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SIBLING- AND FAMILY-LEVEL CLUSTERING OF UNDERWEIGHT CHILDREN IN NORTHERN INDIA

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Summary. Child undernutrition remains a major child health and developmental issue in low- and middle-income countries. The concentration (clustering) of underweight children among siblings at the family level is known to exist in India. This study examined the extent and covariates of clustering of underweight children at the sibling and family level in Uttar Pradesh, the largest state of northern India. Clustering of underweight (low weight-for-age) children was assessed using data on 7533 under-five children from the National Family Health Survey (NFHS) conducted in 2005–06, analysed using binary logistic and binomial regression models. Related bio-demographic, socioeconomic and health care variables were used as covariates in the models. The odds of being underweight for the index child were about two times higher (OR = 2.34, $p < 0.001$) if any of the siblings within the household was malnourished or underweight. A longer birth interval increased the odds of a child being underweight. The odds of underweight were significantly lower (OR = 0.69, $p < 0.001$) for children born to normal-weight mothers compared with those born to underweight mothers. Similarly, the odds of underweight were significantly lower (OR = 0.49, $p = 0.01$) for children born to educated mothers (high school and above) compared with those born to illiterate mothers. The results of the binomial regression model suggested that the deviations between observed and expected number of children were positive (3.09, 3.78 and 2.71) for 1, 2 and 2+ underweight children within the households of underweight women, indicating the concentration of underweight children among underweight/malnourished mothers. Underweight children were found to be clustered among underweight mothers with multiple underweight siblings. The findings suggest that policy interventions need to focus on underweight mothers with multiple underweight children.

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Introduction

Malnutrition among children continues to be one of the world's most serious child health and child development issues (Deaton & Dreze, 2009). It is a major concern for researchers, academics and policymakers owing to its far reaching consequences, which go beyond the level of individual health and well-being and extends across generations (Martorell & Zongrone, 2012). Evidence suggests that a lack of proper nutrition can increase the risk of childhood morbidity, lead to poor physical and cognitive development resulting in poor school performance, reduced adult size, a reduced capacity to work, loss of productivity and wages, increased health care costs and even initiate the poverty trap (Caulfield *et al.*, 2006; Grantham *et al.*, 2007; Walker *et al.*, 2007; Tarozzi & Mahajan, 2007; Lim *et al.*, 2012; Dewey & Begum, 2011; UNICEF, 2011; Martorell & Zongrone, 2012). It is also known to be associated with poor survival outcomes (Black *et al.*, 2008; Hoddinott *et al.*, 2008).

Undernutrition, which is responsible for nearly half (45%) of child deaths among under-five children worldwide, results in 3.1 million child deaths annually (Black *et al.*, 2013). India has one of the world's highest percentages of malnourished children under the age of five (43%), surpassed only by Bangladesh, Yemen and Timor-Leste (UNICEF, 2008), and this contributes to a high child mortality rate (Bharati *et al.*, 2008; Krishnan *et al.*, 2012). Therefore, an acceleration of policies and programmes to improve the nutritional status of children in the country is required.

The clustering of underweight children, defined as the concentration of underweight children among a subgroup of the population, has received little attention in India. The problem of clustering of underweight children at the sibling and family level has a conceptual similarity to death clustering. For example, studies worldwide indicate that the incidence of childhood deaths is not randomly distributed across families, but, rather, that there is a clustering of death among siblings (Curtis *et al.*, 1993; Guo, 1993; Zenger, 1993; Arulampalam & Bhalotra, 2006; Øyen *et al.*, 2009; Saha & Soest, 2011). In a broad sense, clustering of underweight children, parallel to death clustering, may be expressed as heterogeneity in the risk of underweight children between subgroups of the population. Individual clustering can be understood as the underweight sibling related to another underweight sibling within the same family, while family-level clustering is the concentration of multiple underweight children among a small fraction of underweight mothers in family/ families (Sastry, 1997; Pradhan & Arokiasamy, unpublished data; Omariba *et al.*, 2008).

Studies have shown that clustering of underweight children occurs heavily among the families of poor socioeconomic status (Pande, 2003; Pande & Yazbeck, 2003; Mishra *et al.*, 2004; Pal & Ghosh, 2007; Kumar & Mohanty, 2011a, b); still, the question arises as to why some families experience disproportionately higher levels of clustering of underweight children and not all families. Is genetic frailty an important cause of clustering of underweight children? Previous research on child nutrition in India has mainly dealt with the role of various socioeconomic, maternal and environmental factors in determining the levels and pace of child nutrition transition (Arokiasamy, 2004; Bharati *et al.*, 2008; Subramanyam *et al.*, 2011; Fenske *et al.*, 2013; Kumar & Ram, 2013; Meshram *et al.*, 2014). These studies have identified a number of factors associated with the nutritional status of children in India. However, there has been very little research on clustering of underweight children at the sibling (individual) and family level in the country. Heterogeneity in the prevalence of underweight children also has considerable implications for child nutrition programmes. Developing an understanding of clustering of underweight children can help in formulating intervention policies on heterogeneity in the prevalence of underweight children. Therefore, the objective of this study was to assess the level and pattern of clustering of underweight children at the sibling (individual) and family level in the northern Indian state of Uttar Pradesh.

Methods

Data

Data were from the third (2005–06) National Family Health Survey (NFHS-3). The study focused on Uttar Pradesh, which is the most populous state of northern India with a population of 199 million (Office of the Registrar General and Census Commissioner, India, 2011), i.e. 16% of the total Indian population. The state lags behind in demographic, health and child nutrition indicators compared with all the major states of India. The NFHS-3 collected detailed information on fertility, mortality, family planning and important aspects of nutrition, health and health care from a nationally and state-representative sample. It also collected information on household condition, economic status, household amenities and women's background characteristics, and the complete birth histories of women, including each child's date of birth, sex and survival status. It included health questions for children up to age five years: breast-feeding status, immunization, measurement of height and weight, occurrence of diarrhoea, fever and acute respiratory infection. Also, nutritional information was gathered for all children under age five in the household. Data on childhood health care are available for children born in the last 5 years preceding the survey. The NFHS-3 survey covered a representative sample of 10,026 households for Uttar Pradesh, and 12,183 women in the age group 15–49 years and 11,458 men in the age group 15–54 years were interviewed. The analytical sample size for this study consisted of 7533 children under the age of five.

Outcome variable

Child underweight (low weight-for-age) was the outcome indicator for poor child nutritional status. Underweight, a measure of protein–energy undernutrition, is defined as those children aged 0–59 months with a weight-for-age measurement less than −2SD below the median value of the reference population. Underweight children are estimated based on an international reference population recommended by the World Health Organization (WHO Multicenter Growth Reference Study Group, 2006) and accepted by the Government of India. The WHO standard adopted a prospective approach describing how healthy children should grow. The use of underweight has been supported by previous studies, which have suggested that underweight is a comprehensive indicator of child nutritional status (Deaton & Dreze, 2009).

Explanatory variables

The nutritional status of any previous sibling and that of the mother within the household are the key explanatory variables for the sibling-level clustering of underweight children. The nutritional status of any previous sibling was classified as underweight (no, yes). Body mass index (BMI, kg/m^2) was the indicator of mother's nutrition status. Mother's BMI was calculated from the heights and weights of women aged 15–49 years collected by the NFHS-3 and classified according to the WHO cut-offs, i.e. underweight, BMI < 18.5; normal weight, BMI 18.50–4.99; and overweight/obese; BMI ≥ 25. Women who were pregnant at the time of the survey and women who gave birth during the two months preceding the survey were excluded.

The following bio-demographic, socioeconomic and health care variables were used as predictors: sex (male and female); age of mother at birth of the child, categorized as: <18 years, 18–24 years, 25–34 years and 35–49 years. An important departure is the use of a newly constructed combination variable of birth order and birth interval. Earlier analyses have dealt with the effects of birth order and birth interval separately. However, a recent study by Arokiasamy and Gautam (2008) used a variable combining birth order and birth interval to examine their combined effect on the nutritional status of children (first order; order 2–3 and <24 months; order 2–3 and ≥24 months; order 3+ and <24 months; and order 3+ and ≥24 months). Birth order and birth interval are two closely related bio-demographic variables that often have compounding effects if they are treated separately. The reason is that higher birth order children are generally associated with shorter birth intervals in view of the larger number of births, and vice versa. Therefore, the composite index of birth order with birth interval classification is helpful to determine the relative effects of birth order and birth interval.

The study also included size of child at birth (small, medium, large), duration of breast-feeding (<12 months, 12–18 months, 18 + months), place of residence (urban, rural), religion (Hindu, other), caste (scheduled castes and scheduled tribes (SC/STs), other backward castes (OBCs) and other) and wealth index (low, middle, and high). A household wealth quintile was estimated for each household on the basis of ownership of various assets and housing conditions. Other explanatory variables were: mother's education (no education, up to primary-level completed, up to secondary-level completed, and high school and above), mother's media exposure (no, partial and full), mother's working status (not working, working) and place of delivery (home, government institution and private institution). Delivery assistance (yes or no) is often cited as the most important dimension of health care for infant and child undernutrition because it is highly correlated with antenatal care as well as immunization and care during the first years of life (Bhat *et al.*, unpublished data). Finally, Caesarean birth (yes, no) is also considered as a predictor as it is believed that those children delivered by Caesarean tend to be at higher nutritional risk.

Ethics

The NFHS survey was conducted under the scientific and administrative supervision of the International Institute for Population Sciences, Mumbai, India, an autonomous institute under the Ministry of Health and Family Welfare, Government of India. The institute conducted an independent ethics review of the NFHS protocol. Data collection procedures were also approved by the ORC Macro (Calverton, MD, USA) institutional review board. Oral informed consent for the interview/survey and measurements was obtained by interviewers from the participating mothers (IIPS, 2007). The analysis was carried out anonymously, using publicly available secondary data and with no identifiable information on the survey participants, for which ethical approval is not required.

Statistical analysis

The sibling-level clustering of underweight children was examined using binary logistic modelling (Koening *et al.*, 1990; Lantz *et al.*, 1992; Miller *et al.*, 1992; Gribble, 1993; Omariba *et al.*, 2008); that is, to determine whether an underweight child in a family is related to any previous underweight sibling in the same family after controlling for bio-demographic, socioeconomic and health care variables. In the regression model, the nutritional status of any previous sibling within the family was incorporated as a variable to assess sibling-related clustering of underweight children in the form of the index child. It is also important to recognize that the incidence of clustering of underweight children can occur in the reverse way; that is, in all cases of multiple underweight siblings, an underweight child can either be preceded by an older sibling or followed by another underweight younger sibling in the family. In essence, this suggests that multiple underweight siblings are more likely to be clustered in the same family.

The logistic regression model is commonly used when the independent variables include both numerical and nominal measures and the outcome variables (dependent variables) are binary or dichotomous. The advantage of logistic regression analysis is that it requires no assumption about the distribution of the independent variables. Another advantage is that the regression coefficient can be interpreted in terms of odds ratios. The logistic regression model is commonly estimated by a maximum likelihood function. For the dependent variables, the logistic model takes the following form:

$$\text{Logit}\, p = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + \ \ldots \ + b_kx_k + e_k$$

$$\text{Logit}\, p/1 - p = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + \ \ldots \ + b_kx_k + e_k$$

where, b_0 is the intercept and b_1, b_2, b_3, …, b_k represent the coefficients of each of the predictor variables in the model, while e_k is an error term. The natural logarithms of the odds of the outcomes are represented by e_k.

The family-level clustering of underweight children was assessed using the binomial distribution model (E. Ronsmans, unpublished data; Zaba & David, 1994; Gupta, 1997; Pradhan & Arokiasamy, unpublished data). Family-level clustering refers to the concentration of underweight children among a small fraction of underweight mothers. It is an extended form of individual-level clustering among siblings. The binomial model is considered suitable to see whether the distribution of the number of underweight children for women follows a certain form. It assesses the extent of heterogeneity or clustering of underweight children, which is measured as the difference between observed and expected number of underweight children by bio-demographic and socioeconomic risk factor classification. This approach estimates the distribution of failure (underweight children) to be expected in a given number of trials with a constant probability of failure. It generates the expected distribution of underweight children in a group of live-born children who are subject to a given nutritional risk. An excess of women with a different number of underweight children over the expected number is taken to indicate clustering.

Under the null hypothesis of no clustering, the distribution of women by the number of underweight children is binomial and the probability of observing k underweight children for women with family size n is given by:

$$P(X=k)=(n!/k!(n-k)!)p^k(1-p)^{n-k}0 \leq k \leq n.$$

Accordingly, the probability of observing k underweight children for parity 1 women is given by:

$$P(X=k)=(1!/k!(1-k)!)p^k(1-p)^{1-k}k=0,\ 1.$$

The probability of observing 0 (no) underweight children for parity 1 women is given by:

$$P(X=0)=p^0(1-p)^1=q,$$

and the probability of observing 1 underweight child for women of parity 1 is:

$$P(X=1)=p^1(1-p)^0=p.$$

Similarly, the probability of observing k underweight children for women of parity j can be estimated. Further, the expected number of women experiencing j underweight children is:

$$E(j)=\Sigma w_i P(X=j/i)\,/\,\Sigma w_i.$$

The average number of underweight children among women with n children is np and the variance is $np(1-p)$. The parameter p is estimated from the observed proportion of underweight children among all live births of women of a given age. If the null hypothesis (H_0) is violated, the departure from the chance distribution can be assessed by a χ^2 test, in which the observed distribution of underweight children is compared with the expected distribution under H_0. Rejection of H_0 implies the presence of clustering, but it does not distinguish between different causes. The binomial distribution was fitted to the data using the observed proportion of children who were underweight for all the women within each group of equal family size n and the expected number of women by number of underweight children was later combined for all women. Statistical analysis was performed with the help of statistical software STATA 10 SE (Stata Corporation, 2007).

Results

Background characteristics of study sample

Table 1 presents the descriptive statistics of the study sample of 7533 children. About half of the children (49%) were born to mothers aged 18–24 years, while only 12% children were born to mothers aged less than 18 years and 35–49 years. About a quarter of the children were of birth order 2–3/≥24 months birth interval, and another quarter were birth order 3+/≥24 months birth interval. Only 11% of children were of birth order 3+/<24 months birth interval. About two-thirds (64%) were of normal size at birth, while one in five was of small size at birth. Only 30% were breast-fed for 18+ months. About 36% of the mothers were underweight and 6% were overweight/obese. The majority of the children were from Hindu communities (80%). Similarly, rural children constituted the majority (80%) of the sample. Half belonged to Other Backward Castes (OBCs). More than a quarter (27%) were from Scheduled Castes and Scheduled Tribes

Table 1. Percentage distribution of sample children[a] by bio-demographic, socioeconomic status and health care variables, Indian NFHS, 2005–06

Variables	*n*	%
Bio-demographic variables		
Sex of child		
Male	3885	51.6
Female	3646	48.4
Age of mother at birth of child		
<18 years	476	6.3
18–24 years	3700	49.1
25–34 years	2903	38.5
35–49 years	454	6.1
Birth order/birth interval		
First order	1650	21.9
Order 2–3/ <24 months	897	11.9
Order 2–3/ ≥24 months	1951	25.9
Order 3 + / <24 months	877	11.7
Order 3 + / ≥24 months	2148	28.6
Size of child at birth		
Small	1552	20.6
Medium	4830	64.2
Large	1145	15.2
Mother's BMI		
Underweight	2523	36.6
Normal	3985	57.7
Overweight/obese	396	5.7
Socioeconomic variables		
Place of residence		
Urban	1519	20.2
Rural	6013	79.8
Religion		
Hindu	5913	78.6
Other	1607	21.4
Caste		
SC/ST	2049	27.2
OBC	3792	50.4
Other	1689	22.4
Wealth/income		
Low	4160	55.2
Middle	1501	19.9
High	1871	24.9
Mother's education		
No education	4975	66.0
Up to primary	940	12.5
Up to secondary	746	9.9
High school and above	871	11.6
Mother's media exposure		
No	2685	35.7

Table 1. *Continued*

Variables	*n*	%
Partial	2880	38.3
Full	1963	26.0
Mother's work status		
Not working	5767	76.8
Working	1746	23.2
Health care variables		
Place of delivery		
Home	5971	79.4
Government institution	495	6.6
Private institution	1055	14.0
Delivery assistance		
No	5478	72.8
Yes	2050	27.2
Caesarean birth		
No	7201	95.6
Yes	329	4.4
N	7533	100.0

[a]Children born five years preceding the survey.

(SC/STs), while 22% children belonged to the 'other' category. More than half of the children (55%) were from low socioeconomic status households, while only a quarter (24%) were from high socioeconomic status households. Two-thirds (66%) were born to illiterate mothers. More than a third of the mothers (35%) did not have any media exposure. A quarter of children (23%) were born to working mothers. Most of the children (80%) were born at home, and around three-quarters (72%) were born without assistance at the time of delivery.

Sibling-level clustering of underweight children: logistic model estimates

Table 2 presents the results of logistic regression model analysis, which shows the effect of any previous sibling's nutritional status on the nutritional status of the index child after controlling for bio-demographic, socioeconomic and health care variables. The results reveal that the odds of being underweight for the index child were about two times higher if any of the previous siblings within the household were underweight. After controlling for birth order, if birth interval was longer the odds of child underweight was lower. Children who were of medium and large size at birth had significantly lower odds of being underweight (59% and 47%, respectively) compared with children who were of small size at birth. Similarly, the odds of being underweight were significantly lower (by 31%) for children who were born to normal-weight mothers compared with the children of underweight mothers. Children of 'other' caste group were significantly less likely (by 11%) to be underweight than children of scheduled castes and scheduled tribes. The odds of being underweight were significantly lower (by 43%) for children who were born in high socioeconomic status households compared with children born in low

Table 2. Binary logistic model analysis for clustering of underweight children by bio-demographic, socioeconomic and health care variables

Variables	Underweight (%)	Odds Ratio (95% CI)
Nutritional status of any previous sibling (individual clustering)		
Not underweight (Ref.)	—	
Underweight	—	2.34*** (1.80–3.04)
Bio-demographic variables		
Sex of the child		
Male (Ref.)	41.8	
Female	42.5	0.87 (0.67–1.12)
Age of mother at birth of child		
<18 years (Ref.)	43.5	
18–24 years	39.9	0.60 (0.20–1.74)
25–34 years	43.5	0.74 (0.25–2.24)
35–49 years	47.1	1.39** (0.11–2.36)
Birth order/birth interval		
First order (Ref.)	36.3	
Order 2–3/<24 months	40.9	1.25 (0.92–1.31)
Order 2–3/≥24 months	38.5	0.91** (0.87–1.20)
Order 3+/<24 months	44.8	1.51 (0.79–2.18)
Order 3+/≥24 months	47.9	1.23** (0.68–1.89)
Size of child at birth		
Small (Ref.)	54.3	
Medium	38.2	0.41*** (0.30–0.55)
Large	40.6	0.53*** (0.34–0.83)
Mother's BMI		
Underweight (Ref.)	51.8	
Normal	38.1	0.69*** (0.52–0.90)
Overweight/obese	25.2	0.82 (0.46–1.47)
Socioeconomic variables		
Place of residence		
Urban (Ref.)	33.6	
Rural	44.2	1.14 (0.80–1.63)
Religion		
Hindu (Ref.)	42.5	
Other	40.5	1.07 (0.76–1.49)
Caste		
SC/ST (Ref.)	48.7	
OBC	43.6	0.89 (0.65–1.21)
Other	31.7	0.87 (0.58–1.31)
Wealth index		
Low (Ref.)	49.6	
Middle	40.7	0.75 (0.53–1.06)
High	28.3	0.57** (0.37–0.88)
Mother's education		
No education (Ref.)	48.4	
Up to primary	34.6	0.73 (0.49–1.09)
Up to secondary	37.1	0.71 (0.45–1.13)
High school and above	23.6	0.49** (0.29–0.85)

Table 2. *Continued*

Variables	Underweight (%)	Odds Ratio (95% CI)
Mother's media exposure		
No (Ref.)	49.4	
Partial	43.3	0.95 (0.70–1.30)
Full	31.7	0.97 (0.65–1.42)
Mother's work status		
Not working (Ref.)	40.1	
Working	48.9	1.31** (0.96–1.79)
Health care variables		
Place of delivery		
Home (Ref.)	45.1	
Government institution	32.4	1.09 (0.52–2.30)
Private institution	31.0	1.41 (0.75–2.64)
Delivery assistance		
No (Ref.)	46.5	
Yes	31.3	0.83 (0.50–1.38)
Caesarean birth		
No (Ref.)	43.0	
Yes	27.1	0.69 (0.28–1.66)

***$p \leq 0.01$; **$p < 0.05$.

socioeconomic status households. The odds of being underweight were significantly lower (by 51%) for children who were born to educated mothers (high school and above) compared with children born to illiterate mothers. On the other hand, the odds of being underweight were significantly higher (by 31%) for the children of working mothers compared with the children of non-working mothers.

Family-level clustering of underweight children: binomial model estimates

Table 3 shows the observed and expected numbers of underweight children by bio-demographic (maternal) and socioeconomic variables. Significance was taken at $p < 0.05$. A positive deviation from the expected was seen if the mother's age at the birth of her child was 35+, but the opposite was found if it was either 15–19 or 20–34 years. A positive deviation from the expected was found for 1, 2 and 2+ underweight children for malnourished/underweight women, which was reversed for normal and overweight/obese women. An increasing positive deviation for women with 2 and 2+ underweight children points to the fact that heterogeneity in underweight increases with parity. A higher than expected proportion of women with a pregnancy interval of <24 months was observed with 1, 2 and 2+ underweight children (deviations of 2.25, 3.47, 2.18).

A positive deviation (1.93, 1.91 and 1.12) was observed for 1, 2 and 2 + underweight children residing in rural areas as well as for the children of SC/ST mothers. A positive deviation (3.04, 2.72 and 1.68) was found for 1, 2 and 2+ underweight

Table 3. Difference in the observed and expected number of women with different levels of underweight children under the binomial model

Variables	Deviation from expected number of underweight children (0–59 months)			
	0	1	2	2+
Bio-demographic variables				
Mother's age				
15–19	15.41	−7.33	−6.11	−2.61
20–34	7.13	−4.48	−4.93	−1.32
35–49	−12.60	5.65	5.17	3.58
Mother's BMI				
Underweight	−5.87	3.09	3.78	2.71
Normal	−5.02	−2.06	−3.99	−2.01
Overweight/obese	3.02	−4.77	−4.07	−1.29
Parity				
1	−0.91	3.21	—	—
2	1.44	4.54	2.39	—
3	1.91	1.92	3.22	1.18
>3	5.66	−6.58	4.30	2.22
Birth interval				
<24 months	−2.73	2.25	3.47	2.18
≥24 months	3.59	−1.32	−0.45	−0.93
Socioeconomic variables				
Place of residence				
Urban	7.71	−4.80	−2.01	−1.17
Rural	−3.45	1.93	1.91	1.12
Religion				
Hindu	2.90	−3.26	−2.56	−2.29
Other	3.21	−4.22	−3.31	−2.01
Caste				
SC/ST	−3.41	1.86	1.32	1.21
OBC	1.33	1.01	3.21	−0.78
Other	1.92	−0.76	−1.22	−0.67
Wealth index				
Low	−7.49	3.04	2.72	1.68
Middle	2.39	0.92	−1.28	−0.78
High	17.82	−11.85	−6.09	−3.29
Mother's education				
No education	−9.12	4.34	3.61	2.59
Up to primary	4.90	−2.31	−2.22	−1.95
Up to	19.33	−10.56	−7.89	−3.42
High school and above	28.91	−15.43	−6.74	−4.92

children of low socioeconomic status households, which was reversed for the children of medium and high socioeconomic status households. A positive deviation (4.34, 3.61 and 2.59) was observed for 1, 2, and 2+ underweight children of illiterate mothers.

Discussion

This study examined the extent and pattern of clustering of underweight children at the sibling and family level using NFHS-3 (2005–06) data. The results of the binary logistic regression and binomial distribution models showed that underweight children were clustered among households with underweight siblings, higher parity mothers, mothers aged 35–49 years, children born with shorter birth intervals, those of small size of child at birth, breast-feeding for less than 12 months, underweight mothers, children of SC/ST mothers, low socioeconomic status households, as well as among the illiterate mothers. The prevalence of underweight was much higher for the index child if their siblings were underweight – a clear demonstration of the likelihood of an underweight child being clustered with one or more underweight younger or older sibling; these findings are similar to those of previous studies (Lalou & Mbacke, 1992; Sereebutra *et al.*, 2006). The possible mechanism for such a relationship may be understood through the 'dilution effect': as the number of children increases, family resources available to an individual child decrease (Beenstock & Sturdy, 1990; Bronte-Tinkew & DeJong, 2004). The family resources may be either financial, which determine the purchase of health goods, services and food (Doan & Bisharat, 1990; Berman *et al.*, 1994; Behrman, 1995, 1998) or the availability of time to care for a child (Blake, 1981; Horton, 1988; UNICEF, 2013).

Parity is a core determinant of underweight in children, and the clustering of underweight children. This study found a significant association between mother's parity and the clustering of underweight children. Thus, a heavy concentration of underweight children in general, and multiple underweight children in particular, was demonstrated for mothers who were underweight, illiterate, from low socioeconomic status households, SC/ST, aged 35–49 years and high parity, and for children with shorter birth intervals. On the other hand, educated mothers and those of high socioeconomic status had a lower than expected risk of having underweight children, as well as multiple underweight children. A higher household socioeconomic status explains a major part of the positive deviations for no risk of underweight children and low risks of multiple underweight children. The deviation varied from −9.12 to 28.91 by education of women and from −7.49 to 17.82 by wealth/income for women with no underweight child.

The results further revealed that for the same order of birth, if the birth interval is longer the odds of being underweight are lower. This finding concurs with that of a previous study, which indicated that the impact of birth interval on the nutritional status of children is stronger than that of birth order (Zottarelli *et al.*, 2007). Underweight children were found to be concentrated among underweight mothers. This supports the hypothesis that there is greater likelihood of multiple underweight children among underweight mothers. One of the possible reasons may be that women of low BMI status give birth to the maximum number of low-birth-weight babies, which ultimately leads to more underweight children. This finding has been supported by previous studies (Pojda & Kelley, 2000; Varela-Silva *et al.*, 2009; Dekker *et al.*, 2010; Subramanian *et al.*, 2010). Underweight children were found to be clustered among low socioeconomic status households, as found by previous studies (Mazumdar, 2010; Subramanyam *et al.*, 2010; Pathak & Singh, 2011). Mother's education was found to be a robust determinant of the nutritional status of children. Underweight children were found to be extremely clustered among illiterate mothers, and this is in line with the findings of previous studies (Norhayati *et al*., 1997; Delpeuch *et al*., 2000; Semba *et al.*, 2008; Van de Poel *et al.*, 2008; Subramanyam *et al*., 2010). This may be because illiterate mothers are not only less aware of the necessities and ways and means of providing nutritionally balanced food to children, but are also economically incapable of providing such nutrition-rich food (Bharati *et al.*, 2007).

However, the findings of this study should be interpreted with caution in light of certain limitations. The factors responsible for the clustering of underweight children could be bio-demographic, socioeconomic or health related. However, regardless of socioeconomic background, the extent of heterogeneity that certain mothers have with regard to children – for example, certain mothers have no underweight children while others do, and certain mothers have more than one underweight child – cannot be explained by these factors alone. It might have been due to the genetic frailty of mothers passed on to their children, which needs to be investigated in future research.

In conclusion, this study found that underweight children were clustered among mothers with multiple underweight siblings, and this was more pronounced among underweight mothers. Overall, it is mother's underweight status, in conjunction with their poor socioeconomic status, that drives the nutritional deprivation of children and multiple siblings. Policy intervention needs to focus on the children of households with multiple underweight children. The clustering of underweight children is mediated by a variety of interconnected factors that include, amongst others, size of the child at birth, birth interval, sex composition of siblings, mother's parity and their poor nutritional status. Understanding such interconnected mechanisms is a subject for further investigation. The children of underweight and uneducated mothers from poor socioeconomic status households need specially focused intervention to improve their nutritional status and well-being. This study strongly recommends further research and advocacy to ensure that appropriate child health and nutrition programmes are included in the national child health and development policy agenda of India.

References

Arokiasamy, P. (2004) Regional patterns of sex bias and excess female child mortality in India. *Population* **59**(6), 833–863.

Arokiasamy, P. & Gautam, A. (2008) Neonatal mortality in the empowered action group states of India: trends and determinants. *Journal of Biosocial Science* **40**(2), 183–201.

Arulampalam, W. & Bhalotra, S. (2006) Sibling death clustering in India, state dependence versus unobserved heterogeneity. *Journal of the Royal Statistical Society, Series A* **169**, 829–848.

Beenstock, M. & Sturdy, P. (1990) The determinants of infant mortality in regional India. *World Development* **18**(3), 443–453.

Behrman, J. R. (1995) Household behavior, preschool child health and nutrition, and the role of information. In Pinstrup-Andersen, P., Pelletier, D. & Alderman, H. (eds) *Child Growth and Nutrition in Developing Countries: Priorities for Action*. Cornell University Press, New York.

Behrman, J. R. (1998) Intra-household allocation of resources, is there a gender bias? In United Nations (ed.) *Too Young to Die: Genes or Gender?* United Nations, New York.

Berman, P., Kendall, C. & Bhattacharya, K. (1994) The household production of health, integrating social science perspectives on micro-level health determinants. *Social Science & Medicine* **38**(2), 205–215.

Bharati, S., Pal, M. & Bharati, P. (2008) Determinants of nutritional status of pre-school children in India. *Journal of Biosocial Science* **40**(6), 801–814.

Bharati, S., Pal, M., Bhattacharya, B. N. & Bharati, P. (2007) Prevalence and causes of chronic energy deficiency and obesity of women in India. *Human Biology* **79**, 395–412.

Black, R. E., Allen, L. H., Bhutta, Z. A., Caulfield, L. E., de Onis, M., Ezzati, M. *et al.* (2008) Maternal and child undernutrition, global and regional exposures and health consequences. *The Lancet* **371**, 243–260.

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P. *et al.* (2013) Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet* **382**, 427–451.

Blake, J. (1981) Family size and the quality of children. *Demography* **18**, 621–662.

Bronte-Tinkew, J. & DeJong, G. (2004) Children's nutrition in Jamaica: do households structure and household economic resource matter? *Social Science & Medicine* **58**, 499–514.

Caulfield, L. E., Richard, S. A., Rivera, J. A., Musgrove, P. & Black, R. E. (2006) Stunting, wasting and micronutrient deficiency disorders. In Jamison, D. T., Breman, J. G., Measham, A. R., Alleyne, G., Claeson, M. *et al*. (eds) *Disease Control Priorities in Developing Countries*. Oxford University Press, New York, pp. 551–567.

Curtis, S. L., Diamond, I. & McDonald, J. W. (1993) Birth interval and family effects on postneonatal mortality in Brazil. *Demography* **30**(1), 33–43.

Deaton, A. & Dreze, J. (2009) Food and nutrition in India: facts and interpretation. *Economic & Political Weekly* **XLIV**(7), 42e65.

Dekker, L. H, Mora-Plazas, M., Marín, C., Baylin, A. & Villamor, E. (2010) Stunting associated with poor socioeconomic and maternal nutrition status and respiratory morbidity in Colombian schoolchildren. *Food Nutrition Bulletin* **31**(2), 242–250.

Delpeuch, F., Traissac, P., Martin-Prével, Y., Massamba, J. P. & Maire, B. (2000) Economic crisis and malnutrition: socioeconomic determinants of anthropometric status of preschool children and their mothers in an African urban area. *Public Health Nutrition* **3**(1), 39–47.

Dewey, K. G. & Begum, K. (2011) Long-term consequences of stunting in early life. *Maternal & Child Nutrition* (Supplement 3), 5–18.

Doan, R. M. & Bisharat, L. (1990) Female autonomy and child nutritional status: the extended family residential unit in Amman, Jordan. *Social Science & Medicine* **31**(7), 783–789.

Fenske, N., Burns, J., Hothorn, T. & Rehfuess, E. A. (2013) Understanding child stunting in India: a comprehensive analysis of socio-economic, nutritional and environmental determinants using additive quantile regression. *PLoS One* **8**(11), e78692.

Grantham-McGregor, S., Cheung, Y. B., Cueto, S., Glewwe, P., Richter, L. & Strupp, B. (2007) Child development in developing countries. 1. Developmental potential in the first 5 years for children in developing countries. *The Lancet* **369**, 60–70.

Gribble, J. N. (1993) Birth intervals, gestational age, and low birth weight: are the relationships confounded? *Population Studies* **47**(1), 133–146.

Guo, G. (1993) Use of sibling data to estimate family mortality effects in Guatemala. *Demography* **30**(1), 15–32.

Gupta, M. D. (1997) Socio-economic status and clustering of child deaths in rural Punjab. *Population Studies* **51**, 191–202.

Hoddinott, J., Maluccio, J. A., Behrman, J. R., Flores, R. & Martorell, R. (2008) Effect of a nutrition intervention during early childhood on economic productivity in Guatemalan adults. *The Lancet* **371**, 411–416.

Horton, S. (1988) Birth order and child nutritional status: evidence from the Philippines. *Economic Development and Cultural Change* **36**, 341–353.

IIPS & Macro International (2007) *National Family Health Survey (NFHS-3), 2005–2006, India*, Volume II. International Institute for Population Sciences, Mumbai.

Koening, M. A., Philips, J. F., Campbell, O. M. & D'Souza, S. (1990) Birth intervals and childhood mortality in Bangladesh. *Demography* **27**, 251–265.

Krishnan, A., Nawi, N. G., Kapoor, S. K., Pandav, C. S. & Byass, P. (2012) Temporal trends and gender differentials in causes of childhood deaths at Ballabgarh, India – need for revisiting child survival strategies. *BMC Public Health* **12**, 555.

Kumar, A. & Mohanty, S. K. (2011a) Socio-economic differentials in childhood immunization in India, 1992–2006. *Journal of Population Research* **28**(4), 301–324.

Kumar, A. & Mohanty, S. K. (2011b) State of child health among poor and non-poor in urban India. *GENUS* **LXVII**(1), 1–19.

Kumar, A. & Ram, F. (2013) Influence of family structure on child health: evidence from India. *Journal of Biosocial Science* **45**(5), 577–599.

Lalou, R. & Mbacke, C. (1992) The micro consequences of high fertility on child malnutrition in Mali. In Lloyd, C. (ed.) *Fertility, Family Size and Structure*. Population Council, New York.

Lantz, P., Parting, M. & Palloni, A. (1992) Using retrospective surveys for estimating the effects of breast-feeding and child spacing on infant and child mortality. *Population Studies* **46**, 121–139.

Lim, S. S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K. *et al.* (2012) A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet* **380**, 2224–2260.

Martorell, R. & Zongrone, A. (2012) Intergenerational influences on child growth and undernutrition. *Paediatric and Perinatal Epidemiology* (Supplement 1), 302–314.

Mazumdar, S. (2010) Determinants of inequality in child malnutrition in India. *Asian Population Studies* **6**(3), 307–333.

Meshram, I. I., Balakrishna, N., Arlappa, N., Rao, K. M., Laxmaiah, A. & Brahmam, G. N. (2014) Prevalence of undernutrition, its determinants, and seasonal variation among tribal preschool children of Odisha state, India. *Asia-Pacific Journal of Public Health* **26**(5), 470–480.

Miller, J. E., Trussell, J., Pebley, A. R. & Vaughan, B. (1992) Birth spacing and child mortality in Bangladesh and the Philippines. *Demography* **29**, 305–318.

Mishra, V., Roy, T. K. & Retherford, R. D. (2004) Sex differentials in childhood feeding, health care, and nutritional status in India. *Population and Development Review* **30**(2), 269–295.

Norhayati, M., Noorhayati, M. I. & Mohammad, C. G. (1997) Malnutrition and its risk factors among children 1–7 years old in rural Malyasian communities. *Asia Pacific Journal of Clinical Nutrition* **6**, 260–264.

Office of the Registrar General and Census Commissioner, India (2011) *Provisional Population Totals Paper 1 of 2011 India Series-1*. Government of India, New Delhi.

Omariba, W. R., Rajulton, F. & Beaujot, R. (2008) Correlated mortality of siblings in Kenya: the role of state dependence. *Demographic Research* **18**(11), 311–336.

Pal, P. & Ghosh, J. (2007) Inequality in India: a survey of recent trends. *Department of Economic and Social Affairs Working Paper* No. 45. United Nations, New York.

Pande, R. P. (2003) Selective gender differences in childhood nutrition and immunization in rural India: the role of siblings. *Demography* **40**(3), 395–418.

Pande, R. P. & Yazbeck, A. S. (2003) What's in a country average? Wealth, gender, and regional inequalities in immunization in India. *Social Science & Medicine* **57**, 2075–2088.

Pathak, P. K. & Singh, A. (2011) Trends in malnutrition among children in India: growing inequalities across different economic groups. *Social Science & Medicine* **73**(4), 576–585.

Pojda, J. & Kelley, L. (2000) *Low Birthweight*. ACC/SCN Nutrition Policy Paper No. 18. WHO, Geneva.

Øyen, N., Boyd, H. A, Poulsen, G., Wohlfahrt, J. & Melbye, M. (2009) The clustering of premature deaths in families. *Epidemiology* **20**(5), 757–765.

Saha, U. R. & Soest, A. V. (2011) Infant death clustering in families: magnitude, causes, and the influence of better health services, Bangladesh 1982–2005. *Population Studies* **65**(3), 273–287.

Sastry, N. (1997) Family-level clustering of childhood mortality risk in Northeast Brazil. *Population Studies* **51**(3), 245–261.

Semba, R. D., de Pee, S., Sun, K., Sari, M., Akhter, N. ***et al.*** (2008) Effect of parental formal education on risk of child stunting in Indonesia and Bangladesh: a cross-sectional study. *The Lancet* **371**, 322–328.

Sereebutra, P., Solomon, N., Aliyu, M. H. & Jolly, P. E. (2006) Socio-economic and environmental predictors of childhood stunting in rural Guatemala. *Nutrition Research* **26**(2), 65–70.

Stata Corporation (2007) *Stata Statistical Software, Release 10*. StataCorp LP, College Station, TX.

Subramanian, S. V., Ackerson, L. K. & Smith, G. D. (2010) Parental BMI and childhood undernutrition in India: an assessment of intrauterine influence. *Pediatrics* **126**(3), e663–e671.

Subramanyam, M. A., Kawachi, I., Berkman, L. F. & Subramanian, S. V. (2010) Socio-economic inequalities in childhood undernutrition in India: analyzing trends between 1992 and 2005. *PLoS One* **5**(6), e11392.

Subramanyam, M. A., Kawachi, I., Berkman, L. F. & Subramanian, S. V. (2011) Is economic growth associated with reduction in child undernutrition in India? *PLoS Medicine* **8**(3), e1000424.

Tarozzi, A. & Mahajan, A. (2007) Child nutrition in India in the nineties. *Economic Development and Cultural Change* **55**(3), 441–486.

UNICEF (2008) *The State of the World's Children 2008*. New York, USA.

UNICEF (2011) *Levels & Trends in Child Mortality: Report 2011*. New York, USA.

UNICEF (2013) *Improving Child Nutrition. The Achievable Imperative for Global Progress*. New York, USA.

Van de Poel, E., Hosseinpoor, A. R., Speybroeck, N., Van Ourti, T. & Vega, J. (2008) Socioeconomic inequality in malnutrition in developing countries. *Bulletin World Health Organization* **86**(4), 282–291.

Varela-Silva, M. I., Azcorra, H., Dickinson, F., Bogin, B. & Frisancho, A. R. (2009) Influence of maternal stature, pregnancy age, and infant birth weight on growth during childhood in Yucatan, Mexico: a test of the intergenerational effects hypothesis. *American Journal of Human Biology* **121**(5), 657–663.

Walker, S. P., Wachs, T. D., Gardner, J. M., Lozoff, B., Wasserman, G. A., Pollitt, E. ***et al.*** (2007) Child development in developing countries. 2. Child developmental-risk factors for adverse outcomes in developing countries. *The Lancet* **369**, 145–157.

WHO Multicenter Growth Reference Study Group (2006) *WHO Child Growth Standards*. WHO, Geneva.

Zaba, B. & David, P. (1994) The concentration of childhood mortality risk in populations. *Centre for Population Studies, London School of Hygiene and Tropical Medicine, Research Paper*, pp. 94–103.

Zenger, E. (1993) Siblings' neonatal mortality risks and birth spacing in Bangladesh. *Demography* **30**(3), 477–488.

Zottarelli, L. K., Sunil, T. S. & Rajaram, S. (2007) Influence of parental and socioeconomic factors on stunting in children under 5 years in Egypt. *East Mediterranean Health Journal* **13**(6), 1330–1342.