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ORIGINAL COMMUNICATION

Maternal activity in relation to birth size in rural India. The Pune Maternal Nutrition Study

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Objective: To describe the relationship of the mother's physical activity to the birth size of her baby in a rural Indian population.
Design: Prospective observational study.
Setting: Six villages near Pune, Maharashtra, India.
Subjects: A total of 797 women were studied after excluding abortions and termination of pregnancies (112), foetal anomalies (8), multiple pregnancies (3), incomplete pre-pregnancy anthropometry (14) and pregnancies detected later than 21 weeks of gestation (168).
Method: An activity questionnaire was developed after focus group discussions and incorporated community-specific activities. It was validated against an observer-maintained diary. Activity scores were derived using published data on energy costs to weight the contributions of various activities. It was then administered to assess physical activity at 18 (± 2) and 28 (± 2) weeks of gestation.
Outcome measures: Birth outcome, maternal weight gain and neonatal anthropometry.
Results: The activity questionnaire was used to classify women into light, moderate and heavy activity categories. Maternal activity did not influence the incidence of prematurity or stillbirth, or the duration of gestation. It was inversely related to maternal weight gain up to 28 weeks of gestation ($P=0.002$). Higher maternal activity in early, as well as mid gestation, was associated with lower mean birth weight ($P=0.05$ and 0.02, respectively), and smaller neonatal head circumference ($P=0.005$ and 0.009) and mid-arm circumference ($P=0.03$ and 0.01) after adjusting for the effect of major confounding factors.
Conclusions: The Findings suggest that excessive maternal activity during pregnancy is associated with smaller foetal size in rural India, The approach described for developing an activity questionnaire has potential for adoption in other settings.
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Introduction

Women from rural communities in developing countries like India have a high physical workload, including both farm labour and domestic chores. Energy expenditure could therefore be an important factor affecting the relationship between maternal nutrition and birth size. Manual work has been associated with low birth weight in undernourished women in developing countries (Tafari *et al*, 1980; Launer *et al*, 1990). Strenuous physical work has also been associated with increased rates of abortion and premature delivery (Teitelmann *et al*, 1990; Ahlborg, 1995; Barnes *et al*, 1991). Investigators speculate that strenuous occupations increase uterine contractions and therefore increase the risk of premature birth (Simpson, 1993; Keith & Luke, 1991). Similarly, it is postulated that nonsupine postures may affect uteroplacental blood flow (Briend, 1979; Suonio *et al*, 1976) and therefore birth size.

Maternal activity might therefore be a potentially modifiable risk factor for reducing low birth weight prevalence (Kramer, 1987). Studies from India have examined the associations between birth weight and maternal age, parity, lack

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of antenatal care (Trivedi & Mavalankar, 1986; Theodore *et al*, 1992) social variables (Grover, 1982) and maternal pre-pregnant nutritional status and dietary intake (Vijayalakshmi & Lakshmi, 1985; Bhatia *et al*, 1983a,b; Rao *et al*, 2001), but few studies have examined the relationship between maternal physical activity and neonatal size.

We have recently carried out a study to examine the relationship between maternal nutrition, physical activity and birth size among women living in rural Maharashtra State, India. Direct measurement of energy expenditure in this community was not practical because the sophisticated equipment required is culturally unacceptable and disruptive to the rural lifestyle of these women. On the other hand, one of the commonly used indirect methods of measuring energy expenditure, the diary method, was impractical as the majority of women were illiterate and used to measuring time. Also, these women are too pre-occupied with their daily routine work to cooperate in other elaborate methods of measuring activity.

Studies reported in the literature indicate that interviewer-assisted activity questionnaires can yield reliable data for assessing habitual physical activity (Phillippaerts & Lefevre, 1998). Such questionnaires, however, provide data on requency and duration of activity but reveal little quantitative information about the intensity of physical activity. We set out to devise a questionnaire approach which would be simple, quick and feasible to administer, to study maternal activity among rural women from Maharashtra. Applying values of energy costs for different physical activities from the literature, we were able to convert the women's activity into semi-quantitative scores. This helped to classify women into broad categories of light, moderate and heavy activity. We validated our approach against a conventional observer-maintained diary method and then used it to study the relationship of physical activity to birth size.

Methods

Subjects

The study was undertaken in six villages, 40–50 km from Pune city and covered a population of approximately 35 000. Of 2675 married eligible women (15–40 y), 2466 women (92%) agreed to take part. The area is drought prone and most families lived by subsistence farming on small landholdings. The majority of women (75%) worked on their farms or as labourers, in addition to their domestic chores, which are tedious and hard. Most families were vegetarian and the usual diet consisted of pearl millet roti and dal or a vegetable curry. Socio-economic status was assessed using a standardized questionnaire (Pareek & Trivedi, 1964), which derives a composite score based on occupation and education of the head of the household, caste, type of housing, and family ownership of animals, land material possessions. Full details of the study including dietary intakes have been reported earlier (Rao *et al*, 2001).

Gestation

Field workers visited the women every month to record the date of their last menstrual period; women who missed two successive periods were examined by ultrasound at 15–18 weeks to record sonographic gestational age (Hadlock, 1990). Gestational age was derived from the last menstrual period, unless it differed form the sonographic estimate by more than 2 weeks, in which case the latter was used. Women entered the study if a singleton pregnancy of less than 21 weeks gestation was confirmed. All women reporting missing a period between June 1994 to April 1996 were thus enrolled in the study. Of the 1102 women enrolled, 797 women were studied after excluding abortions and termination of pregnancies (112), foetal anomalies (8), multiple pregnancies (3), incomplete pre-pregnancy anthropometry (14) and pregnancies detected later than 21 weeks of gestation (168). The method of workload assessment was developed during the pre-recruitment phase.

Weight

Women were measured every 3 months to record their weight. The last weight recorded before confirmation of pregnancy was used as pre-pregnant weight and the measurement was repeated during pregnancy at 18 ± 2 and 28 ± 2 weeks gestation to get estimates of weight gain during pregnancy.

Nutritional intakes

The conventional 24 h recall method was modified and made more objective by incorporating information on portion sizes, which were weighed at each mealtime by a trained fieldworker. Women were interviewed at 18 and 28 weeks of gestation by one of four nutritionists to record consumption of food items in chronological order from morning until dinnertime. At the time of diet survey interviewers ensured that the women was not fasting or suffering from any illness and had reported foods consumed outside home on the day of visit. It was observed that mean energy and protein intakes at 18 and 28 weeks were low: energy, 7.4 ± 2.1 MJ and 7.0 ± 2.0 MJ; protein, 45.4 ± 14.1 g and 43.5 ± 13.5 g respectively. These represented approximately 70–75% of recommended intakes (Indian Council of Medical Research, 1998) at both time points.

Development of the activity questionnaire

Focus group discussions (FGDs). Use of FGDs in social science research is well known but they have not been used in community-based nutrition studies in India. In all, four FGDs were held with groups of eight to 10 women, representing young pregnant and elderly women. Women voluntarily participated in FGDs. A tape recorder was kept at the centre with prior consent of the women and the discussions were moderated around eight to 10 important relevant

questions related to activity of rural women. The FGDs aimed to obtain information about the different activities that women undertake in this rural community, to understand their perception of light and strenuous activities and to know their perception of the distance and time for activities involving walking. We also enquired if physical workload is altered during pregnancy and by season.

Activity questionnaire. The information gained from FGDs provided insights into the lifestyle of rural women. The data obtained from the FGD assisted in developing the activity questionnaire, which was field tested for discriminating active women from others and was finalized (Appendix). Details of their typical daily activity from morning until evening were recorded under three broad categories as 'resting', 'domestic' and 'other' activities, including farming work. Women who were not working on the farm were either engaged as construction workers or were running a small shop or stitching clothes, and were included under 'other' activities, constituting 13.9% of the population.

In the 'resting' category women were asked about the time they went to bed and got up, whether and for how long they rested during the day and how many TV programs they watched in the evening. The 'domestic' category involved the variety of activities besides cooking, such as fetching water, washing utensils and clothes, fetching firewood, and cleaning animal sheds. These activities were recorded in terms of simple numeric measures such as number of roties prepared each meal time, number of trips to the well and number of animals cared for. Perception of the distance from home to the farm or to the well was recorded as 'near', 'far' or 'mid-way', while the time spent in actual farm work was recorded in terms of half day or full day and number of days in a week.

Activity scores. Using published data for the energy expenditure of activities (Lawrence *et al*, 1985), a weighted score was derived, which reflected as a base unit an activity level of 1 kcal per minute for a 30 min slot of time. For example, the time required to make up to 10 roties was around 30 min and, considering the energy costs for bread making (2.3 kcal), the activity score for making 10 roties works out at 2.3×1 (one slot of 30 min). For making an additional 10 roties the score was increased by 25% as the initial time for dough preparation is saved. Similarly, farm work is listed as expending 3.5 kcal energy/min; 6 h of farm work had a score of 3.5×12 $(6\,\text{h} \times 2) = 42$. For sleeping and resting activities a different weighting was used to reflect the fact that, if a woman spents less time sleeping, she would be spending more time working. For all the activities in the questionnaire, the scores were computed (Appendix). A total daily activity score and separate scores for the components resting, domestic and other were derived.

Validation. The time spent in each activity and the energy expenditure scores obtained using the questionnaire were compared in 42 women from the same study population with those derived from a detailed observer-maintained diary. A trained nutritionist stayed with each woman throughout the day and recorded her minute-to-minute activity (including posture) from waking (7 am) until bedtime (9 pm). Distances walked by the women were measured using a pedometer (CMS Instruments Ltd, London, UK). We were not able to select the subjects randomly as it depended on the willingness of the family for the women to be followed closely throughout the day. The short activity questionnaire was administered the following day by a different nutritionist.

The validation study aimed to determine (i) whether the specific tasks recorded in the questionnaire reflected observed behaviour, (ii) whether the simple numeric measures of various activities reflected the time spent in these activities, and (iii) to test and validate the perceptions of women about the 'near' or 'far' distance using a pedometer.

The activity questionnaire thus developed was administered at 18 ± 2 weeks and 28 ± 2 weeks gestation to 797 women in the study.

Birth outcome

Birth outcome was recorded as prematurity (gestation < 37 weeks), stillbirth or livebirth. Birth size was measured in terms of several anthropometric measurements. Babies were measured by one of five trained fieldworkers within 72 h of birth. Birth weight was measured to the nearest 50 g using a Saltar spring balance (Salter Abbey, Suffolk, UK); crown–heel length was measured to the nearest 0.1 cm using a portable Pedobaby Babymeter (ETS J.M.B., Brussels, Belgium). Triceps and subscapular skinfold were measured to the nearest 0.2 mm, on the left side of the body, using Harpenden skinfold callipers (CMS Instruments, London, UK). Occipito-frontal head circumference and mid-upper-arm circumference (MUAC) were measured to the nearest 0.1 cm using fibre glass tapes (CMS Instruments). Abdominal circumference was measured at the level of umbilicus in expiration. Placental weight was recorded to the nearest 5 g using Ishida scales, after trimming of the umbilical cord and membranes. Inter- and intra-observer variation studies were conducted 3-monthly to ensure quality of these measurements.

Statistical methods

Proportions of pre-term and low birth weights in activity groups were tested by χ^2 test. Multiple regression analysis was carried out for examining the relationship of maternal activity with birth size after adjusting for major confounding variables. Maternal weight, sex of the new-born, gestation, parity and weight gain (28th week) were direct predictors while social class (as a group variable), and protein and energy intakes (as a continuous variable) were indirect predictors. Comparisons of mean activity scores for farming and

non-farming women were done using *t*-tests for independent samples. The data were analysed using the software package SPSS/PC version 5.0.

Results

Focus group discussions revealed that almost all the women performed domestic activities that included cooking, washing clothes and utensils, sweeping the house and fetching water and firewood. Women perceived fetching water and washing clothes as the most strenuous activities. They often carried three containers filled with water, placing two on their head and one on their waist/hip. The capacity of each container was 10 – 15 l (weighing in total about 45 kg). While fetching water, women were required to bend and pull a bucketful of water from the well, often without even using a simple pulley.

In addition, many women did farm work in which specifically 'female' tasks tended to be those requiring prolonged bending, squatting or standing. These included weeding, onion planting, harvesting groundnuts and threshing grains. Some women were also engaged in caring for and milking animals. Women had no recreation other than chitchatting. Going to the market to sell or buy things was often done by an elderly man or woman in the house. During slack periods farming activities were replaced by other tasks such as stitching quilts and making pappadam and vermicelli stocks for use throughout the year. There was a strong belief among these women that working until late gestation led to an easier delivery.

It was clear from the focus group discussions that women were able to state with confidence the number of roties they prepared in a day or the number of trips they made to the well. They were not, however, able to describe the time taken in particular activities. Similarly, women were not able to assess distances accurately but perceived the farm or the well as 'near' or 'far'. FGDs were thus helpful in indicating possible simple numeric measures proportional to time or distance for various activities.

Validation results

The women who took part in the validation study were similar to those enrolled in the main study in respect of age (20.8 ± 2.9 *vs* 21.4 ± 3.5 y, respectively) and pre-pregnancy weight (42.8 ± 5.3 *vs* 41.6 ± 5.1 kg, respectively) but were slightly taller (153.8 ± 4.5 *vs* 151.9 ± 5.0 cm, respectively, $P < 0.05$).

The actual observed time for several activities confirmed the assumptions made in formulating the activity questionnaire. Thus mean time observed for making up to five roties (measured on 15 women) was 24.4 min, while that observed for six to eight roties (measured on 11 women) was 40.1 min. Similarly, time spent in washing clothes (for five persons) was 28.3 min (measured on 15 women) while that for five to 10 persons (observed on 11 women) was 70.6 min. These observations revealed that time spent cooking was proportional to the number of roties/chapaties, that spent in washing clothes or utensils was proportional to the number of persons, and time spent caring for animals was proportional to the number of animals.

Perceptions of distance varied according to whether the woman was carrying a load or not. Thus, when examined with pedometers, it was observed that the average distance for walking without a load perceived as 'far' was higher (4.7 ± 2.67 km observed on 8 women) than that for walking with a load (1.5 ± 0.36 km observed on three women).

Mean time recorded during validation for various broad categories, ie farming, domestic activity and resting, were 323.4 ± 127.8, 616.8 ± 148.4 and 479.3 ± 48.9 min, respectively (Table 1). The mean activity scores estimated from the activity questionnaire show that, despite large differences in time spent in domestic and farming work, their scores were similar owing to the higher energy costs of farming activities. The correlation of the actual time observed with the activity scores was significant in all three broad categories of activities, as well as with the total activities. The negative correlation for the resting category indicates that women spending a long time resting had a lower activity score. Data collected on total daily observed time in various activities and daily activity score were cross-classified (2×2) on the basis of the median values, to examine sensitivity and specificity. The median was preferred as the majority of women were from farming families and the distribution of activity scores was skewed. It was observed that the activity scores had a high sensitivity (70%) and specificity (70%) for identifying women engaged in high levels of activity.

Activity patterns of rural mothers (main study)

The activity pattern of the rural mothers in the main study based on the validated questionnaire (Table 2) shows that

Table 1 Results of the validation study

Activity	*No.*	*Time (min), mean ± s.d.*	*Activity score, mean ± s.d.*	*Correlation[a] between observed time and activity scores*
Domestic	42	616.8 ± 148.4	25.0 ± 10.8	0.34 ($P < 0.03$)
Farming	19	323.4 ± 127.8	30.4 ± 12.9	0.68 ($P < 0.001$)
Resting/sleeping	42	479.3 ± 48.9	7.64 ± 1.63	−0.49 ($P < 0.001$)

[a]Spearman rank correlation.
Sensitivity (for identifying women doing higher activity: above median score) = 15/21 = 70%.
Specificity (for identifying women doing low activity: below median score) = 15/21 = 70%.

Table 2 Activity pattern of rural women at 18 weeks of gestation

Activity	*Percentage of women reporting*[a] (n = *779*)	*Activity score, mean ± s.d.*	*Contribution (%) to day's activity score*
Rest in afternoon	80.5	6.18 ± 0.82	10.11 ± 3.59
Watching TV	47.4	4.57 ± 0.58	8.62 ± 3.74
Cooking roties:			
Morning	67.2	2.70 ± 0.76	4.63 ± 2.54
Evening	87.5	2.40 ± 0.38	3.83 ± 1.85
Both	58.1	5.00 ± 0.86	8.71 ± 4.31
Washing clothes	92.4 (for average 6 persons)	5.32 ± 1.80	7.92 ± 3.42
Washing utensils	95.1 (for average 7 persons)	5.21 ± 1.79	7.87 ± 3.59
Breast feeding	17.9 (average 2 times/day)	1.17 ± 0.75	1.70 ± 1.38
Care of animals	57.1 (for average 5 animals)	5.18 ± 3.88	6.32 ± 4.82
Milking	19.4 (for average 2 animals)	1.57 ± 0.92	1.94 ± 1.04
Fetching firewood	64.8 (for average 4 days/wk)	2.10 ± 1.42	2.70 ± 1.93
Near	83.8	1.72 ± 0.83	2.29 ± 1.43
Far	16.2	4.07 ± 2.06	4.83 ± 2.66
Fetching water	86.6 (average 2 trips/day and average 3 containers/trip)	13.43 ± 11.47	17.61 ± 11.72
Distance from house:			
Near	77.3	9.89 ± 6.53	14.24 ± 8.61
Mid-way	7.4	18.23 ± 8.92	23.10 ± 10.69
Far	15.3	29.03 ± 16.98	31.91 ± 13.86
Working on farm	66.8 (average 6 days/week)	33.69 ± 11.03	38.74 ± 11.36
Distance from house:			
Near	64.2	32.51 ± 10.85	37.84 ± 11.36
Far	35.8	36.78 ± 9.03	40.80 ± 9.47
Whole day	90.0	36.09 ± 8.41	40.67 ± 9.21
Half day	10.0	14.85 ± 8.20	21.76 ± 10.87
Working as labourer	4.5 (45.7% whole day and average 3.5 days/week)	15.16 ± 11.41	18.22 ± 13.21
Stitching and others	11.7 (average 1 h/day)	0.46 ± 3.11	2.53 ± 3.83
Sitting/chit-chatting	2.9 (average 4 h/day)	9.10 ± 5.52	15.69 ± 11.00

[a]Out of 797 pregnant women information on activity was available on 779.

the majority of the women cooked and washed clothes and utensils as their main domestic activities. Only 3.3% of women did not report any cooking activity; this was due to an additional helping hand, such as an elderly woman, a sister-in-law or a mother-in-law in the house. Women who did not cook were often involved in animal care or milking. Over 85% of women fetched water and made an average of two trips to the well, carrying three containers at a times, while 64.8% of women had to collect firewood. Fetching water contribute on average 17.6% to the total daily score while that for firewood collection contributed 2.7%. Washing utensils and clothes also made a considerable contribution (7.7%).

Sixty-seven percent of women worked on the farm and of these 90% worked a full day. This activity had the highest mean contribution to the daily score (38.7%). They had some rest (about 30 min) during the lunch hour, while women not working on the farm could enjoy an afternoon nap in the house. Only 3% of women reported leisure activitiers such as chit-chatting. It was noticeable that 18% of women were breast-feeding their youngest child, although many stopped in late gestation.

Table 3 Mean (95% confidence intervals) activity scores in early and late gestation for women from farming (F) and non-farming (NF) families

Activity	*18 weeks of gestation*		*28 weeks of gestation*	
Category	*NF (271)*	*F (508)*	*NF (344)*	*F (392)*
Resting	17.9 (17.6 – 18.2)	19.9 (19.7 – 20.1)	18.1 (17.9 – 18.3)	19.5 (19.3 – 19.7)
Domestic	26.8 (25.1 – 28.5)	32.0 (30.8 – 33.2)	26.0 (24.5 – 27.5)	30.9 (29.5 – 32.3)
Other	3.2 (2.6 – 3.8) (87)[a]	36.0 (35.3 – 36.7)	2.9 (2.4 – 3.5) (101)[a]	34.2 (33.3 – 35.1)
Total	45.7 (43.9 – 47.5)	87.9* (86.5 – 89.3)	44.8 (43.2 – 46.4)	84.3* (82.4 – 86.2)

[a]These are women doing other activities like running shop or stitching clothes.
*Activity score significantly ($P < 0.01$) different between F and NF.

Table 4 Birth outcome and birth size by levels of maternal activity

	Activity at 18 weeks gestation				*Activity at 28 weeks gestation*			
Variables	*Low*	*Medium*	*High*	*P*[a]	*Low*	*Medium*	*High*	P[a]
Singleton deliveries[b]	(254)	(255)	(254)		(238)	(250)	(247)	
Percentage still births (*n*)[c]	0.4 (1)	1.2 (3)	1.2 (3)	0.56	—	1.6 (4)	1.2 (3)	0.17
Live births[d,e]	(233)	(236)	(233)		(224)	(229)	(229)	
Weight gain (kg)	2.1 (1.99–2.19)	2.1 (1.94–2.24)	1.97 (1.87–2.07)	0.29[h]	6.1 (5.96–6.14)	5.4 (5.28–5.52)	5.1 (4.99–5.15)	0.001[h]
Gestation (week)	39.1 (39.06–39.14)	38.8 (38.76–38.83)	39.1 (39.06–39.13)	0.98[h]	39.1 (39.06–39.14)	39.2 (39.16–39.24)	38.8 (38.76–38.84)	1.10[h]
Percentage premature (*n*)[c]	9.9 (23)	11.2 (26)	8.2 (19)	0.56	9.0 (20)	8.8 (20)	10.6 (24)	0.78
Percentage LBW (*n*)[c]	28.6 (66)	38.4 (89)	30.3 (70)	0.05	32.0 (71)	31.4 (71)	33.2 (75)	0.92
Term deliveries[f]	(208)	(206)	(212)		(202)	(206)	(202)	
Birth weight (g)[g]	2724 (2698–2750)	2615 (2590–2640)	2655 (2636–2674)	0.05	2695 (2671–2719)	2661 (2636–2686)	2626 (2601–2651)	0.02
Head circumference (cm)[g]	33.4 (33.3–33.5)	32.9 (32.8–33.0)	33.0 (32.9–33.1)	0.005	33.3 (33.2–33.4)	33.0 (32.9–33.1)	32.9 (32.8–33.0)	0.009
Mid-arm circumference (cm)[g]	9.8 (9.8–9.9)	9.6 (9.6–9.7)	9.6 (9.6–9.7)	0.03	9.8 (9.7–9.8)	9.7 (9.6–9.7)	9.6 (9.5–9.6)	0.01
Triceps skinfold (mm)[g]	4.24 (4.2–4.28)	4.10 (4.08–4.12)	4.32 (4.3–4.34)	0.16	4.22 (4.19–4.25)	4.15 (4.12–4.18)	4.24 (4.21–4.27)	0.50
Placental weight (g)[g]	373 (370–376)	354 (351–357)	354 (353–356)	0.02	366 (364–367)	355 (352–358)	357 (353–361)	0.35

[a]*P* after adjusting for direct predictors (sex, parity, gestation, pre-pregnancy weight, weight gain upto 28th week) and indirect predictors (social class, energy and protein intakes).
[b]Of 770 singleton deliveries, activity data available for 763 and 735 women at 18th and 28th week respectively.
[c]Proportions were compared using χ^2 test.
[d]Live births excluding stillbirth, congenital abnormalities and information.
[e]Of 702 live births, activity data available for 702 and 682 women at 18th and 28th week, respectively.
[f]Of 633 full-term deliveries, activity data available on 626 and 610 women at 18th and 28th week, respectively.
[g]Values represent adjusted mean (95% CI) values.
[h]*P* after adjusting for sex, parity, pre-pregnancy weight and gestation or weight gain.

Table 5 Birth size by levels of activity for pre-pregnant weight <45 kg of rural mothers

Variables[a]	Activity at 18 weeks gestation				Activity at 28 weeks gestation			
	Low	*Medium*	*High*	P[b]	*Low*	*Medium*	*High*	P[b]
			Pre-pregnant weight <45 kg					
Term deliveries	(153)	(155)	(154)		(153)	(154)	(146)	
Birth weight (g)	2694 (2668–2720)	2583 (2558–2608)	2629 (2607–2650)	0.14	2665 (2641–2689)	2633 (2604–2662)	2597 (2573–2621)	0.09
Head circumference (cm)	33.3 (33.2–33.4)	32.8 (32.7–32.9)	32.9 (32.8–33.0)	0.01	33.2 (33.1–33.3)	32.9 (32.8–33.0)	32.9 (32.8–33.3)	0.06
Mid-arm circumference (cm)	9.77 (9.73–9.81)	9.55 (9.51–9.59)	9.62 (9.58–9.66)	0.09	9.72 (9.69–9.75)	9.62 (9.58–9.66)	9.58 (9.55–9.61)	0.09
Triceps skinfold (mm)	4.19 (4.15–4.23)	4.06 (4.03–4.09)	4.32 (4.28–4.36)	0.07	4.19 (4.16–4.22)	4.13 (4.08–4.18)	4.19 (4.16–4.22)	0.85
Placental weight (g)	369.5 (366.3–372.7)	346.3 (343.7–348.9)	347.9 (344.6–351.2)	0.02	361.4 (358.4–364.4)	349.6 (347–352.2)	348.9 (345.0–352.8)	0.15

[a]Values represent adjusted mean (95% CI) values.
[b]*P* after adjusting for direct predictors (sex, parity, gestation, pre-pregnancy weight, weight gain upto 28th week) and indirect predictors (social class, energy and protein intakes).

Mean activity scores for broad categories of activities are given in Table 3. Mean daily activity scores differed significantly ($P<0.001$) between farming and non-farming groups. Activity scores in winter (harvesting season) were higher (89.9 ± 15.3) than in summer (85.5 ± 15.8). Farming women performed similar levels of domestic activities to non-farming women in addition to hard work on the farm. Further, there was no significant difference between mean activity scores at 18 and 28 weeks of gestation, in both farming and non-farming groups, indicating that physical activity at later gestation was not substantially reduced compared with that in earlier pregnancy.

Physical activity, maternal weight gain and birth outcome

Of 797 women, 14 had late termination of pregnancy, while one died of pregnancy-induced hypertension and 12 had spontaneous abortions. Of 770 singleton deliveries, eight babies were stillborn, nine had congenital abnormalities and 51 did not have birth measurement. Sixty-nine of the remaining 702 babies were born premature (<37 weeks gestation).

Maternal weight gain was not related to activity score at 18 weeks but was inversely related at 28 weeks of gestation. Women in the lowest third of activity gained more weight (6.1 ± 2.9 kg) up to 28 weeks than women in the highest third (5.1 ± 2.7 kg; $P<0.01$).

Birth outcome was compared in thirds of total activity score at 18 and 28 weeks of gestation (Table 4). There was no association between maternal activity and the incidence of prematurity or stillbirth. We were unable to examine associations with spontaneous abortion because of inadequate information (the earliest sonographic confirmation of pregnancy took place at 14 ± 2 weeks).

Physical activity and birth size

This analysis was limited to the 633 women who delivered at term. The proportion of low-birth-weight (LBW) babies (<2500 g) was significantly ($P<0.05$) lower (28.6%) among women in the lowest third of activity at 18 weeks gestation than among those in the medium (38.4%) or highest third (30.3%). At 28 weeks, however, the proportion of LBW did not differ.

Associations of maternal daily activity scores with the babies' measurements at birth were also examined (Table 4). After adjusting for direct as well as indirect predictors, activity score at 18 weeks was inversely related to birth weight ($P=0.05$), head circumference ($P=0.005$), mid-arm circumference ($P=0.03$) and placental weight ($P=0.02$). Similarly, activity score at 28 weeks was inversely related to birth weight ($P=0.02$), head circumference ($P=0.009$) and mid-arm circumference ($P=0.01$). Maternal activity was not related to neonatal body fat, as measured by triceps skinfold thickness.

The above analysis was performed separately for women with pre-pregnant weight below and above 45 kg to examine

Table 6 Birth size by levels of domestic, farming and strenuous activity

	Activity			
Variables[a]	*Low*	*Medium*	*High*	P[b]
		Domestic (28 weeks)		
Term deliveries	(210)	(200)	(195)	
Birth weight (g)	2686 (2659–2713)	2683 (2658–2708)	2612 (2592–2632)	0.01
Head circumference (cm)	33.2 (33.1–33.3)	33.1 (33.0–33.2)	32.9 (32.8–33.0)	0.006
Mid-arm circumference (cm)	9.73 (9.68–9.78)	9.74 (9.70–9.78)	9.57 (9.53–9.61)	0.05
Triceps skinfold (mm)	4.22 (4.19–4.25)	4.26 (4.23–4.29)	4.13 (4.11–4.15)	0.18
Placental weight (g)	360.5 (357.0–364.0)	372.1 (368.8–375.4)	344.4 (342.7–346.1)	0.03
		Farming (18 weeks)		
Term deliveries	(205)	(177)	(228)	
Birth weight (g)	2725 (2697–2753)	2637 (2620–2654)	2614 (2581–2647)	0.02
Head circumference (cm)	33.3 (33.2–33.4)	32.9 (32.8–33.0)	32.9 (32.8–33.0)	0.008
Mid-arm circumference (cm)	9.83 (9.79–9.87)	9.65 (9.61–9.69)	9.57 (9.53–9.61)	0.03
Triceps skinfold (mm)	4.21 (4.17–4.25)	4.21 (4.19–4.25)	4.18 (4.13–4.23)	0.37
Placental weight (g)	368.9 (366.8–371.0)	350.9 (348.4–353.4)	361.9 (356.6–367.2)	0.08
		Fetching water (28 weeks)		
Term deliveries	(197)	(233)	(180)	
Birth weight (g)	2718 (2692–2744)	2655 (2631–2679)	2606 (2583–2629)	0.0005
Head circumference (cm)	33.2 (33.1–33.3)	33.1 (33.0–33.2)	32.9 (32.8–33.0)	0.01
Mid-arm circumference (cm)	9.78 (9.74–9.82)	9.68 (9.64–9.72)	9.59 (9.56–9.62)	0.03
Triceps skinfold (mm)	4.27 (4.22–4.32)	4.24 (4.22–4.26)	4.07 (4.05–4.09)	0.02
Placental weight (g)	368.3 (366.5–370.1)	362.4 (359.2–365.6)	344.8 (342.5–347.1)	0.005

[a]Values represent adjusted mean (95% CI) values.
[b]*P* after adjusting for direct predictors (sex, parity, gestation, pre-pregnancy weight, weight gain upto 28th week) and indirect predictors (social class, energy and protein intakes).

how differences in pre-pregnant nutritional status affect associations of activity with various neonatal measurements (Table 5). None of the trends were significant for women with weight above 45 kg. In contrast, in the other group (ie < 45 kg) they were significant and negative for head circumference ($P = 0.01$) and placental weight ($P = 0.02$) at the 18th week of gestation and for weight gain ($P = 0.002$) at 28th week of gestation.

Separate analyses were carried out for the subcategories of total activity, 'domestic' and 'other', which included farming activities (Table 6). Domestic activity was inversely associated with birth weight ($P = 0.01$), head circumference ($P = 0.006$), mid arm circumference ($P = 0.05$) and placental weight ($P = 0.03$) only at 28 weeks. However, farming activity at 18 weeks was inversely related to birth weight ($P = 0.02$), head circumference ($P < 0.01$) and mid-arm circumference ($P = 0.03$), and these associations remained significant at 28 weeks.

According to the women's perception, fetching water was the most strenuous activity. At 28 weeks' gestation this single activity was inversely associated with birth weight ($P < 0.001$), head circumference ($P = 0.01$), mid-arm circumference ($P = 0.03$) and placental weight ($P < 0.01$) after adjusting for the confounding variables (Table 6). Inverse association of baby's triceps skinfold thickness was seen ($P = 0.02$) only when activity of fetching water was considered separately, which was not seen for the total activity score. Babies born to women who were not performing this strenuous activity were heavier by 112 g than those born to women who fetched water.

Discussion

We have earlier studied the maternal intakes in relation to birth size among these rural mothers (Rao *et al*, 2001). Maternal energy intakes showed no significant relationships with neonatal size. However, the relationship between maternal nutrition and foetal growth cannot be fully understood by measurement of maternal food intake alone. In communities where women are involved in hard work like farming, consideration of physical activity becomes essential. Direct methods of measuring energy expenditure are expensive and complicated to perform in field conditions, especially in a place like rural India. A large number of alternative approaches have emerged in the literature, including simple categorization of subjects as 'active' and 'non-active' (Washburn *et al*, 1990), 7 day activity recall (Warwick & Macqueen, 1988; Schoeller & Racette, 1990) or 24 h recall (Bernstein *et al*, 1998), using activity questionnaires. In simplifying conventional methods, it is advantageous to take into consideration community peculiarities. We therefore developed a community-specific activity questionnaire. We observed that maternal activity was inversely related to maternal weight gain up to 28 weeks, birth weight, head circumference and mid-arm circumference of the new born.

Focus group discussions provided valuable information about the women's lifestyle and more importantly helped identify simple numerical variables to quantify the intensity of various activities. Our questionnaire was quick and easy to administer and was therefore applicable with minimal disruption to their daily activity. It performed well in validation when compared with minute-to-minute observer-maintained diaries and was able to reveal the differences in activity patterns of farming and non-farming groups.

Our questionnaire revealed that domestic tasks contribute a high proportions of the woman's daily activity and that farming women had a similar domestic workload to that of non-farming women. Times spent in farming activities was comparable to that observed by Bleiberg *et al* (1980) in female farmers from Upper Volta. Time spent in domestic work was, however, considerably more than that reported in other studies, effectively reducing their resting time, which was less than that reported in Upper Volta (Bleiberg *et al*, 1980, 1981). In developing countries excess physical activity may reduce maternal weight gain (Langhoff-Roos *et al*, 1987). In our study, among women in the highest third of activity score, weight gain up to 28 weeks of gestation was significantly lower than that for women in the lowest third.

Weight gain during pregnancy is known to be a strong determinant of birth size and several factors are known to influence weight gain in pregnancy. Pre-pregnancy weight has been shown to be negatively associated with weight gain in poor and undernourished women (Kirchengast & Hartmann, 1998). In women from Sri Lanka, maternal weight gain was inversely associated with parity but positively with income and maternal education (Wanalawansa & Wikramanayake, 1987). Dietary energy intakes were associated with weight gain in pregnant women from Bangla Desh (Tawfeek *et al*, 1999), while restrained eaters were observed to experience significantly lower weight gain compared to their recommended range based on pre-pregnant BMI (Lonway *et al*, 1999). Our data also shows association of weight gain (28th week) with pre-pregnant weight ($P < 0.001$), social class ($P = 0.02$), gestation ($P = 0.03$), parity ($P = 0.003$), energy intake ($P = 0.01$) and protein intake ($P = 0.01$). However, the association between maternal activity and weight gain has been investigated only by few (Dewey & McCrony, 1994; Agarwal *et al*, 2001). Our study showed that maternal activity, especially during mid gestation, had an inverse effect on weight gain even after controlling for all above-mentioned maternal factors.

We observed that maternal activity was not associated with the occurrence of prematurity or stillbirth, or with length of gestation. Some studies offer supportive evidence for this relationship (Naeye & Peters, 1982; Teitelman *et al* 1990), while other do not show a relationship between employment category and pregnancy outcome (Berkowitz *et al*, 1983; Meyer & Daling, 1985; Hartikanen-Sorri & Sorri, 1989). The variation in the result could be partly due to the fact that most studies have not adequately controlled for potentially confounding variables (Dewey & McCrony, 1994) or due to variations in categorisation of jobs as sedentary or active.

Maternal activity was, however, associated with the incidence of low birth weight in our study. In fact, total daily maternal activity at 18 and 28 weeks was negatively associated with almost all the birth measurements except length. Separate analysis for farming activity scores showed similar associations. The odds ratio for delivering a low-birth-weight baby was 1.93 (95% CI 1.47 – 2.39) at the 18th week and 1.63 (95% CI 1.21 – 2.05) at the 28th week among women engaged in farming compared with mothers not doing farming (as the reference category). Lima *et al* (1999) had also reported that heavy agricultural work throughout pregnancy significantly reduced birth weight in low income north-east Brazilian women. In the case of 'domestic' activity, we observed inverse association with birth size only at 28 weeks.

Separate data analysis for women with pre-pregnant weight below and above 45 kg showed that the trends with the activity at 18th week were significant only for head circumference and placental weight and that at the 28th week with weight gain, mainly among the undernourished women (< 45 kg). The adverse effects of excessive or strenuous activity, therefore, are worse in undernourished women. Agarwal *et al* (2001) also have reported that hard activity in undernourished Indian rural women in later pregnancy reduced foetal weight as well as length. In relatively well-nourished US women, moderate exercise has only a small effect on birth weight and in some reports it is associated with higher birth weight, possible because of improved placental blood flow. Strenuous exercise, on the other hand, appears to reduce birth weight in both populations (Clapp, 2000).

The relationship between maternal activity and birth size was strong for one specific activity, namely fetching water, which was perceived as a strenuous activity by rural mothers. Lima *et al* (1999) had also found lower mean birth weights among mothers who fetched water during pregnancy. An adverse influence of prolonged standing on birth outcome and birth size has been reported in Filipino women (Barnes *et al*, 1991). Many investigators (Simpson, 1993; Keith & Luke, 1991) have speculated that strenuous occupations increase uterine contraction and therefore increased the risk of premature birth. The biological basis for harmful effect of heavy work on pregnancy outcome has been identified as it decreases uterine and placental blood flow, thereby reducing the foetal supply of oxygen and nutrients which restricts intra-uterine growth (Lima *et al* 1999). In contrast, leisure time exercise, especially in the second trimester was observed to protect against pre-term delivery (Misra *et al*, 1998; Berkowitz *et al*, 1983).

We found that higher maternal activity scores in earlier as well as later pregnancy were associated with lower mean birth weight, head circumference and mid-arm circumference. The fact that these relationships were even stronger for the strenuous activity of fetching water, points towards the possible effects of certain postures such as bending in this case. Our observation that higher activity in early gestation

resulted in lower placental weight gives some support to this speculation. Physiological consequences of maternal activities involving certain postures thus needs further investigation. Interestingly, measures of neonatal fat were related only to this strenuous activity. A negative association of maternal physical activity with head circumference has not been reported before and raises the question whether this indicates an adverse impact on brain growth.

In conclusion, reduction in maternal physical activity offers significant means for improving neonatal size in this rural Indian community. It is often assumed that pregnant women can economize their energy expenditure by curtailing some activities (Ferro-Luzzi, 1985). However, the extent to which such economization is possible may be limited by social, seasonal or other constraints (Panter-Brick, 1993). For example, in rural India, social beliefs, such as desire for more sleep during pregnancy being interpreted to be a sign of female foetus, or working until late gestation being thought to result in an easy deliver, may create difficulties in reducing maternal activity. Programmes aimed at reducing strenuous workload during pregnancy will, therefore, need to adhere to these community beliefs before it is likely that recommended changes will be adopted. The impact of changes in workload on household food security will also need to be considered.

Our findings demonstrate the strength of FGDs in designing a community-specific activity questionnaire. This may improve the chances of demonstrating a relationship between physical activity and foetal growth when sophisticated methods are not practical. We therefore feel that the approach described in this study has the potential for adaptation for other settings, especially for rural communities in developing countries where women have monotonous lives with clearly defined routine tasks. Finally, the findings in this study suggest that limiting maternal strenuous activities could be a potential intervention for improving birth size in rural Indian community.

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APPENDIX

Maternal Activity Questionnaire (Visit no.)

Date: / /

Total no. of persons in house:
No. of helping hands:
Whether the woman works on farm: yes/no

Name of the subject:
Couple number:

Name of CWW:

Name of village:

Category	Activity	Description	Numeric measures	Score
Resting	Night sleep	Bed time	<6	12
		Wake-up time	6–8	9
		(No. of hours)	≥ 8	6
	Afternoon nap	No. of hours	0	7
			0–1	6
			1–2	5
	Watching TV	No. of programmes	0	7
			1	5.5
		No. of movies in a week	2	5.0
			3	4.5
			≥ 3	4.0
Domestic	Cooking	No. of roties:	<10	2.3
		Morning	10–20	3.0
		Evening	≥ 20	5.5
	Washing clothes	No. of persons	<5	3.5
		Helping hands[a]	5–10	7.0
		Yes/No	≥ 10	8.0
	Washing utensils	No. of persons	<5	3.5
		Helping hands[a]	5–10	7.0
		Yes/No	≥ 10	8.0
	Care of animals	No. of animals:		
		Milking animals: (no.)	Number	Number $\times$ 1
	Fetching of Firewood	Distance: Near/far	Near	3
		Daily/weekly (frequency)[b]	Far	6
	Fetching of Water	Distance: Near/midway/far	Near	2 $\times$ No. trips
		No. of trips/day	Midway	4 $\times$ No. trips
		No. of containers[c]	Far	6 $\times$ No. trips
	Breast feeding	Frequency	Frequency	Frequency $\times$ 0.5
Other	Farming	Distance: Near/far	Near	
		Whole/half day	Whole day	38.5
		Daily/weekly frequency[b]	Half day	20.5
			Far	
			Whole day	41.0
			Half day	23.0
	Labourer construction/sand workers	Whole/half day	Whole day	42
		Daily/weekly frequency[b]	Half day	24
	Stitching:	Daily/weekly frequency[b]	Hours	Hours $\times$ 18
	Machine/manually	(no. of hours)		
	Activities other than farming	Making pappadam/vermicelli	Hours	Hours $\times$ 18
		Daily/weekly frequency[b]		
		(no. of hours)		

[a]In case of helping hand available the activity score is reduced by half.
[b]For activities performed weekly the activity score is multiplied by (respective frequency/7).
[c]In case of more than one container carried at a time the activity score is multiplied by number of containers.