RESEARCH PAPER

Risk of Childhood Obesity in Children With High Birth Weight in a Rural Cohort of Northern India

DINESH KUMAR[1] SEEMA SHARMA,[2] SUNIL KUMAR RAINA[1]

[1]*Department of Community Medicine, Dr Rajendra Prasad Government Medical College, Kangra, Himachal Pradesh.*
[2]*Department of Pediatrics, Dr Rajendra Prasad Government Medical College, Kangra, Himachal Pradesh.*
Correspondence to: Dr Dinesh Kumar, Associate Professor, Department of Community Medicine, Dr Rajendra Prasad Government Medical College, Kangra, Himachal Pradesh. dinesh9809@gmail.com
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Objective: To compare the risk of early childhood obesity (BMI *z*-score of ≥+2SD) among children of more than 7 years of age with a birth weight of more than 3500 g to a birth weight of 2500-2999 g.

Methods: Retrospective birth cohort study among children of 7 to 10 years of age in 22 villages of Himachal Pradesh with not-exposed (birth weight: 2500 to 2999 g) and exposed (> 3500 g) group.

Results: A total of 379 and 377 participants were enrolled in not-exposed and exposed group, respectively. Adjusted relative risk (aRR) between exposed and high BMI (>+2SD) was 4.9 (95%CI: 1.3-17.5) adjusted for mean age, gender, mean years of schooling, consumption of butter, fruits, vegetables, and indoor playing.

Conclusion: High birth weight (>3500 g) increases and normal birth weight decreases the risk of childhood obesity up to five times in rural India.

Keywords: *Body mass index, Catch-up growth, Outcome, Overweight.*

The nutrition in utero influences the risk of developing chronic diseases in adulthood like obesity, metabolic syndrome, and heart diseases [1]. Maternal nutrition and health status affect in utero growth and development reflected by birth weight as an outcome [2]. High birth weight (>3500 g) is associated with morbidities later in life like obesity and associated chronic diseases [3,4]. Adiposity during childhood and adolescence was related to a high level of blood glucose, insulin, and insulin resistance [5]. Apart from in utero nutrition and health, postnatal dietary patterns are also associated with chronic diseases in adulthood.

India observed a rising trend of overweight and obesity in both high and low socioeconomic groups [6]. Childhood overweight and obesity warrants early detection and appropriate intervention for the prevention of chronic diseases. Longitudinal studies and birth cohorts provide evidence for causal relationship between risk factors and chronic diseases in adulthood during antenatal and postnatal period. Indian birth cohorts have been established and followed up to delineate risk factors associated with chronic diseases [7,8]. Similar data of birth cohort in rural areas of northern India are limited [9]. Likewise, other studies from India were hospital-based [10,11], or were done in southern part of India around immediate vicinity of a metropolitan city [12,13]. Cultural and dietary diversity has been observed in rural India for preference of food items, ways of cooking food, and pattern of physical activity.

This study was done to measure the relative risk for early childhood obesity among children more than 7 years of age with a birth weight of more than 3500 g as compared to birth weight of 2500-2999 g in rural northern India.

METHODS

A retrospective cohort study was conducted in 22 villages of a health block of district Una, Himachal Pradesh, covering a population of about 6.9 million with 1.4 million households. The local census by the health administration showed that the health block had a population of 71,416 with 14,107 households. The study was approved by the institutional ethics committee.

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Children with birth weights from 2500 to 2999 g were considered as not-exposed and more than 3500 g as an exposed group. The category of birth weight 3000-3499 g was not included to avoid overlap between high (exposed) and normal (not-exposed) birth weight. Inclusion criteria for recruitment were children who possessed immunization cards mentioning her/his birth weight, born in year 2011-12, a native resident of the village, and with an informed consent of parents. Participants with a known cause for pathological obesity were excluded from the study. Recruitment was carried out in two phases: phase-I (2013-14) and phase-II (2021-22).

Data were collected by a trained field attendant using a pretested questionnaire containing information about background characteristics like gender, socioeconomic status, and schooling, followed by diet and physical activity. Dietary assessment was done using interviewer-administered questionnaire where information regarding consumption of food items like fruits, vegetables, cooking oil, additional butter/ghee while eating, salt while cooking were collected from parents of participants. For the study purpose, indoor physical activities were focused on activities requiring mild exertion like carrom board, ludo, mobile games, playing with toys without physical exertion, etc. whereas, outdoor activities included moderate to severe exertion like cricket, football, race, etc. Udai Pareek scale was used to measure socioeconomic status in both phases of surveys. Anthropometric assessment was done for body height (in meters) without shoes by Seca portable stadiometer (Seca Corporation) with participant's head in the Frankfurt plane, and body weight (in kg) was measured by a portable Tanita SC-240 body composition analyzer (Tanita Corporation) with minimal light clothing and removal of heavy clothing, pocket items, and shoes. Both height and weight were measured twice, and a third time only if the difference in the two values of height and weight was more than 0.5 cm and 0.5 kg, respectively. The final value was an average of the two closest values. Body fat (in percentage) was measured by Tanita SC-240 body composition analyzer and two consecutive measurements were taken. If the difference between the two measurements was more than 2.0%, a third value was taken and an average of two closest values was considered for analysis. Body mass index (BMI) was calculated for every child by dividing weight (in kilograms) by the square of height (in meters). The BMI *z*-score was calculated using age- and sex-specific reference data as per the World Health Organization (WHO) charts. Obesity was defined as BMI *z*-score more than 2 standard deviations (SD).

Sample size assumptions were made with incidence of obesity of 11% in not-exposed and 15% in the exposed group with a relative risk (RR) of 1.7 [18]. The sample size of 748 (374 in each group) was calculated at 5% level of significance and 80% study power.

Statistical analysis: Data were entered in Microsoft Excel and analyzed using the R studio software package (version 3.3.1). Unpaired students *t* test and chi-square test were used to compare for statistical significance for continuous and categorical variables between groups. The relative risk (RR) with a 95% confidence interval (95% CI) was calculated to assess the strength of association between birth weight and childhood obesity. Binary logistic regression analysis was done to observe unadjusted RR and adjusted RR (aRR) of obesity and high birth weight for child age, gender, years of schooling, mean fraction of time spent playing indoors, and consumption of fruits, vegetables, and Ghee/butter. Variables that were significantly different in descriptive analysis. The analysis was also adjusted for potential confounders like the age of the mother and socioeconomic status.

RESULTS

A total of 399 (93 exposed, 306 non-exposed) participants were enrolled in the first phase and 349 (284 exposed, 73 non-exposed) in the second phase. The mothers were the respondent for all participants.

The sociodemographic characteristics and dietary consumption patterns are shown in **Table I**. None of the families in both groups were consuming salt more than 5 grams of salt per person per day. Fried food consumption was observed to be high but the difference was statistically indifferent (**Table I**). The physical activity assessment and anthropometry compared between non-exposed and exposed groups are shown in **Table II**.

The risk ratio (RR) (95% CI) of high BMI (≥+2SD) high birth weight (>3500 g) was 7.0 (2.1-13.8; *P*=0.002), which was statistically significant even when adjusted for age, gender, years of schooling, consumption of butter, daily consumption of fruits and vegetables, and proportion of time played indoor [aRR (95%CI) 4.9 (1.3-17.5); *P*=0.005]. With high BMI, adjusted measures of association was significant only for females [aRR (95%CI) 0.4 (0.1-0.9); *P*=0.037]. Adjusted association was statistically significant between low BMI (≤-2SD) and exposed group [aRR (95%CI) 0.5 (0.4-0.7); *P*<0.001].

DISCUSSION

The current rural birth cohort study observed a significant association of high birth weight (more than 3500 g) than normal birth weight (2500-2999 g) with obesity. The outdoor physical activity assessment was similar in exposed and non-exposed group.

The current study was a birth cohort with an adequate sample size in a rural setting. The non-inclusion of birth weight category of 3000 to 3499 g in the sample avoided the exposure ascertainment bias. Potential covariates like mean fraction of time spent on indoor physical activity, addition of extra *ghee*/butter, and frequency of healthy diet

Table I General Characteristics of Rural Cohort of Himachal Pradesh

Characteristics	*Not exposed (n=379)*	*Exposed (n=377)*	*P value*
Respondent age (y)[a]	33.5 (4.2)	33.9 (4.2)	0.133
Birth weight (kg)[a]	2.6 (0.4)	3.7 (0.2)	<0.001
Age of child (y)[a]	8.6 (1.1)	9.0 (1.0)	<0.001
Child age-group			
7	68 (17.9)	33 (8.8)	<0.001
8	120 (31.7)	89 (23.6)	0.012
9	94 (24.8)	99 (26.3)	0.631
10	97 (25.6)	156 (41.4)	<0.001
Female	194 (51.2)	159 (42.2)	0.012
SES categories			
Lower middle	28 (7.4)	16 (4.2)	0.060
Middle	283 (74.7)	283 (75.1)	0.899
Upper middle	68 (17.9)	78 (20.7)	0.329
School going	377 (99.5)	377 (100.0)	0.169
Public school	293 (77.7)	276 (73.2)	0.150
Duration of education (*y*)[a]	2.7 (1.3)	3.2 (1.2)	<0.001
Breast fed	365 (96.3)	361 (95.8)	0.724
Ghutti/honey	364 (96.0)	361 (95.8)	0.889
Vegetarian	296 (78.1)	303 (80.4)	0.435
Days in a week of fruits consumption	6.3 (1.4)	6.4 (1.3)	0.342
Consumption of fruits/day	1.0 (0.2)	1.1 (0.2)	0.032
Days in a week of vegetables consumption	6.9 (0.4)	7.0 (0.3)	0.029
Consumption of vegetables/day	1.5 (0.5)	1.8 (0.4)	<0.001
Mustard oil as a cooking oil	376 (99.2)	376 (99.7)	0.574
Amount of cooking oil a day (mL)	11.6 (2.9)	11.7 (3.3)	0.599
Amount of butter/ghee day (*g*)[a]	14.2 (33.4)	4.7 (20.4)	<0.001
Amount of salt while cooking/day (g)[a]	7.9 (2.2)	7.6 (2.1)	0.051
Salt > 5 g/d	326 (86.0)	315 (83.6)	0.358
Fried food consumption in a wk			
One	251 (66.2)	250 (66.3)	0.976
Two	114 (30.1)	114 (30.2)	0.976
Number of times fried food/day[a]	2.7 (1.3)	2.8 (1.3)	0.239

Data expressed as no. (%) or [a]mean (SD). Exposed group: birth-weight>3500g; not exposed group: birthweight 2500-2999 g.

Table II Physical Activity and Anthropometric Assessment of Rural Cohort of Himachal Pradesh

Characteristics	*Not exposed (n=379)*	*Exposed (n=377)*	*P value*
Physical activity			
Indoor playing	281 (74.1)	293 (77.7)	0.247
Daily	252 (66.5)	280 (74.3)	0.018
Time (min/d)	123.9 (87.0)	138.9 (82.2)	0.015
Outdoor playing	377 (99.5)	372 (98.7)	0.244
Daily	335 (88.4)	334 (88.6)	0.931
Time (min/d)[a]	157.5 (62.0)	156.6 (51.9)	0.816
Physical sports at School	54 (14.2)	52 (13.8)	0.857
Time (min/d)[a]	30.4 (4.3)	31.7 (5.8)	0.539
Fraction of time played Indoor	38.4 (24.3)	42.5 (24.2)	0.020
Anthropometry,[a]			
Height (cm)	118.8 (9.3)	123.7 (8.3)	<0.001
Weight (kg)	20.3 (4.6)	23.9 (6.0)	<0.001
BMI (kg/m^2)	14.1 (1.9)	15.3 (2.7)	<0.001
Percent of body fat	8.5 (2.4)	10.0 (3.9)	<0.001
BMI *z*-score			
-3SD	98 (25.9)	69 (18.3)	0.011
-2SD	133 (35.1)	106 (28.1)	0.023
-1SD	96 (25.3)	98 (26.0)	0.825
At median	36 (9.5)	49 (13.0)	0.128
+1SD	13 (3.4)	35 (9.3)	<0.001
+2SD	3 (0.8)	16 (4.2)	<0.001
+3SD	0 (0.0)	4 (1.1)	0.040

Data expressed as no. (%) or [a]mean (SD). Exposed group: birth-weight>3500g; not exposed group: birthweight 2500-2999 g.

(vegetables and fruits) were included to assess adjusted measures of association. This study had a few limitations as well like we relied on proxy measures like indoor and outdoor games as a measure of physical activity. Also, failure to collect information on intrauterine growth and maternal nutrition posed a limitation to the measurement of association. Additional information on consumption of baked goods/biscuits, sugar-sweetened beverages, etc. could have been more informative. The education of the mother could have been associated with BMI, but for the study purpose, the socioeconomic status was assumed to be a more useful covariate for BMI after the age of six years.

In a hospital-based study [8], children with high mean birth weight had associated decline in physical growth in their first two years of life [8]. This was different from current study that was community-based and observed children from 7 to 10 years of age. Factors like physical activity and nutrition in later part of childhood were potential confounders in this study. The risk of obesity stayed significant as a measure of association for birth weight category and BMI after adjusting these covariates.

The available evidence from India suggests that the large size at birth and high birth weight predict high fat and lean body mass at the age of 6 years [14], and a high post-natal size at the age of 9 years [15]. Pooled analysis of five birth cohorts in low-and middle-income countries (LMICs) observed a positive significant association between high birth weight and BMI (OR 95% CI: 1.3; 1.2-

WHAT IS ALREADY KNOWN?

- High birth weight observed to be associated with high body mass index (BMI) among children based upon evidence observed mostly form hospital-based and cross-sectional studies.

WHAT THIS STUDY ADDS?

- Study adds to the literature a significant positive association between high birth weight and high BMI among children in rural areas.

1.3) [16]. Similarly, a 12-country cross-sectional study on children from 9-11 years of age observed a positive association between birth weight and BMI. Multivariable adjusted odds (95%CI) for BMI (≥ +2SD) was observed to be 1.5 (1.1-1.9) and 2.1 (1.5-2.9) among children with birth weight 3500-3999 and >4000 g, respectively [4]. A population-based study among children of age from 6 to 10 years observed that the risk of being overweight increases with each unit increase in birth weight for both boys and girls [17]. Low birth weight was associated with a decreased risk for overweight [18], and high birth weight (>4000 g) with a higher risk (1.7-1.8) of childhood obesity [18,19]. However, a recent meta-analysis did not observe any signi-ficant association between weight gain and childhood obesity in children born as small or appropriate for gestation age [20].

Focusing on childhood obesity is important to develop early intervention, as it is associated with adulthood obesity [21]. Childhood obesity is a major public health concern with increased risk for cardio-vascular disease, hypertension, type-2 diabetes mellitus and metabolic syndrome [22,23], with obesity during adolescence [24]. An increase in BMI during adolescence had increased risk of adverse metabolic profile in adulthood [25].

The study presents findings in community-based rural settings of 22 villages in the northern part of India. Most of the community-based birth cohort studies in India were from villages in the vicinity of a metropolitan/large city of Sothern India where the current one is far from any large city. The current study also reflects diversified dietary and physical activity pattern of the northern part of rural India compared to other parts of the world and India.

To conclude, high birth weight (>3500 g) was observed with an increased risk of childhood obesity and decrease the risk of undernutrition (BMI < -2SD) in rural areas among children of 7 to 10 years of age. In the study area, undernutrition was observed more than overnutrition along with consumption of fried foods. The dual burden of under- and over-nutrition could be addressed by observing trend of risk factors with a specific focus on at-risk children. A population-based approach to inter-ventions focusing on healthy foods and physical activity will have the potential to address both under- and over-nutrition.

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