Original Article

The relationship between maternal physical activity during pregnancy and birth weight

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Introduction: Earlier studies in India have demonstrated an inverse relationship between physical activity and birth weight in rural women who had high levels of physical activity related to agricultural and domestic activities. There are no data on urban Indian women from a wide range of socio-economic backgrounds with varying levels of physical activity. This study assessed the role of different domains of physical activity during pregnancy and its relation to birth weight. **Methods**: Data on maternal anthropometry and maternal physical activity level were collected at the 1st trimester (baseline), the 2nd trimester and the 3rd trimester of pregnancy. Birth weight for 546 live born babies was measured immediately after delivery. **Results**: The time spent in sedentary activities (median "cut-off" of 165 min/d) was significantly associated with maternal body weight in the first trimester of pregnancy (51.2 kg vs. 54.1 kg, $p<0.001$). Women in the highest tertile of physical activity level in the 1st trimester were 1.58 times (95% CI: 1.02-2.44) more likely of having a baby in the lowest tertile of birth weight with reference to the first tertile. This significant association continued after adjustment for maternal weight and energy intake. **Conclusion**: The present study shows that physical activity in the first trimester is associated with low birth weight in Indian babies.

Key Words: pregnancy, physical activity, low birth weight, nutrition, India

INTRODUCTION

Women from developing countries are at higher risk of poor birth outcomes,[1] including low birth weight, abortions, still births and pre-term deliveries. Maternal and neonatal morbidity are also high in developing countries like India.[2,3,4] An association between birth weight and maternal factors such as age, parity, access to primary health, maternal pre-pregnant nutritional status including maternal weight and dietary intake has been demonstrated in some earlier Indian studies.[5,6,7] Earlier results from the cohort being studied in the present report have also shown that a low antenatal Vitamin B_{12} level is significantly associated with low birth weight.[8]

An important additional effect on birth weight could be daily physical activity which is an important and variable factor in the antenatal period, since women have variable physical activities at work outside the house and with domestic household chores. The importance of this is highlighted in studies which have demonstrated that manual physical activity during pregnancy is associated with small for gestation age (SGA) babies[1] and lower birth weights and pregnancy weight gain, particularly when energy intake is sub-optimal.[9] Similarly, strenuous physical work during pregnancy has also been associated with increased rates of abortion and pre-term delivery.[10] Increased household chores have been related to preterm birth,[11] while the evidence for leisure time physical activity suggests that participation in moderate to vigorous activity throughout pregnancy may enhance birth weight, with more intense physical activity regimens resulting in the opposite effect.[12] In India, studies have demonstrated an inverse relationship between daily physical activity and birth weight in a cohort of rural women, the majority of whom had high levels of physical activity related to agricultural and domestic activities.[13] However, there are no data on urban Indian women from a wide range of socio-economic backgrounds with varying levels of physical activity.

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Manuscript received 8 December 2006. Initial review completed 29 January 2007. Revision accepted 7 March 2007.

Therefore, this study was conducted to assess the relationship between maternal physical activities in different domains either at home or at the work place as well as of the aggregate PAL in all trimesters of pregnancy, with birth weight, in a cohort of urban Indian women from a wide range of socio-economic backgrounds.

SUBJECTS AND METHODS

Study Design

The study was a prospective cohort study of 546 pregnant women conducted at St John's Medical College Hospital, Bangalore, India, to determine the association between maternal physical activity during pregnancy and birth weight. This hospital caters to patients from diverse socioeconomic status. The Institutional Ethical Review Board at St John's Medical College Hospital approved all study procedures, and written informed consent was obtained from each study subject at enrollment.

Study population

All pregnant women aged 17-40 years who were below 20 weeks of gestation, and registered for antenatal screening at the Department of Obstetrics and Gynecology at St. John's Medical College Hospital were screened for the study. Details of the study design of this prospective study have been described earlier.[8] In brief, women with multiple pregnancies, a clinical diagnosis of chronic illness such as diabetic mellitus, hypertension, heart disease and thyroid disease as well as women who tested positive for hepatitis B, HIV or syphilis infections were excluded from the study. In addition, women who anticipated moving out of the city before delivery were not recruited.

Of 923 women who consented to be part of the study, 850 women were recruited into the study; (73 women were excluded for the following reasons: 57 subjects were planning to deliver their babies outside Bangalore area; 1 was diabetic; 5 had twin pregnancies; 7 tested positive for VDRL, Hepatitis B and HIV infections, 2 subjects were not pregnant and 1 subject had chickenpox), 103 were lost to follow up and 113 delivered in a facility outside of St. John's Medical College Hospital. A total of 634 women delivered at St. John's Medical College Hospital; 46 of them had fetal losses and the remaining 588 had live births. Birth weights for 547 live born babies were measured within 24 hours of delivery; 20 babies had their birth weights recorded within 48 hours of delivery. Neonates of mothers who had gestational diabetes mellitus (GDM) were excluded from this analysis (proportion of mothers with GDM = 3.7%, n=21), leaving 546 cases in this study set.

Sociodemographic and anthropometric information

Information on age, parity, education, occupation, socioeconomic status and tobacco use was collected at recruitment. None of the women consumed tobacco in any form. The exact gestational age was calculated from the reported first day of the last menstrual period (LMP) and confirmed by a subsequent ultrasonographic scan within 2 weeks of the initial visit. In addition, data on maternal anthropometry and maternal physical activity level were collected by trained research assistants at the 1st trimester (baseline, 12.3 ± 3.0 weeks), the 2nd trimester (24.2 ± 1.4 weeks) and the 3rd trimester (34.1 ± 1.5 weeks) of pregnancy. Weight was recorded using a digital balance (Soehnle, Germany) to the nearest 100 g; height was measured using a stadiometer to the nearest 1 cm. Maternal body mass index (BMI) was calculated using weight (kg) and height (m) at baseline (kg/m^2). Maternal weight gain in the second trimester was calculated as the average weekly weight gain between the weight measured at baseline and the weight measured at the second trimester of pregnancy. Similarly, weight gain in the third trimester was calculated as the average weekly weight gain between the weight measured at the second trimester and that measured at the third trimester of pregnancy.

Dietary data

Habitual dietary intake for the preceding 3 months of each trimester was assessed using a food frequency questionnaire (FFQ) that was interviewer administered by a trained research assistant. This questionnaire was developed for the urban middle class residing in South India.[14] Nutrient composition of the food item was calculated using standard food conversion tables for the ingredients.[15] Whenever available, Indian data was used. However, for some nutrients, for which Indian data was not available, USDA data in the public domain was used.[16] This FFQ was validated against three 24-h food recalls (n=100) for each of the three trimesters of pregnancy (Dwarkanath et al, unpublished data, 2005).

Physical activity questionnaire

The physical activity information was obtained using a previously validated physical activity questionnaire.[17] This interviewer based questionnaire, designed for urban settings, accounted for the activities (duration and frequency) performed during the day (24 hours). Information was collected for activities in 5 domains – occupational activity outside the house, discretionary exercise, household chores, sedentary activities, hobbies and sleep. If the duration of activities did not add up to 1440 minutes in a day, the residual time was assigned a sedentary activity value. Following this, physical activity ratios (PAR) were assigned for each of the activities reported using comprehensive tables for the cost of physical activities.[18,19] Where the PAR for an activity was not available, the PAR for the most closely related activity was used.

Physical activity data are expressed as the duration (minutes/day), or as the product of the intensity (PAR) and duration (PAR-min). A composite measure of daily physical activity, the physical activity level (PAL), was also calculated, as the ratio of the total energy expenditure (TEE; kJ/day) and the basal metabolic rate (BMR; kJ/day). Basal metabolic rate was estimated using standard WHO equations,[20] and this was used as the value throughout pregnancy, since earlier work on pregnant urban South Indian women has demonstrated that the BMR expressed per kg body wt/day was not significantly different across the three trimesters of pregnancy.[21] The physical activity questionnaire was assessed for its repeatability and validity. The estimates of physical activity were highly repeatable, when the questionnaire was re-administered within a 4 wk period (e.g., r=0.86, p<0.01 for 24-h energy expenditure). Relative validity was

Table 1. Maternal socio-demographic characteristics at baseline

Parameters	All live births (N=546)
Age (years) †	24.4 ± 4.1
Gestational age, (LMP in weeks) †	12.3 ± 3.0
Parity‡	
0	327 (59.9)
1-2	204 (37.4)
≥3	15 (2.8)
Educational level‡	
Up to middle school	184 (33.7)
High school & Diploma	222 (40.7)
University degree and above	140 (25.6)
Employment status‡	
Employed outside the home	159 (29.1)
Housewives	387 (70.9)

LMP = Last menstrual period; †Mean ± SD; ‡N (%)

Table 2. Maternal anthropometric and physical activity characteristics at baseline

Parameters	Value	Number
Body weight (kg)	52.6 ± 9.6	546
Height (m)	1.55 ± 0.06	546
BMI (kg/m^2)	22.0 ± 3.9	546
PAL	1.47 ± 0.16	546
PAL Domains		
Occupation (PAR-min)	275 ± 468	546
Household Chores (PAR-min)	511 ± 290	546
Sleep (min)	493 ± 56	546
Sedentary activity (min)	175 ± 102	546
Discretionary exercise (PAR-min)	25.1 ± 53.7	546
Weight gain (kg/ week)		
12-24 wk gestation	0.39 ± 0.20	405
Weight gain (kg/week)		
24-34 wk gestation	0.49 ± 0.25	335

Mean ± SD.; Numbers of subjects for each measurement vary because of missing values later in pregnancy.

Table 3. Maternal weight in relation to levels of physical activity in the three trimesters of pregnancy.

Parameter	Maternal weight (kg)	Number
Trimester 1		
Sedentary activity	53.5 ± 10.2	198
Moderate activity	51.8 ± 9.0	150
Trimester 2		
Sedentary activity	57.4 ± 10.2	150
Moderate activity	59.7 ± 10.4	100
Trimester 3		
Sedentary activity	62.7 ± 10.7	183
Moderate activity	61.3 ± 9.9	88

Mean ± SD.; Numbers of subjects for each measurement vary because of missing values later in pregnancy; No significant differences in body weight between women with sedentary and moderate activities in each trimester of pregnancy

assessed by comparing energy intake (using repeated 24 h dietary recalls) and expenditure (using the physical activity questionnaire) over the same period. A correlation between the two measures was; r=0.33, p<0.05.[17]

Birth data

The baby birth weight was measured to the nearest 10 g soon after delivery on a standard beam scale balance.

Statistical analysis

All analyses were done with the SPSS program (version 13.0, SPSS, Chicago, IL). Results are presented as mean ± SD. Logistic regressions models were used to identify the significant predictors of birth weight among maternal physical activity domains during pregnancy. For logistic regression, the birth weight was divided into tertiles and further divided into two groups to obtain a binary variable; group 1 (lowest tertile) and group 2 (higher two tertiles). A multivariate model (with 3 covariates) was developed with maternal weight, energy intake and education level. Two-sided p values <0.05 were considered statistically significant. For analysis, the exercise domain was treated as a categorical variable (presence or absence) among the mothers in the three trimesters. Those mothers who exercised during their pregnancy, were further classified as low or high exercisers using 105 PAR-min (median value) as the cut off. Similarly, the work domain was also treated as a categorical variable (working or not working). Women who worked outside the home were assigned to low or heavy categories using a median value of 975 PAR-min as the cut-off. The household chores domain was expressed in terms of PAR-min while the sedentary activity and sleep domains were expressed in terms of duration.

RESULTS

Maternal socio-demographic information is presented in Table 1. The mean age of the study subjects was 24.4 ± 4.1 years, ranging from 17 to 40 years, and the mean gestational age was 12.3 ± 3.0 weeks at enrolment. About 60 % of the mothers were primiparous; educational status of the women was very variable. A large proportion of the women were housewives (71%). The mean birth weight was 2812 ± 471 g with a mean gestational age of 38.5 ± 1.6 weeks. Maternal energy intake during pregnancy was 2058 ± 603 (n=545), 2189 ± 510 (n=410) and 2234 ± 635 (n=411) kcal/d, respectively, in the three trimesters.

Maternal anthropometry and PAL of the mothers at recruitment are presented in Table 2; the mean weight and height of the women was 52.6 ± 9.6 kg and 1.55 ± 0.06 m respectively. About one in six mothers had a low BMI at recruitment (< 18.5 kg/m2). The mean PAL of the mothers at recruitment was 1.47 ± 0.16. Since physical activity and maternal body weight are expected to be inversely associated, and this association is a link between physical activity and birth weight, we assessed maternal weight at each trimester with respect to activity groupings based on the PAL (sedentary and mild activity PAL ≤ 1.40, moderate activity PAL ≥ 1.55). There was no significant difference in maternal weight between the activity groups based on PAL throughout the pregnancy (Table 3). In terms of specific domains of activity, the time spent in sedentary activities (using a cutoff of 165 min as a median) was significantly associated with maternal body weight in the first trimester of pregnancy (51.2 kg vs. 54.1 kg, p<0.001). This association did not persist as the pregnancy progressed. The time spent on household chores and duration of sleep also did not affect maternal body weight. Birth weight was associated with maternal weight in the 1st trimester as well as with gestational

Table 4. Odds ratio for low birth weight by tertiles of maternal physical activity level (PAL) in each trimester

Variable	Median (IQR)	Model 1† OR (95% CI)	Model 2‡ OR (95% CI)	Model 3§ OR (95% CI)	Model 4¶ OR (95% CI)
PAL	Tertile 1(n = 183)				
Trimester 1	1.33 (1.30-1.36)	1.0	1.0	1.0	1.0
	Tertile 2 (n = 182)				
	1.44 (1.41-1.47)	1.23 (0.79,1.92)	1.23 (0.79, 1.92)	1.24 (0.80, 1.95)	1.27 (0.81, 1.99)
	Tertile 3 (n = 181)				
	1.61 (1.56 - 1.73)	1.58 (1.02, 2.44)*	1.57 (1.01, 2.44)*	1.57 (1.01, 2.44)*	1.56 (1.00, 2.44)
PAL	Tertile 1(n = 140)				
Trimester 2	1.33 (1.29 -1.36)	1.0	1.0	1.0	1.0
	Tertile 2 (n = 136)				
	1.45 (1.42-1.48)	1.60 (0.97, 2.64)	1.44 (0.65, 3.23)	1.62 (0.97, 2.71)	1.66 (0.99, 2.80)
	Tertile 3 (n = 130)				
	1.61 (1.56-1.68)	1.46 (0.88, 2.44)	1.54 (0.46, 5.12)	1.69 (0.99, 2.87)	1.65 (0.96, 2.81)
PAL	Tertile 1(n = 137)				
Trimester 3	1.31 (1.27-1.34)	1.0	1.0	1.0	1.0
	Tertile 2 (n = 139)				
	1.42 (1.38-1.45)	0.80 (0.48, 1.33)	0.77 (0.46, 1.30)	0.77 (0.45, 1.31)	0.68 (0.39, 1.18)
	Tertile 3 (n = 138)				
	1.59 (1.52-1.65)	1.28 (0.78, 2.09)	1.23 (0.74, 2.03)	1.29 (0.78, 2.13)	1.29 (0.77, 2.18)

* $p<0.05$; IQR – Interquartile range; †Model - Univariate analysis, ‡Model - Multivariate logistic regression adjusted for maternal weight, §Model - Multivariate logistic regression adjusted for maternal weight, energy intake, ¶Model - Multivariate logistic regression adjusted for maternal weight, energy intake and education.

weight gain in the 2nd trimester. Women in the lowest tertile of weight in the 1st trimester were 2.16 times (95% CI: 1.39-3.34) more likely to have a baby in the lowest tertile of birth weight.

A direct link between physical activity and birth weight was also assessed. Maternal PAL was assessed for associations with birth outcomes (Table 4); by univariate analysis, women belonging to the highest tertile of PAL in the first trimester had significantly higher odds (OR: 1.58, 95% CI: 1.02-2.44) of having a baby in the lowest tertile of birth weight ($p<0.05$). This significant association continued when adjusted for maternal weight (OR: 1.58, 95% CI: 1.01-2.44), and energy intake (OR: 1.57, 95% CI: 1.01-2.44). However after adjusting for maternal education, PAL in the 1st trimester was not a significant predictor of low birth weight ($p=0.051$). This non significance may be due to the inverse relationship of PAL in the 1st trimester with maternal education, and education being directly related to the birth weight. Women with a higher education level (university degree) had babies with a significantly higher birth weight as compared to babies born to the mothers who had an education only up to middle school. There was no difference in the gestational age of babies born to mothers who were grouped in tertiles according to their PAL in the 1st trimester (38.6 ± 1.4, 38.6 ± 1.4, and 38.5 ± 1.3 weeks, respectively, for the three tertiles). Therefore, in these logistic regressions, gestational age was not adjusted for. Activity in the sedentary, exercise, sleep and household chore domains in all trimesters also did not show any significant associations with birth weight. For the work domain, there were no significant associations with birth weight for women working outside the home when compared to housewives. This trend, of non significant associations of PAL or domain based physical activity was observed in all the three trimesters.

The effect of maternal physical activity on other birth outcomes such as baby length, head circumference and mid upper arm circumference was also examined. Multivariate logistic regression adjusting for maternal characteristics as well as birthweight of the baby showed that in the first trimester of pregnancy, the odds of having a baby with a smaller head circumference (lowest tertile of head circumference) increased with increasing level of PA and was significantly so for the highest tertile of PAL as compared to the lowest tertile of PAL (OR: 1.89, 95% CI: 1.07-3.34, $p=0.028$).

DISCUSSION

In developing countries like India, women are responsible for a wide range of household work and childcare duties, as well as work outside the home. These women are also the women at highest risk for a poor birth outcome.[1] The present study assessed associations between birth weight and maternal physical activity, but since maternal weight in the first trimester and gestational weight gain is associated with birth weight,[8] associations between physical activity and these maternal anthropometric indices were also assessed. Physical activity can be assessed through an integrated index such as PAL, assessed through the administration of a physical activity recall questionnaire, or, through the assessment of the time spent in, and the intensity of, different activities in the domains of work, domestic chores, transport, leisure and sleep. The instrument used in the present study to measure physical activity, and by extension, energy expenditure, was an interviewer administered questionnaire, which is admittedly a relatively crude measure. However, its strengths lay in its simplicity and its attempt to capture all domains of physical activity; furthermore, it had been tested for relative validity in a weight stable population.[17] Ideally, one would require an instrument that was tested against a gold standard for total energy expenditure, however, there was no such instrument available at this time in India.

The relationship between physical activity and birth weight might be expected to operate through the maternal

weight either at the first trimester, or in terms of gestational weight gain, since these variables are associated with birth weight.[8] In this framework, relationships might be expected between physical activity and maternal weight or gestational weight gain; in sequence, these anthropometric variables might have a subsequent relationship with birth weight, and finally, a direct relationship between maternal physical activity and birth weight might also be demonstrated. If this latter relationship were adjusted for maternal weight, it suggests that maternal physical activity has a direct association with birth weight, independent of its effects on maternal weight gain. In the present study, women who had moderate/heavy physical activity in the 1st trimester of pregnancy had a significantly higher odds of giving birth to lower birth weight babies as compared to women who had sedentary physical activity. This significant relationship could not be completely demonstrated for the 2nd and 3rd trimesters. The general finding that women who were moderately or heavily active had a higher risk of having low birth weight babies is in agreement with a study of Ethiopia in which women were compared between categories of hard and light work during pregnancy.[9]

The significant association between maternal activity and birth weight continued even after adjusting for maternal weight. Gestational age was not adjusted for in this relationship since we found that the gestational age did not vary between the tertiles of physical activity in the mother. This is in agreement with an earlier study[13] and a meta analysis[22] in which the length of gestation was shown not to be associated with maternal physical activity. It is not clear as to what the maternal weight-independent relationship between physical activity and birth weight implies. It could be related to the body composition of the mother linked to different amounts of energy stores.

Since the PAL is an aggregate index of all physical activities, it is worth analyzing maternal physical activity in separate activity domains with respect to birth weight. Leisure time exercise was not significantly associated with maternal weight during the first and second trimesters and this remained even with categories of low/medium or heavy exercise. Moreover leisure time activity was reported only in a small proportion of women (about 27%) and hence this relationship of non significance could be related to the small numbers.

In the domain of household chores, earlier studies have shown correlations between activity in this domain and preterm births. Mothers who did half or less of their household chores delivered 9.4 % of the preterm babies compared with the 4.9 % delivered by the mothers who completed all chores.[11] In the present study, there was no effect of household activity on the maternal weight, weight gain, or with birth weight. In addition, sleep was not related to baby birth weight, but this might also be due to a very small scatter of the number of hours reported to be spent in sleep. We also quantified the duration of time spent in sedentary activities, and could not demonstrate a direct relationship with birth weight. This is in contrast to studies that have been able to demonstrate a direct effect between maternal rest (greater than 21 days in the last trimester) and birth weight and birth length.[23]

The present study has shown that heavy work outside the home in any of the trimesters was not associated with birth weight. However there was a trend of higher birth weight among women who reported light work outside home in the third trimester as compared to those reported heavy work. Few studies have shown association of work in the third trimester and preterm births and low birth weight. In one study, a 150g – 400 g decrease in birth weight occurred in women who continued to work outside the home during the third trimester compared with those who remained at home during pregnancy.[24] A similar, non-significant, decrease of 181 g in birth weight for babies of women who worked in a heavy mode outside the home during the third trimester was observed in the present study. Reports from Africa also show that hard physical work by women during pregnancy can retard fetal growth and increase fetal/neonatal mortality.[9,25] Indeed, the detrimental effect of third trimester work upon birth weight has been reported to be exacerbated if pregnant women worked in a standing position, were hypertensive, were poorly nourished, or had other young children at home.[9] These parameters were not assessed in the present study.

In conclusion, the present study shows that physical activity in the first trimester of pregnancy is an important factor in determining birth weight in Indian babies, even after accounting for baseline maternal weight, energy intake and educational status. Significant associations of higher maternal weight or gestational weight gain with lower physical activity were not found in the present study, and it is possible that physical activity may have as yet unexplained direct effects on birth weight.

ACKNOWLEDGEMENTS

We greatly appreciate the assistance of Nancy Nanditha M, Manjula V, Selvi MN, Mercy Flora A and Amutha N in the collection and entry of data. We thank the women and their infants who participated in this study and the doctors and nurses who made this study possible.

AUTHOR DISCLOSURES

Pratibha Dwarkanath, Sumithra Muthayya, Mario Vaz, Tinku Thomas, Arun Mhaskar, Rita Mhaskar, Annamma Thomas, Swarnarekha Bhat and Anura Kurpad, no conflicts of interest.

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婦女懷孕期間的體能活動與嬰兒出生體重的相關性

前言：印度早期的研究指出，從事大量與農業以及家事的鄉村婦女，其體能活動與嬰兒出生體重為負相關。目前還沒有印度城市地區，較大範圍的社經背景及各種強度的體能活動量的婦女的相關數據。本研究評估婦女懷孕期間，不同狀況的體能活動量與對其嬰兒出生體重的角色。**方法**：收集婦女妊娠第一期、第二期與第三期的體位資料及體能活動量。在分娩後立即測量 546 名活產嬰兒之出生體重。**結果**：花費在靜態活動的時間(中位數切點為 165 分/天)與婦女妊娠第一期時的體重顯著相關(51.2 公斤 vs. 54.1 公斤，p<0.001)。當妊娠第一期的體能活動量位在最高三分位，其產下的嬰兒出生體重在最低三分位的機會為在體能活動量最低三分位者的 1.58 倍。在校正婦女體重與熱量攝取量之後，仍然顯著性。**結論**：本研究顯示第一孕期的體能活動量與印度嬰兒低出生體重相關。

關鍵字：懷孕、體能活動、低出生體重、營養、印度。