; no, 1-4 times, ≥5, abstainer, and unknown) or usual frequency of alcohol consumption per month (HUNT 2; continuous variable), education (<10, 10-12, >12 years, and unknown), marital status (unmarried, married, and previously married; information only available in HUNT 1) and parity (primiparous, 1-2 children, and 3-6 children). Regarding smoking, 8 women reported smoking as unknown, and were therefore categorized into never smoking. Covariates were removed from the model if there was no meaningful difference between adjusted and unadjusted estimates. All estimates were adjusted for maternal age, smoking and parity. Possible interactions between LTPA and each of the variables adjusted for on newborn birth weight were estimated using multiplicative interaction term. However, we did not detect any statistically significant interaction. Tests for trend across LTPA categories were conducted by treating the categorical variables as continues variables.

Additionally, we analyzed the association between LTPA level measured before and during pregnancy with PI (PI continuous, PI <90^{th} percentile vs >90^{th} percentile) in both surveys, using linear and logistic regression as described above.

Women with high BMI tend to have higher risk of delivering a newborn with excessive weight (Fleten et al., 2010; Frederick et al., 2008; Jolly et al., 2003). Since women with high BMI may be less likely to be physically active (Fell et al., 2009; Hegaard et al., 2010a; Owe et al., 2009b), BMI may be a potential confounder. However, physical activity can affect BMI, and in turn, birth weight, and BMI might thereby also be considered as an intermediate variable. Therefore, BMI was not included as a confounder in the primary analyses. However, additional analyzes was conducted for the combined effect of pre- pregnancy BMI and total LTPA level measured before pregnancy in HUNT 1 (categories merged into no activity/low LTPA, medium/high LTPA) and HUNT 2 (categories merged into no activity/<3 h easy

LTPA, ≥3 h easy/<1 h hard LTPA, and ≥1 hard LTPA) in relation to birth weight, using linear and logistic regression as described above.

All statistical analyses were performed using the statistical software program, SPSS 17.0, Windows.

Ethics

The study was approved in the Regional Committee for Ethics, and by HUNT. Each subject gave written informed consent prior to participation.

Results

Of the 2,026 women, who participated in HUNT 1 *before* pregnancy, mean baseline maternal age was 26.9 years. Mean birth weight of their offspring was 3,620 g (SD, 502) and a total of 416 (20.5%) newborns weighed 4,000 g or more (i.e. macrosomia). Of the 2,286 women and their offspring included in HUNT 2 mean maternal age was 27.2 years, mean birth weight was 3,688 g (SD, 495), and 573 (25.1%) of these newborns weighed 4000 g or more. Among the 251 women who participated *during* pregnancy in HUNT 1, mean baseline maternal age was 28.1 years. Mean birth weight of their offspring was 3,624 g (SD, 484) and a total of 53 (21.1%) newborns weighed at or above 4,000 g. The distribution of maternal characteristics in HUNT 1 and HUNT 2 according to total summary score of LTPA before and during pregnancy is given in Table 1a and Table 1b.

A higher proportion of newborns with excessive weight were born to multiparous women (23.0% in HUNT 1 and 29.4% in HUNT 2) compared with primiparous women (13.0% in HUNT 1 and18.1% in HUNT 2). In relation to maternal age, the highest proportion of newborns with macrosomia was observed among women aged 30-39 years compared with women in the younger age groups. Regarding maternal weight, a higher percentage of newborns with macrosomia were born to women with BMI ≥25.0 kg/m^2 (27.2% in HUNT 1 and 32.0% in HUNT 2), compared with offspring delivered by women with BMI <25.0 kg/m^2 (19.1% in HUNT 1 and 21.1% in HUNT 2). Women who reported that they never smoked had the highest percentage of newborns with macrosomia, compared with current and former smokers. Macrosomia was also more evident among women with a low educational level (<10 years), compared with higher educated women (> 10 years).

No apparent association was seen between the different measures of LTPA before and during pregnancy and PI of the offspring (data not shown).

Among women who participated in HUNT 1 *before* pregnancy, there was no clear association between the different measures of LTPA and birth weight of their offspring. However, women who reported being inactive before pregnancy showed a tendency to have infants with a lower

Table 1a Characteristics of the study population in HUNT 1 (N= 2,026) and HUNT 2 (N= 2,286) according to total leisure time physical activity (LTPA)* before pregnancy (mean and percentages).

	No activity	Low	Medium	High
HUNT 1				
No participants (% of total)	147 (7.3)	647 (31.9)	641 (31.6)	591 (29.2)
Mean age at baseline, y	26.8	27.2	26.7	26.6
Parity (% primiparous)	20.4	28.2	28.5	40.6
Smoking (% current smoking)	53.1	44.0	38.8	31.3
Mean body mass index, kg/m²	22.4	22.3	22.5	22.4
Education (% college/university)	8.2	16.1	20.6	25.4
Alcohol (% no drinking last 2 wk)	49.7	45.7	46.0	43.1
Marital status (% married)	53.1	55.6	49.5	46.7
Birth weight of offspring (% ≥4000 g)	13.6	22.9	20.0	20.3
HUNT 2				
No participants (% of total)	75 (3.3)	526 (23.0)	845 (37.0)	840 (36.7)
Mean age at baseline, y	27.4	28.0	27.3	26.6
Parity (% primiparous)	22.7	27.6	34.2	49.8
Smoking (% current smoking)	46.7	33.3	25.9	21.9
Mean body mass index, kg/m²	24.9	24.9	24.4	24.3
Education (% college/university)	12.0	35.2	41.1	44.3
Alcohol (% <1 per month)	29.3	31.6	25.0	17.9
Birth weight of offspring (% ≥4000 g)	30.7	25.5	25.7	23.7

* Total LTPA level in HUNT 1 combining information on frequency, duration, and intensity among those who exercised once a week or more; medium defined as less than median score, and high defined as equal to, or more than median score. Total LTPA level in HUNT 2 combining information on average hours per week with light or hard physical activity the preceding year; categorized as no activity, <3 h light, ≥3 h light/<1 h hard, and ≥1 h hard.

birth weight (Table 2) and had about 40% lower risk of giving birth to a newborn at or above 4,000 g (OR, 0.59; 95% CI, 0.4-0.9) compared with women with a high total LTPA level (Table 3).

No clear association was found between LTPA participation and infant birth weight among women who participated in HUNT 2 before pregnancy; mean birth weight of the offspring did not vary much across the different categories of total LTPA (Table 2). Although not statistically significant, a slightly higher risk of having a newborn with macrosomia was found among inactive women (OR, 1.31; 95% CI, 0.8-2.2) (Table 3).

Table 1b Characteristics of the study population in HUNT 1 (N= 251) according to total leisure time physical activity (LTPA)* during pregnancy (mean and percentages).

	No activity	Low	Medium/High
No participants (% of total)	20 (8.0)	89 (35.5)	142 (56.6)
Mean age at baseline, y	29.3	27.9	28.1
Parity (% primiparous)	20.0	29.2	26.8
Smoking (% current smoking)	25.0	43.8	27.5
Mean body mass index, kg/m²	25.0	24.6	25.0
Education (% college/university)	5.0	15.7	17.6
Alcohol (% no drinking last 2 wk)	80.0	83.1	73.9
Marital status (% married)	75.0	56.2	64.0
Birth weight of offspring (% ≥4000 g)	15.0	24.7	19.7

*Total LTPA level combining information on frequency, duration, and intensity among those who exercised once a week or more; medium defined as less than median score, and high defined as equal to, or more than median score. The two latter categories of total LTPA during pregnancy were merged into one single category of medium/high activity.

There were no statistically significant associations between the different measures of LTPA and birth weight of the offspring among women who participated in HUNT 1 *during* their pregnancy. However, women who were categorized as inactive during pregnancy showed a tendency to give birth to offspring with lower birth weight compared with women in the highest activity groups (Table 4). A similar trend was observed for the risk of having a newborn with macrosomia; inactive women measured during pregnancy had a slightly lower risk for delivering a high birth weight infant (Table 5).

In additional analysis we assessed the combined effect of pre-pregnancy BMI and LTPA before pregnancy in relation to birth weight. Among women in HUNT 1, we found that those who were overweight (BMI ≥25.0 kg/m^2) before pregnancy and reported no or low LTPA level gave birth to infants with significantly higher mean birth weight (134 g; 95% CI, 41.0-227.3) and had a higher risk for delivering a macrosomic infant (OR, 1.87; 95% CI, 1.2-2.9), compared with women with BMI <25.0 kg/m^2 who had a medium or high LTPA level (Table 6).

Table 2 Leisure time physical activity (LTPA) before pregnancy and mean birth weight (BW)

LTPA	N	Mean BW(g)	Crude Mean diff(g)	#Adjusted Mean diff(g)	≠ (95% CI)	P for trend
HUNT 1						
Frequency of LTPA before pregnancy						
No activity	147	3589.0	-25.2	-26.9	(-137.9- 84.2)	
<1 pr wk	647	3632.5	18.3	21.7	(-64.8- 108.3)	
1 pr wk	591	3639.7	25.5	31.0	(-56.1- 118.1)	
2-3 pr wk	491	3590.4	-23.7	-24.4	(-113.2- 64.4)	
≥4 pr wk*	150	3614.1	0	0		0.49
Total LTPA before pregnancy ±						
No activity	147	3589.0	-38.9	-53.0	(-141.8-35.8)	
Low (<1/wk)	647	3632.5	4.6	-3.5	(-58.3-51.4)	
Medium	641	3606.9	-21.0	-36.9	(-91.5-17.8)	
High*	591	3627.9	0	0		0.56
HUNT 2.						
Total LTPA before pregnancy						
No activity	75	3700.2	32.9	25.1	(-91.6-141.9)	
<3 h light	526	3700.1	32.9	18.2	(-36.2-72.7)	
≥3 h light,<1 h hard	845	3699.1	31.9	17.2	(-30.0-64.4)	
≥ 1h hard*	840	3667.2	0	0		0.39

* Reference category; ≠ CI, confidence interval for adjusted mean difference, # adjusted for age (20-24, 25-29, 30-34, 35-39), parity (primiparous, 1-2, 3-6 children) and smoking (never, former, current). ± Total LTPA level in HUNT 1 combining information on frequency, duration, and intensity among those who exercised once a week or more; medium defined as less than median score, and high defined as equal to, or more than median score.

In addition, we conducted a subanalysis among the overweight women, comparing those with no or low LTPA levels before pregnancy in HUNT 1 with those with medium/high levels. The offspring of overweight women who reported no or low LTPA level had significantly higher birth weight (132 g; 95% CI, 20.4-243.7) and higher odds ratio for macrosomia (OR, 1.99; 95% CI, 1.1-3.5), compared with the offspring of overweight women who had a medium/high LTPA level. A test for an interaction between BMI and LTPA level before pregnancy gave a p- value of 0.076, indicating that the effect of LTPA was somewhat different in the two BMI groups.

Table 3 Leisure time physical activity (LTPA) before pregnancy and odds ratio (OR) for macrosomia (≥4000g)

LTPA	N	Cases	Crude OR	#Adjusted OR	≠ (95% CI)	p for trend
HUNT 1.						
Frequency of LTPA before pregnancy						
No activity	147	20	0.69	0.68	(0.4-1.3)	
<1 per wk	647	148	1.29	1.30	(0.8-2.1)	
1 per wk	591	122	1.13	1.16	(0.7-1.8)	
2-3 per wk	491	98	1.09	1.10	(0.7-1.8)	
≥4 per wk*	150	28	1.0	1.0		0.89
Total LTPA before pregnancy ±						
No activity	147	20	0.62	0.59	(0.4-0.9)	
Low (<1/wk)	647	148	1.16	1.13	(0.9-1.5)	
Medium	641	128	0.98	0.93	(0.7-1.2)	
High*	591	120	1.0	1.0		0.65
HUNT 2.						
Total LTPA before pregnancy						
No activity	75	23	1.43	1.31	(0.8-2.2)	
<3 h light	526	134	1.10	1.00	(0.8-1.3)	
≥3 h light,<1 h hard	845	217	1.11	1.03	(0.8-1.3)	
≥1 h hard*	840	199	1.0	1.0		0.54

*Reference category; ≠ CI, confidence interval for adjusted OR, # adjusted for maternal age (20-24, 25-29, 30-34, 35-39), parity (primiparous, 1-2, and 3-6 children) and smoking (never, former, current). ± Total LTPA level in HUNT 1combining information on frequency, duration, and intensity among those who exercised once a week or more; medium defined as less than median score, and high defined as equal to, or more than median score.

In HUNT 2, a significantly higher mean birth weight (132.3 g (59.2-205.3), 150.3 g (82.1-218.6) and 147 g (76.9-217.1), respectively) and higher risk of giving birth to a macrosomic infant (OR (95% CI); 1.71 (1.2-2.4), 1.70 (1.2-2.4) and 1.77 (1.3-2.5) respectively) was found among overweight women, in the categories of low, light, and light/hard LTPA respectively, compared with women with BMI <25.0 kg/m^2 who reported ≥1 hour hard LTPA per week respectively) (Table 6).

A subanalysis was conducted among the overweight women comparing the three different LTPA levels before pregnancy in HUNT 2. No significant difference in birth weight or in odds ratio for macrosomia was found in offspring of overweight women across the different levels of LTPA.

Table 4 Leisure time physical activity (LTPA) during pregnancy and mean birth weight (BW)

LTPA	n	Mean BW(g)	Crude Mean diff(g)	#Adjusted Mean diff(g)	≠ (95% CI)	p for trend
HUNT 1						
Frequency of LTPA during pregnancy						
No activity	20	3565.0	-50.3	-70.3	(-303.5- 162.1)	
<1 pr wk	89	3616.6	1.3	30.6	(-118.9- 180.1)	
1 pr wk	74	3656.9	41.6	58.2	(-96.7- 213.0)	
≥2 pr wk*	68	3615.3	0	0		0.88
Total LTPA during pregnancy ±						
No activity	20	3565.0	-72.0	-100.3	(-319.6- 119.0)	
Low (<1/wk)	89	3616.6	-20.4	-0.3	(-125.2- 124.7)	
Medium/High*	142	3637.0	0	0		0.57

* Reference category; ≠ CI, confidence interval for adjusted mean difference, # adjusted for age (20-24, 25-29, 30-34, 35-39), parity (primiparous, 1-2, and 3-6 children) and smoking (never, former, current). ± Total LTPA level combining information on frequency, duration, and intensity among those who exercised once a week or more; medium defined as less than median score, and high defined as equal to, or more than median score.

Table 5 Leisure time physical activity (LTPA) during pregnancy and odds ratio (OR) for macrosomia (≥4000g)

LTPA	N	Cases	Crude OR	#Adjusted OR	≠ (95% CI)	p for trend
HUNT 1						
Frequency of LTPA during pregnancy						
No activity	20	3	0.62	0.59	(0.1-2.4)	
<1 per wk	89	22	1.16	1.35	(0.6-2.1)	
1 per wk	74	13	0.75	0.84	(0.4-1.1)	
≥2 per wk*	68	15	1.0	1.0		0.93
Total LTPA during pregnancy ±						
No activity	20	3	0.72	0.64	(0.2-2.4)	
Low (<1/wk)	89	22	1.34	1.47	(0.8-2.9)	
Medium/high*	142	28	1.0	1.0		0.88

*Reference category; ≠ CI, confidence interval for adjusted OR, # adjusted for maternal age (20-24, 25-29, 30-34, 35-39), parity (primiparous, 1-2, and 3-6 children) and smoking (never, former, current). ± Total LTPA level combining information on frequency, duration, and intensity among those who exercised once a week or more; medium defined as less than median score, and high defined as equal to, or more than median score.

Table 6 The combined effect of pre- pregnancy maternal BMI and total leisure time physical activity (LTPA) before pregnancy; mean birth weight (BW) and odds ratio (OR) for macrosomia (≥4000 g).

BMI AND LTPA ±	n	Crude Mean BW	Crude Mean Diff	#Adjusted Mean Diff	≠ (95% CI)	Cases (≥4000g)	Crude OR	#Adjusted OR	≠ (95%CI)
HUNT 1									
≥25 kg/m^2 and no activity/low LTPA	118	3742.1g	129.7	134.1	(41.0-227.3)	37	1.86	1.87	(1.2-2.9)
≥25 kg/m^2 and medium/high LTPA	186	3642.3g	29.8	33.1	(-42.5-108.7)	42	1.19	1.20	(0.8-1.8)
<25 kg/m^2 and no activity/low LTPA	676	3603.9g	-8.6	-8.4	(-55.6-38.8)	131	0.98	0.97	(0.8-1.2)
<25 kg/m^2 and medium/high LTPA*	1,046	3612.4g	0	0		206	1.0	1.0	
HUNT 2									
≥25 kg/m^2 and no activity/<3 h light LTPA	254	3766.8g	150.1	132.3	(59.2-205.3)	82	1.91	1.71	(1.2-2.4)
≥25 kg/m^2 and ≥3 h light,<1 h hard LTPA	304	3789.4g	172.7	150.3	(82.1-218.6)	98	1.91	1.70	(1.2-2.4)
≥25 kg/m^2 and ≥1 h hard LTPA	274	3771.6g	154.9	147.0	(76.9-217.1)	86	1.83	1.77	(1.3-2.5)
<25 kg/m^2 and no activity/<3 h light LTPA	347	3651.3g	34.6	22.1	(-43.6-87.9)	75	1.11	1.01	(0.7-1.4)
<25 kg/m^2 and ≥3 h light,<1 h hard LTPA	541	3648.4g	31.7	19.2	(-38.4-76.7)	119	1.13	1.05	(0.8-1.4)
<25 kg/m^2 and ≥1 hard LTPA*	566	3616.7g	0	0		113	1.0	1.0	

*Reference category; ≠ CI, confidence interval for adjusted mean difference and adjusted OR; BMI, body mass index. # adjusted for age (20-24, 25-29, 30-34, 35-39) parity (primiparous, 1-2, and 3-6 children), and smoking (never, former, current). ± Total LTPA level in HUNT 1combining information on frequency, duration, and intensity among those who exercised once a week or more; medium defined as less than median score, and high defined as equal to, or more than median score; categories merged into no activity/low LTPA, medium/high LTPA. Total LTPA level in HUNT 2 combining information on average hours per week with light or hard physical activity the preceding year; categories merged into no activity/<3 h light LTPA, ≥3 h light/<1 h hard LTPA, and ≥1 hard LTPA).

Discussion

Major findings

In this study we examined the association of LTPA measured either before or during pregnancy with birth weight, and especially the risk of delivering a high birth weight infant among Norwegian women. Additionally, we explored the combined effect of BMI and LTPA in relation to birth weight and risk of macrosomia. We found no clear association between the different measures of LTPA before or during pregnancy with birth weight in either of the surveys. However, there was an unexpected decreased risk for delivering a macrosomic infant among women who were inactive before or during pregnancy in HUNT 1 compared with women with the highest level of LTPA. In HUNT 2, however, women who were inactive before pregnancy had a slightly increased risk for having an offspring with macrosomia. Regarding the combined effect of pre- pregnancy BMI and LTPA before pregnancy in relation to birth weight, the results in HUNT 1 showed that overweight women (BMI ≥25.0 kg/m^2) who reported no or low levels of LTPA gave birth to heavier infants and had higher risk for having an infant with macrosomia compared with those who had a BMI <25.0 kg/m^2 and a medium or high LTPA level. Moreover, this group of women gave birth to offspring with significantly higher birth weight and higher odds ratio for macrosomia compared with the offspring of overweight women who had a medium or high LTPA level. In HUNT 2, however, significant higher birth weight and higher risk for macrosomia was evident in offspring of overweight women across all categories of LTPA.

Physical activity before and/or during pregnancy related to birth weight

To our knowledge there are few studies that have investigated the association between physical activity before pregnancy with the risk of delivering a high birth weight infant in Norway (Owe et al., 2009a; Voldner et al., 2008), and the results are inconsistent.
Our finding that inactive women before pregnancy had lower risk for delivering a macrosomic infant is in contrast with findings reported by Voldner et al. (2008) who showed that inactivity (defined as <1 h per week) before pregnancy increased the risk of fetal macrosomia with an OR of 2.9, compared with physically active women (>1 h per week). However, in the present study, we defined women as inactive if they did not report any kind of leisure activity, whereas women who reported LTPA level as <1 h per week was defined as having a low activity level in HUNT 1. It may be that the inactive women in our study represent a group of women in the extreme end. Owe et al. (2009a) found no association between frequency of

regular exercise performed before pregnancy and newborns with excessive birth weight (≥90^{th} percentile). However, contradictory to our findings, they found that regular exercise during pregnancy (at least three times per week) reduced the odds of giving birth to newborns with excessive birth weight by 23-28%. This is confirmed by Alderman et al. (1998) who found that women who frequently perform physical activity (≥2 h per week) during pregnancy were at lower risk of infant LGA compared with women who were less active. Another study found only a slightly decreased risk of LGA in offspring of women exercising during pregnancy compared with those who did not exercise (Juhl et al., 2010). Unlike the present study, they observed a dose- response relation with LGA, which indicated a decreasing risk of large infants with increasing amount of exercise (hour per week). However, Hegaard et al. (2010b) and her colleagues reported no association between sports and leisure time physical activity performed during pregnancy and low birth weight (<2,500 g), high birth weight (≥4,500 g), or average birth weight. The inconsistent results in the studies may be due to different measures of physical activity, and definitions used to classify intensity, amount, and type of physical activity. A review conducted by Hegaard et al. (2007) concludes, however, that women who perform leisure time physical activity before and/or during pregnancy have better or unchanged outcomes of pregnancy, including birth weight.

Since few women in the present study were pregnant when participating in HUNT 1, the results concerning LTPA measured during pregnancy should be interpreted cautiously. However, the tendency of lower birth weight and lower odds ratio for macrosomia among inactive women during pregnancy was similar with the results obtained among pre-pregnancy inactive women. This may indicate that inactivity before or during pregnancy may result in lower birth weight. It may be speculated that inactive women may have an overall unhealthier lifestyle, including nutrition and diet, which may restrict infant growth during pregnancy. A recent study found that a sedentary lifestyle among women in pregnancy was associated with lower birth weight (Both et al., 2010). This is confirmed by Schramm et al. (1996), who observed that mothers of very low birth weight infants were less likely to be physically active during their pregnancy. Thus, it may be speculated if mothers who give birth to infants with lower birth weight may be in poorer physical health during pregnancy, and therefore may have been encouraged and advised to restrict their activity or not do exercise. A study by Leiferman & Evenson (2003) found that women who did not engage in regular LTPA before and during pregnancy were more likely to give birth to a very low birth weight infant (<1,500 g), compared with regular exercises (exercised or play sport at least 3 times a week). Also, women who stopped exercising during their pregnancy had an increased risk for delivering a very low (<1,500 g) and low (<2,500 g) birth weight infant. Clapp et al. (2000) showed that pre-pregnancy sedentary women who followed an 8 week moderate exercise regimen (weight-bearing exercise, 3-5 times a week) during early pregnancy gave birth to children who were heavier, longer, and with a higher lean body mass, compared with the control group with no exercise. However, it has been suggested that both excessive and insufficient physical activity in pregnancy is related to an inadequate fetal growth (Takito et al., 2009).

Although pre- pregnancy physical activity level has been associated with physical activity level during pregnancy (Haakstad et al., 2009; Hegaard et al., 2010a; Owe et al., 2009b), it has also been shown that the exercise level declines in pregnancy compared with the pre-pregnancy level (Fell et al., 2009; Haakstad et al., 2007; Hegaard et al., 2010a; Owe et al., 2009b). On the other hand, some women who are inactive before pregnancy may be motivated by pregnancy and start exercising in pregnancy (Fell et al., 2009; Hegaard et al., 2010a). Our data did not allow us to examine if pre-pregnancy LTPA level was associated with the activity level during pregnancy. It can be speculated if the level of pre-pregnancy activity is merely a marker for activity level during pregnancy, or if women who are physically active before pregnancy may cope with demands and strains during pregnancy better compared with more inactive women, and that this also could affect the baby.

Maternal BMI, physical activity, and birth weight

An association between maternal BMI and exercise has previously been reported (Fell et al., 2009; Hegaard et al., 2010a; Owe et al., 2009b). Women who were overweight pre-pregnancy (≥25.0 kg/m^2) were less likely to exercise regularly during pregnancy (Owe et al., 2009b). This is also confirmed by Fell et al. (2009), showing less practice of activity during pregnancy among pre-pregnancy obese women. Women who are sedentary or perform light activity before pregnancy have been found more likely to be obese (BMI ≥30.0 kg/m2) (Hegaard et al., 2010a). Unlike the present study, most previous studies have treated maternal BMI as a potential confounder in the analyses of the association between physical activity and birth weight (Hegaard et al., 2010b; Juhl et al., 2010; Leiferman & Evenson, 2003; Owe et al., 2009a), overlooking the possibility that BMI may be considered as an intermediate variable, in that physical activity can affect BMI, and in turn, birth weight.

There is growing evidence that overweight and obesity before pregnancy is a significant risk factor for macrosomia (Bhattacharya et al., 2007; Ehrenberg et al., 2004; Fleten et al., 2010;

Frederick et al., 2008; Jolly et al., 2003; Voldner et al., 2008). Fleten et al. (2010) found no significant association between frequency of exercise during pregnancy and birth weight when maternal pre-pregnancy BMI was taken into account. This may suggest that overweight and obesity is more important than the activity level regarding the risk of giving birth to a macrosomic infant. Löf et al. (2008) suggested that a high pre-pregnancy activity level may not prevent high birth weight infants (≥4,000 g) if the women are overweight and gain much weight in pregnancy. Still, physical activity may improve maternal weight control before and during pregnancy (Hammer et al., 2000; Melzer et al., 2010). Moreover, since high birth weight increases the risk for complications during pregnancy and at delivery (Jolly et al., 2003; Stotland et al., 2004; Voldner et al., 2009), a reduced incidence could also reduce the incidence of pregnancy complications.

We are not aware of other studies that have considered the combined effect of pre-pregnancy BMI and LTPA level before pregnancy in relation to birth weight. Our finding that the offspring of overweight women who reported no or low levels of LTPA had significantly higher birth weight and higher odds ratio for macrosomia compared with overweight women who had a medium/high LTPA level, may indicate that pre- pregnancy LTPA may compensate for the consequences of being overweight (i.e. "fat but fit"). Studies have found that the risk of having a newborn with macrosomia (>4,000 g) increases with increasing degree of overweight (Bhattacharya et al., 2007; Mantakas & Farrell, 2010). Thus, we cannot exclude the possibility that overweight women with a medium or high LTPA level may on average have had lower BMI compared to overweight women who had no or low levels of LTPA. Also, having a BMI <25.0 kg/m^2 was associated with a lower offspring birth weight, irrespective of their activity level. However, in HUNT 2, overweight women gave birth to infants with significantly higher birth weight and higher odds ratio for macrosomia within all categories of LTPA, which may indicate that pre- pregnancy LTPA level may not compensate for the consequences of being overweight.

The different results found in HUNT 1 and HUNT 2 could be due to the questions used to assess physical activity. Also, we observed a trend for higher mean BMI across all categories of LTPA in HUNT 2, compared with HUNT 1. The higher BMI in HUNT 2 was expected, since it has been a large increase in the prevalence of overweight and obesity worldwide, and also in Norway (FHI, 2011; WHO, 2011). There were a higher percentage of women delivering an infant at or above 4,000 g in HUNT 2, within all categories of LTPA, and the highest percentage was seen among inactive women.

Gestational weight gain has been associated with birth weight, both alone, and in combination with pre-pregnancy BMI (Frederick et al., 2008; Löf et al., 2008). A recent study by Ludwig & Currie (2010), showed that high maternal weight gain (>24 kg) during pregnancy increased the odds ratio of giving birth to an infant weighing more than 4,000 g with an OR of 2.26, independently of genetic factors. Pre-pregnancy physical activity may help prevent excessive gestational weight gain (Löf et al., 2008; Weisman et al., 2010), as well as regular exercise during pregnancy (Haakstad & Bø, 2011). Thus, physical activity may indirectly contribute to reduce the risk of having an infant with high birth weight. In the present study, only one single measure of BMI was available, either measure before or in pregnancy, and hence, we could not assess the extent or effects of gestational weight gain.

Strengths and limitations

As mentioned above, the inconsistent results using different sources of data in the present study could be due to the nature of the PA questions used in the two health studies. The assessment of physical activity in HUNT 2 was more broadly categorized than in HUNT 1, and the questions in HUNT 2 asked about usual activity the past year, rather than current average activity. It is also possible that subjective interpretation of the questions has been different in HUNT 1 and HUNT 2, and that the potential of over-reporting is larger in HUNT 2, since it is likely that physical activity and its health benefits have received more attention during the past two decades. There may have been some changes in the public health education and awareness regarding smoking, eating and exercising during pregnancy in the years of '84- '94 that may explain some of the differences in the results. We did observe that the distribution of factors, such as smoking and education, within the physical activity categories, was somewhat different in HUNT 1 and HUNT 2.

Since the information regarding physical activity was self-reported it could be subject to misclassification, but the broad categories that were used may have reduced the possibility of misclassification. The questions used to assess LTPA have recently been compared with objective measures, measuring the reliability and validity of the questions in HUNT 1 and HUNT 2 (Kurtze et al., 2007; Kurtze et al., 2008), and was found to perform well. However, these results are not necessary valid for pregnant women, since pregnancy may be a difficult time for assessment of physical activity due to the continuous physiological changes. Another limitation is the small sample size of women who were pregnant when they participated; this resulted in analyses of the association between LTPA during pregnancy and birth weight with low statistical power. Also, some of the women included may have had an illness or condition that disabled them from being physically active that could also be related to birth weight, but apart from diabetes and preeclampsia, we were not able to take such factors into account. Pregnancy related health problems may also have influenced how active they were in pregnancy (Owe et al., 2009b). We cannot exclude that the results are influenced by residual confounding due to unmeasured factors (i.e. genetic factors, history of macrosomia, gestational weight gain). Also, our data did not allow us to investigate continued smoking during pregnancy (how much). Further, we could not assess what kind of LTPA the women practiced during pregnancy, and if it was likely to be the kind of activity that would stimulate glucose and fat metabolism is a sufficient way to affect growth rate of the infant. Work related physical activity was not included in the analyses, and it is possible that this exposure lead to an underestimation of their daily activity level. Since a low level of LTPA was associated with low education, this may indicate that LTPA could be related to heavy manual work/high occupational activity, and may be a possible source of bias in the study.

The strengths of the present study include the prospective design, the large sample size of women reporting physical activity before pregnancy, and that data originates from two surveys, in two different time periods. Moreover, standardized measures of size at birth were obtained from linkage to Medical Birth Registry of Norway.

Conclusion

In conclusion, no clear association was found between the different measures of LTPA before or during pregnancy and birth weight in either of the surveys. However, the result may indicate that inactive women may give birth to infants with lower birth weight and have decreased risk for delivering an infant with high birth weight (i.e. macrosomia). Maternal pre-pregnancy BMI may be more important than the activity level in relation to birth weight. Nevertheless, physical activity may improve maternal weight control, both before and during pregnancy, which again could lower the risk for giving birth to an infant with excessive weight.

The combined effect of maternal BMI and LTPA in relation to offspring birth weight should be considered in future studies, to assess whether physical activity may compensate for the adverse effect of maternal adiposity.

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