

Stunting and severe stunting among infants in India: the role of delayed introduction of complementary foods and community and household factors

Mansi Vijaybhai Dhami^a, Felix Akpojene Ogbo ^{a,b}, Uchechukwu L. Osuagwu^c, Zino Ugboma^d and Kingsley E. Agho ^{a,e}

^aTranslational Health Research Institute (THRI), School of Medicine, Western Sydney University, Campbelltown Campus, Penrith, Australia; ^bGeneral Practice Unit, Prescot Specialist Medical Centre, Makurdi, Nigeria; ^cSchool of Medicine | Diabetes Obesity and Metabolism Translational Research Unit (DOMTRU), Macarthur Clinical School, Campbelltown, Australia; ^dFaculty of Law, Baze University, Abuja, Nigeria; ^eSchool of Science and Health, Western Sydney University, Campbelltown Campus, Penrith, Australia

ABSTRACT

Background: Delayed introduction of solid, semi-solid or soft foods (complementary feeding) and associated factors are related to stunting and severe stunting among children in many low- and middle-income countries. In India, however, there is limited evidence on the relationship between delayed complementary feeding and associated factors with stunting and severe stunting to advocate for policy interventions.

Objectives: The present study investigated the relationship between delayed complementary feeding and associated factors with stunting and severe stunting among infants aged 6–8 months in India.

Methods: Survey data on 13,548 infants aged 6–8 months were obtained from the 2015–16 National Family Health Survey in India. Logistic regression (Generalized Linear Latent and Mixed Models [GLLAMM] with a logit link and binomial family) models that adjusted for clustering and sampling weights were used to investigate the relationship between delayed complementary feeding and associated factors (community, household, maternal, child and health service factors) with stunting and severe stunting among infants aged 6–8 months in India.

Results: The prevalence of stunting and severe stunting was 22.0% (95% CI: 21.0–23.7%) and 10.0% (95% CI: 9.0–11.0%) among infants aged 6–8 months who received no complementary foods, respectively. Delayed introduction of solid, semi-solid or soft foods was associated with stunting (adjusted Odds ratios [aOR] = 1.24, 95% CI: 1.09–1.41) and severe stunting (aOR = 1.21, 95% CI: 1.01–1.45) among infants aged 6–8 months. High maternal education (secondary or higher education) and household wealth (middle, richer and richest) were protective against stunting and severe stunting.

Conclusion: Delayed introduction of complementary foods and associated factors were related to stunting and severe stunting among infants aged 6–8 months in India. Reducing the proportion of infants who are stunted in India would require comprehensive national nutrition policy actions that target the sub-population of mothers with no schooling and limited resources.

ARTICLE HISTORY

Received 20 November 2018
Accepted 21 June 2019

RESPONSIBLE EDITOR

Stig Wall, Umeå University, Sweden

KEYWORDS

Stunting; delayed introduction of complementary feeding; India; infants; nutrition

Background

The introduction of solid, semi-solid or soft foods (complementary feeding) is essential for the infant's optimal growth and development, particularly after the first six months of life as breast milk alone is no longer sufficient for maintaining the infant's nutritional and developmental needs [1]. In India, a recent report has indicated that only about 55% of mothers introduced complementary foods to their infants as recommended by the World Health Organization (WHO, that is, the introduction of complementary food to infants aged 6–8 months) [2]. Inappropriate introduction of complementary foods is associated with adverse child health outcomes and can have subsequent effects across the life span [2–4]. Past studies from India have suggested that lower maternal education, poor

socioeconomic status and limited health service access were associated with the inappropriate introduction of complementary foods [2,5,6].

Stunting, defined as height-for-age less than minus two standard deviations of the WHO Child Growth Standards median [7], is prevalent in many low- and middle-income countries (LMICs), including India. In those countries, under-five mortality is also prevalent, and malnutrition (i.e. stunting, wasting and underweight) may be attributable to more than half of those deaths, highlighting the substantial negative impact of inappropriate nutrition among children in those contexts [8]. Although recent evidence indicates that the prevalence of stunting has reduced from 198 million in 2000 to 151 million in 2017, approximately one in four children younger than 5 years were stunted globally in

CONTACT Felix Akpojene Ogbo  f.ogbo@westernsydney.edu.au  Translational Health Research Institute (THRI), School of Medicine, Western Sydney University, Campbelltown Campus, Penrith, NSW 2571, Australia

© 2019 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

2017 [8]. In South Asia, approximately 38% of children younger than 5 years were stunted in 2017 [9], in which India was the largest contributor (48%), followed by Pakistan (43%), Bangladesh (41%), Nepal (41%) and Sri Lanka (19%) [7].

In India, evidence from discrete subnational studies suggested that stunting was associated with an array of factors. These factors included delayed initiation of breastfeeding [10], colostrum deprivation [11], delayed introduction of complementary foods [11], female gender [12], maternal underweight [13], a lack or fewer than recommended antenatal visit [14], higher birth order [12], lower socioeconomic status [13,15], a lack or lower maternal education [13,15] and a lack of potable water and poor hygiene [16], as well as household food competition [13,17]. Additionally, a national level study conducted in India also indicated that age-appropriate infant and young child feeding practices were associated with child undernutrition [18]. However, while studies from India have reported a high prevalence of delayed introduction of complementary foods [19], as well as a high proportion of stunting among children younger than five years [20,21], there has been no nationally representative studies that investigated the association between delayed introduction of solid, semi-solid or soft foods and associated factors with stunting in India, nor has there been a documented prevalence of stunting by severity. Nationally representative studies in this context are needed as they provide complete information, as well as highlight the characteristics of childhood stunting to match the country's policy directives and interest [22]. Therefore, evidence on the association between the delayed introduction of complementary foods and stunting would be essential to nutrition experts and public health planners in India to help refine current infant and young child (IYCF) policies and interventions to high-priority groups in order to reduce the proportion of stunted children in India.

The present study aimed to investigate the relationship between the delayed introduction of solid, semi-solid or soft foods and stunting and severe stunting among infants aged 6–8 months in India. The study also reports on the association between other potential factors (community, socio-demographic and health service factors) and stunting by severity to provide a broader picture of factors influencing stunting to inform targeted interventions in one of the world's largest population.

Methods

Data sources

The study used data from the 2015–16 National Family Health Survey (NFHS-4) conducted by International

Institute for Population Sciences, Mumbai, India. The Ministry of Health and Family Welfare (MoHFW), Government of India supervised the survey, and technical assistance was provided by the United States Inner City Fund (ICF) International, Maryland. Information on socio-demographic and household status, as well as IYCF data, were collected from a sample of women aged between 15 and 49 years. The response rates were high during data collection, ranging 94.0–99.6% in various states and territories in India, including Andhra Pradesh (94.0%), West Bengal (94.0%) and Bihar (99.6%) [15].

In the survey, approximately 572,000 Indian households were selected from 249,454,252 population using the 2011 census frame that covered each of the 29 states and 7 union territories of India. Each district had a sample based on its size for producing a reliable indicator. Rural areas were administered with a two-stage sampling design. In these areas, the first stage involved the villages (selected based on the probability proportional to the size of the sample) being designated as Primary Sampling Units (PSUs) and the second stage involved a random selection of 22 households. A similar two-stage sampling approach was used in urban areas. The first stage involved the selection of Census Enumeration Blocks (CEBs) and the second stage involved a random selection of 22 CEBs [23]. Additional information on the sampling procedure is provided in the national report of the NFHS-4 [24]. In this study, the analyses were restricted to the youngest living children aged 6–8 months, living with the respondent (women aged 15–49 years) to reduce the potential impact of recall bias, consistent with previously published studies [3,25], yielding a total weighted sample of 13,548 infants.

Outcome variables

The primary outcome variables were stunting and severe stunting, consistent with previously published studies [26–28]. Evidence from LMICs suggests that there is an increased risk of child morbidity and mortality with a varied degree of stunting [29–31] with implication for policy interventions [32]. The outcome variables were expressed as a dichotomous variable. Stunting- was categorised as '0' [not stunted (height-for-age (HAZ) greater than -2 standard deviations (SD)] of the WHO Child Growth Standards median and '1' [stunted (HAZ less than -2 SD)]. Severe stunting was expressed as '0' [not severely stunted (HAZ greater than -3 SD)] and '1' [severely stunted (HAZ less than -3 SD)] [33].

Exposure variables

The main exposure variable was the delayed introduction of solid, semi-solid or soft foods among

infants aged 6–8 months. This was defined in accordance with the WHO guidelines for assessing IYCF practices in the population [1]. In this study, infants aged 6–8 months who appropriately received solid, semi-solid or soft foods were coded as '1', and those who did not receive similar foods were coded as '0' (delayed introduction of complementary foods).

Based on previously published studies [14,28,34–36] and data availability, associated factors examined in the study included community, household, maternal, child and health service factors. Community-level characteristics included geographical regions and area of residence was categorised as urban or rural. For the family or household level attributes, individuals' marital status and household wealth index [15] were considered. The household wealth index was classified into five quintiles (categories) by the IIPS and ICF International, which included poorest, poorer, middle, rich and richest. Maternal characteristics included variables such as age, education and literacy level [37], body mass index (BMI) [37], employment status, type of caste or tribe and religion. Individual factors of the child included sex [15], birth order [14], the perceived size of the baby at birth [36], and the preceding birth interval. Furthermore, the number of visits to ANCs (none, 1 to 3 visits or ≥ 4 visits) [14], place of delivery (health facility or home), type of delivery assistance such as presence of a health care professional or a traditional birth attendant and mode of delivery (caesarean or non-caesarean) were also considered.

Statistical analysis

In this study, we used STATA/MP version 14 (Stata Corp, College Station, TX, USA) to conduct all statistical analyses. The 'svy' command was employed to allow for adjustments for the cluster-sampling design and weight to calculate frequencies and prevalence. We first conducted frequency tabulations for all exposure variables, and this was followed by univariate analyses that independently examined the relationship between stunting and severe stunting by the delayed introduction of complementary foods. Multivariate analyses were used to examine the relationship between the delayed introduction of complementary foods and stunting and severe stunting using logistic regression Generalized Linear Latent and Mixed Models (GLLAMM) with a logit link and binomial family. As part of the multivariate analyses, a staged modelling technique was employed.

As a process of multivariate modelling technique, all community and household level factors were first entered into the baseline multivariate model with the elimination process to remove statistically non-significant variables (Model 1). In the next stage, maternal factors were examined with model 1,

variables that were significantly associated with the outcomes were retained as (Model 2). Next, child factors were assessed with model 2 and associated factors were retained as (Model 3). In the fourth modelling stage, a similar procedure was used for health services factors and those variables with p-values <0.05 were retained as (Model 4). In the final model (Model 5), the exposure variable (delayed introduction of complementary foods) was examined with those variables significant in Model 4 and elimination process were used to retain those variables with p-values <0.05 . In the final model,

we tested the interaction between complementary feeding and mother education and household wealth index and reported any co-linearity. The odds ratios with 95% confidence intervals were calculated to assess the association between the independent variables with the study outcomes.

Results

Characteristics of the study population

In the study population, many mothers (58.5%) had secondary and higher education, 13.3% had primary education, and 28.1% had no education. The majority (89.2%) of the mothers were unemployed and most women resided in rural areas compared to the urban areas (72.8% versus 27.1%) [Table 1].

Relationship between the delayed introduction of complementary foods and stunting and severe stunting

The prevalence of stunting was 22.0% (95% confidence interval [95% CI]: 21.0–23.7%) and that for severe stunting was 10.0% (95% CI: 9.0–11.0%) among infants aged 6–8 months who received no complementary foods in India [Figure 1]. The study indicated that delayed introduction of solid, semi-solid or soft foods was associated with both stunting (aOR = 1.24, 95% CI: 1.09–1.41) and severe stunting (aOR = 1.21, 95% CI: 1.01–1.45) [Table 2].

Other factors associated with stunting and severe stunting

The household wealth index was a significant predictor of stunting among infants such that infants who were born to the richest, richer, middle and poorer households were less likely to be stunted compared to those born in poorest households (aOR = 0.46, 95% CI: 0.36–0.61 for richest, aOR = 0.54, 95% CI: 0.43–0.68 for richer, aOR = 0.66, 95% CI: 0.54–0.80 for middle and aOR = 0.83, 95% CI: 0.70–0.98 for poorer households) [Table 2]. Mothers who had secondary or higher education were less likely to have

Table 1. Characteristics of the study population (N = 13,548).

Characteristic	n	%
Community level factors		
Geographical region		
North	1746	12.8
South	2288	16.8
East	3536	26.1
West	1684	12.4
Central	3910	28.8
North East	384	2.8
Residence		
Urban	3683	27.1
Rural	9863	72.8
Household characteristics		
Household wealth index		
Poorest	3366	24.8
Poorer	3012	22.2
Middle	2712	20.0
Richer	2439	18.0
Richest	2017	14.8
Source of drinking water		
Improved	11411	84.23
Not improved	2136	15.77
Maternal Characteristics		
Mother's age		
15–19 years	923	6.8
20–34 years	11958	88.2
35–49 years	666	4.9
Mother's education		
No education	3808	28.1
Primary	1803	13.3
Secondary and higher	7936	58.5
Employment		
Did not work	2116	15.6
Worked	254	1.8
Mother's religion		
Hindu	10726	79.1
Muslim	2148	15.8
Christianity and others	673	4.9
Type of Caste or tribe		
Scheduled Caste	3101	22.8
Scheduled tribe	1376	10.1
Other backward class	5921	43.7
Others ⁵	3148	23.2
Child Characteristics		
Sex of baby		
Male	7312	53.9
Female	6235	46.0
Perceived Size of baby		
Small	1728	12.7
Average	8960	66.1
Large	2695	19.8
Health Service characteristics		
Antenatal clinic visits		
None	2228	16.4
1–3	4576	33.7
4+	6588	48.6
Mode of delivery		
Non-Caesarean	10961	80.9
Caesarean	2586	19.1
Study outcomes		
Stunting (< 2 SD)		
Not stunted	9143	67.4
Stunted	2325	17.1
Severe stunting (< 3 SD)		
Not severely stunted	10430	76.9
Severely stunted	1038	7.6

n = weighted counts; ⁵ = no caste or tribe/don't know)

babies who were stunted compared to those with no schooling (aOR = 0.81, 95% CI: 0.69–0.94). The mothers' type of caste was associated with stunting such that infants from scheduled tribe or others (no caste or tribe) were less likely to be stunted compared to those in scheduled caste (aOR = 0.79, 95% CI: 0.64–0.96 for scheduled tribe and aOR = 0.79, 95%

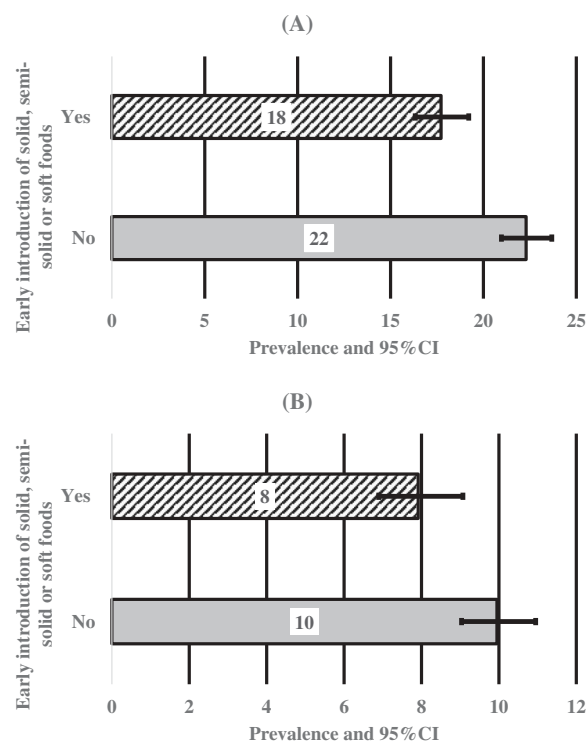


Figure 1. Prevalence and 95% Confidence Intervals (CI) of stunting (A) and severe stunting (B) by the introduction of solid, semi-solid or soft foods among infants aged 6–8 months in India.

CI: 0.64–0.96 for others). Large or average sized babies were less likely to be stunted compared to infants who were perceived to be small (aOR = 0.50, 95% CI: 0.40–0.64 for large-sized babies and aOR = 0.62, 95% CI: 0.51–0.74 for average sized babies, respectively) [Table 2].

Multivariate analyses assessing factors associated with severe stunting indicated that female infants were less likely to be severely stunted compared to male infants (aOR = 0.67, 95% CI: 0.56–0.80) [Table 3]. Infants whose mothers perceived to be large and average-sized infants were less likely to be severely stunted compared to small sized infants (aOR = 0.63, 95% CI: 0.46–0.85 and aOR = 0.64, 95% CI: 0.51–0.82 for large and average-sized infants, respectively). Lower household wealth index was related to severe stunting compared to higher household wealth index (aOR = 0.70, 95% CI: 0.55–0.90 for middle, aOR = 0.68, 95% CI: 0.51–0.92 for the richer, aOR = 0.52, 95% CI: 0.37–0.74 for the richest) [Table 3]. Infants who were delivered by caesarian section were less likely to be severely stunted compared to those who were delivered vaginally (aOR = 0.69, 95% CI: 0.50–0.95).

Overall, the interaction between complementary feeding and household wealth index was significant for both stunting and severe stunting. In contrast, there were no significant associations between the delayed introduction of complementary foods and mother education with stunting and severe stunting.

Table 2. Factors associated with stunting among infants aged 6–8 months in India, NFHS-4.

Variables	OR [95% CI]	P-value	aOR ^y [95% CI]	P-value
Introduction of solid, semi-solid or soft foods				
Early introduction of foods	1.00		1.00	
Delayed introduction of foods	1.33 (1.18, 1.51)	<0.001	1.24(1.09, 1.41)	0.001
Household Wealth Index				
Poorest	1.00		1.00	
Poorer	0.76(0.65, 0.89)	0.001	0.83(0.70, 0.98) *	0.029
Middle	0.58(0.49, 0.70)	<0.001	0.66(0.54, 0.80) *	<0.001
Richer	0.47(0.38, 0.58)	<0.001	0.54(0.43, 0.68) *	<0.001
Richest	0.38(0.30, 0.48)	<0.001	0.46(0.36, 0.61) *	<0.001
Mother's education				
No education	1.00		1.00	
Primary	0.80(0.66,0.98)	0.031	0.90(0.74, 1.09)	0.295
Secondary and higher	0.58(0.50, 0.66)	<0.001	0.81(0.69, 0.94) *	0.008
Type of Caste or tribe				
Scheduled Caste	1.00		1.00	
Scheduled tribe	0.88(0.72, 1.07)	0.217	0.79(0.64, 0.96) *	0.024
Other backward class (OBC)	0.85(0.73, 0.99)	0.04	0.90(0.77, 1.05)	0.196
Others ⁵	0.65(0.53, 0.79)	<0.001	0.79(0.64, 0.97) *	0.031
Sex of baby				
Male	1.00		1.00	
Female	0.78(0.69, 0.88)	<0.001	0.75(0.66, 0.84) *	<0.001
Birth order				
Firstborn	1.00		1.00	
2 nd –4 th	1.13(0.992, 1.307)	0.063	1.02(0.89, 1.18)	0.727
5 or more	1.68(1.35, 2.08)	<0.001	1.17(0.92, 1.48)	0.186
Perceived Size of baby				
Small	1.00		1.00	
Average	0.60(0.50, 0.72)	<0.001	0.62(0.51, 0.74) *	<0.001
Large	0.48(0.38, 0.61)	<0.001	0.50(0.40, 0.64) *	<0.001

*Statistically significant (95% confidence intervals and $P < 0.05$) study variables from multivariate models are shown. Multivariate models adjusted for child, maternal, household, health service and community factors. OR: odds ratios; aOR: adjusted odds ratios; 95%CI: 95% confidence interval; ⁵ = no caste or tribe/don't know

Table 3. Factors associated with severe stunting among infants aged 6–8 months in India, NFHS-4.

Variables	OR [95% CI]	P-value	aOR [95% CI]	P-value
Introduction of solid, semi-solid or soft foods				
Early introduction of foods	1.00		1.00	
Delayed introduction of foods	1.29 (1.07, 1.54)	0.007	1.21(1.01, 1.45)	0.039
Household Wealth Index				
Poorest	1.00		1.00	
Poorer	0.78(0.62, 0.99)	0.047	0.81(0.64, 1.03)	0.093
Middle	0.67(0.52, 0.85)	0.001	0.70(0.55, 0.90) *	0.006
Richer	0.63(0.47, 0.84)	0.002	0.68(0.51, 0.92) *	0.012
Richest	0.46(0.32, 0.67)	<0.001	0.52(0.37,0.74) *	<0.001
Sex of baby				
Male	1.00		1.00	
Female	0.69(0.57, 0.82)	<0.001	0.67(0.56, 0.80) *	<0.001
Perceived size of baby				
Small	1.00		1.00	
Average	0.63(0.50, 0.80)	<0.001	0.64(0.51, 0.82) *	<0.001
Large	0.60(0.44, 0.81)	0.001	0.63(0.46, 0.85) *	0.003
Mode of delivery				
Non-caesarian	1.00		1.00	
Caesarian	0.59(0.43, 0.82)	0.001	0.69(0.50, 0.95) *	0.023

*Statistically significant (95% confidence intervals and $P < 0.05$) study variables from multivariate models are shown. Multivariate models adjusted for child, maternal, household, health service and community factors. OR: odds ratios; aOR: adjusted odds ratios; 95%CI: 95% confidence interval

Discussion

The present study suggested that 22.0% and 10.0% of infants aged 6–8 months who had delayed complementary foods were stunted and severely stunted, respectively. Delayed introduction of solid, semi-solid or soft foods was associated with stunting and severe stunting among infants aged 6–8 months in India. Factors associated with a reduced risk of stunting included higher maternal education, belonging to wealthier households, and perceived size (average or large) of the baby at birth. Female sex, higher

household wealth, perceived size (large and average) of the baby at birth and caesarian births were associated with a reduced risk of severe stunting in India.

Globally, an estimated 3 million deaths among children younger than five years were due to malnutrition in 2018 [8], reflecting the burden of stunting, wasting and underweight among young children. In India, a recent study indicated that about 0.9 million under-5 deaths occurred in 2016, with malnutrition (including stunting) playing an important role [38]. In India, previous small-scale studies have estimated the

prevalence of stunting to be as high as 48% [39] and 51% [10], possibly reflecting variations and/or limitations in sample size or the 'true' burden of stunting in those populations. India is a country with significant variations in socio-economic status, culture and geographical boundaries, with factors such as maternal education and household wealth playing an influential role in infant nutritional status, including stunting.

Our study suggested that delayed introduction of solid, semi-solid or soft foods was associated with stunting and severe stunting in infants aged 6–8 months. This finding is consistent with studies from regional India [10,39], which indicated that children whose mothers delayed the introduction of complementary foods were more likely to be stunted. In contrast, a study conducted in Bangladesh found that the age of introducing complementary feeding was not associated with the linear growth of the infant [40]. However, the study concluded that optimal complementary feeding practice might play an important role in reducing the prevalence of stunting in the second year of a child's life [40]. Evidence suggests that inadequate nutrition in the form of delayed complementary feeding compromises the quality and/or quantity of infant's dietary requirements which in turn results in stunting [41]. Specifically, inappropriate complementary feeding (from poor hygiene and *mycotoxicity* due to incorrect food handling and storage) can result in subclinical infections which alter the gut microbial flora and may result in a change in the barrier mechanism of the gut, with subsequent negative impacts on optimal nutrient absorption [41]. This potentially reflects one of the rationales for why the WHO recommends that the introduction of complementary foods to infants should be timely, adequate, safe and appropriate [42].

The present study found that higher maternal education was associated with a reduced risk of stunting in infants aged 6–8 months. This finding is consistent with previous studies from Kenya [43], and China [35], which demonstrated that higher maternal education was associated with a reduced risk of stunting in infants. Additionally, a study from Pakistan also indicated that stunting in children younger than five years was influenced by maternal education [44] and the socioeconomic status of the household [45]. These findings underpin the notion that educated mothers may have more information in implementing optimal IYCF messages [46–49]. In addition, studies from Ethiopia [50], South Africa [51] and sub-Saharan Africa [50,52] have demonstrated that high maternal education was associated with the introduction of complementary foods that may lead to better childhood nutritional status and healthy infants. Conversely, studies from Lebanon [53] and Nepal [54] suggested that the level of a mother's education did not influence childhood stunting. The observed differences in the findings may be due to methodological differences, including the use of

a limited sample size or the non-adjustment for potential cofactors [53,54].

Globally, socioeconomic variabilities have been shown to be one of the social determinants of health as it influences not only childhood nutrition but also the health of the family [34,51,55,56]. Our study indicated that children from the lowest household wealth category were more likely to be stunted compared to those from middle, richer and rich households. Similarly, studies conducted in South Africa [51], Kenya [55], Philippines [56] and sub-Saharan Africa [34] demonstrated that lower household wealth categories were associated with an increased risk of stunting compared to richer households. Household income influences the nutrition of the family and the baby, due to insufficient intake of food and decreased ability to practise safe-food handling hygiene or to appropriately store food, making it one of the major factors affecting the level of stunting in many LMICs [34,51,55,56].

In the Demographic and Health Survey project, the perceived birth size of the baby serves as a proxy for birth weight, where a mother's perceived size of her baby plays an important role in determining the nutritional status of the child in the short- and long-term [57]. In the present study, babies perceived to be of small birth size by their mothers were more likely to be stunted compared to those perceived to be large or average, consistent with evidence from Tanzania [58], Nigeria [59], Burundi [28], Bangladesh [60], Nepal [61] and regional India [36]. These studies indicated that perceived baby size (small) was associated with childhood stunting. This finding suggests that there may be benefits in combining appropriate antenatal care services and maternal education programs regarding optimal complementary feeding practices so that babies born in India can grow up to lead healthy lives.

Policy implications of the study findings

The present study has policy implications for researchers, health education officers, health administrators, health professionals and the public in India. The study provides nationally representative evidence on the relationship between the delayed introduction of complementary foods and associated factors with stunting and severe stunting among infants aged 6–8 months. In India, recent reports suggest that the Indian government support for essential maternal and child health (MCH) interventions is strong and increasing, demonstrable by various new MCH programs. These include the HealthPhone [62], Integrated Child Development Scheme (ICDS) [63], Prime Minister's Overarching Scheme for Holistic Nourishment (POSHAN) Abhiyaan [64] and cash transfer schemes such as Janani Suraksha Yojna (JSY) [65]. The improvement in the nutritional status of Indian children, maternal health and parental education is at

the core of these programs. Specifically, these initiatives have financial incentives and access to food supplementation from the government to mothers and their households. For example, the Government of India's HealthPhone program focuses on a holistic approach to the health of infants, children, adolescent girls and the mothers to educate and promote optimal complementary feeding practices with a view to reducing adverse health outcomes such as stunting [62,64]. The Indian government aims to reduce stunting by 40% by the year 2025 in line with the WHO global nutrition targets 2025 to improve child health and well-being [66]. Additionally, the partnership for Water Sanitation and Hygiene (WASH) between the United States Agency for International Development and the Government of India would also have great benefit for child's health and development in India [67].

Maternal autonomy and socioeconomic status have been associated with positive childhood nutritional outcomes in various national and sub-national studies [68–71]. Our study suggests that interventions and financial incentives that encourage the appropriate introduction of complementary foods to infants of vulnerable mothers, including those with no education and limited resources, may be helpful in reducing stunting by the year 2025 in India. Despite the current MCH interventions in India, it is unclear whether these services have substantially impacted infant nutritional outcomes in the country. Further studies that evaluate the impact of these initiatives in relation to optimal infant feeding practices may be needed to facilitate timely refinement of those programs to high-priority populations and also allow for efficient use of resources.

Strengths and limitations of the study

The study had a number of methodological limitations which should be taken into account when interpreting the results. First, the potential effect of recall bias may have affected the study results as the survey information were self-reported by mothers through interviews. However, we restricted our analyses to the youngest living children aged 6–8 months, living with the respondent (woman aged 15–49 years) to reduce the potential impact of recall bias, consistent with previous studies [3,25,72]. Second, there could have been a misclassification in the exposures (e.g. number of ANC visits by mothers), which could result in the underestimation or overestimation of the observed associations. Third, our inability to analyse all potential cofactors (such as food insecurity, culture relating to and/or local variations of infant feeding) may have affected the association between the exposure variables and the study outcomes. Lastly, the cross-sectional nature of the data used – collected simultaneously – makes it impossible to establish a temporal association between the exposures and the outcomes.

Despite these limitations, the major strength is in the use of the most recent nationally representative data (NFHS-4). The NFHS-4 data are potentially more nationally representative of the Indian population compared to the previous NFHS due to the large sample population and methodology employed [10,39]. Since the current results are more recent and better represents the current Indian population, the evidence is potentially more beneficial to guide national policy interventions relating to stunting prevention. Also, because the data were collected by trained health personnel who used a validated questionnaire, the study findings are less likely to be influenced by measurement bias. Finally, selection bias is also unlikely to affect the study findings given the high response rates in the survey (94.0–99.6%) [10,39,57].

Conclusion

The study indicated that delayed introduction of complementary foods was associated with stunting and severe stunting among Indian infants aged 6–8 months. Other modifiable factors associated with stunting and severe stunting included a lack of maternal education and lower household wealth. National nutrition efforts need to be context-specific in India to improve the introduction of complementary foods among infants (particularly those aged 6–8 months), while also considering the modifiable maternal vulnerabilities such as poor household wealth and no maternal schooling.

Acknowledgments

This study formed part of the first author's Higher Degree Research studies at the Translational Health Research Institute, School of Medicine, Western Sydney University, Australia. We acknowledge the time and effort of Dr Elizabeth O'Connor in proofreading the entire revised manuscript. The authors are grateful to Measure DHS, ICF International, Rockville, Maryland, USA for providing the data for the analysis.

Author contributions

MVD contributed to the study conceptualisation, contributed to the data analysis, compiled and interpreted the results, drafted the initial manuscript and critically revised the manuscript as submitted. FAO contributed to the study conceptualisation, provided guidance on data analysis, contributed to drafting the original manuscript, interpreted data and critically revised the manuscript as submitted. ULO contributed to drafting the original manuscript, interpreted data and critically revised the manuscript as submitted. ZU interpreted data and critically revised the manuscript as submitted. KEA contributed to the study conceptualisation, provided guidance on data analysis, contributed to the data interpretation and critically revised the manuscript as submitted. All authors read and approved the final manuscript as submitted.

Disclosure statement

No potential conflict of interest was reported by the authors.

Ethics and consent

The Ethics Review Board at the International Institute for Population Sciences, Mumbai, India granted Measure DHS/ICF International ethical approvals before the surveys were conducted, with written informed consent obtained from participants during the surveys. The questionnaires used for the survey were reviewed and approved by ICF International Institutional Review Board (IRB) to ensure they met the United States Department of Health and Human Services regulations for the protection of human participants, as well as the host country's IRB, to ensure compliance with national laws. The first author sought approval from Measure DHS and permission was granted for this use.

Funding information

This study received no specific grant from any funding agency in public, commercial or not-for-profit sectors. Felix Ogbo received early career research funding grant from the Office of the Deputy Vice Chancellor (Research and Innovation), Western Sydney University [0001].

Paper context

There is limited evidence on the broader impact of delayed introduction of complementary foods in India. This paper examined the relationship between the delayed introduction of complementary foods and stunting and severe stunting among infants aged 6–8 months in India. Our study revealed that delayed introduction of complementary foods was associated with stunting and severe stunting among infants in India and supports calls for improvements in national childhood nutrition policy actions.

ORCID

Felix Akpojene Ogbo  <http://orcid.org/0000-0001-5159-2315>

Kingsley E. Agho  <http://orcid.org/0000-0003-4111-3207>

References

- [1] World Health Organization. Indicators for assessing infant and young child feeding practices - Part 1 - definitions. 2008. Available from: http://apps.who.int/iris/bitstream/handle/10665/43895/9789241596664_eng.pdf?sequence=1&isAllowed=y
- [2] Patel A, Pusdekar Y, Badhoniya N, et al. Determinants of inappropriate complementary feeding practices in young children in India: secondary analysis of national family health survey 2005–2006. *Maternal Child Nutr.* 2012;8:28.
- [3] Ogbo FA, Agho K, Ogeleka P, et al. Infant feeding practices and diarrhoea in sub-Saharan African countries with high diarrhoea mortality. *PloS One.* 2017;12:e0171792.
- [4] Ogbo FAPA, Idoko J, Claudio F, et al. Diarrhoea and suboptimal feeding practices in Nigeria: evidence from the national household surveys. *Paediatr Perinat Epidemiol.* 2016;30:346–355.
- [5] Rao S, Swathi P, Unnikrishnan B, et al. Study of complementary feeding practices among mothers of children aged six months to two years - A study from coastal south India. *Australas Med J.* 2011;4:252.
- [6] Senarath U, Agho KE, Akram D, et al. Comparisons of complementary feeding indicators and associated factors in children aged 6–23 months across five South Asian countries. *Matern Child Nutr.* 2012;8:89–106.
- [7] UNICEF South Asia. Stop stunting -in South Asia -a common narrative on maternal and child nutrition-UNICEF South Asia-strategy 2014–2017. 2015. Available from: http://stopstunting.org/wp-content/uploads/2016/05/StopStuntinginSouthAsia-ACommonNarrativeonMaternalandChildNutrition_UNICEF.pdf
- [8] UNICEF. Malnutrition 2018. Available from: <https://data.unicef.org/topic/nutrition/malnutrition/>
- [9] UNICEF South Asia. Stop stunting-South Asia headline results-2017 progress report. 2017. Available from: <http://www.unicefrosa-progressreport.org/stopstunting.html>
- [10] Meshram II, Arlappa N, Balakrishna N, et al. Trends in the prevalence of undernutrition, nutrient & food intake and predictors of undernutrition among under five year tribal children in India. *Asia Pac J Clin Nutr.* 2012;21:568–576.
- [11] Mishra K, Kumar P, Basu S, et al. Risk factors for severe acute malnutrition in children below 5 y of age in India: A case-control study. *Indian J Pediatr.* 2014;81:762–765.
- [12] Priyanka R, Vincent V, Jini M, et al. An assessment of the nutritional status of underfive children in a rural area of Thrissur district, Kerala, India. *Int J Community Med Public Health.* 2016;3:3479–3486.
- [13] Aguayo VM, Nair R, Badgaiyan N, et al. Determinants of stunting and poor linear growth in children under 2 years of age in India: an in-depth analysis of Maharashtra's comprehensive nutrition survey. *Matern Child Nutr.* 2016;12:121–140.
- [14] Sharma AK, Baig VN, Yadav AK, et al. Prevalence and risk factors for stunting among tribal under-five children at South-West, Rajasthan, India. *Natl J Community Med.* 2016;7:461–467.
- [15] Fenske N, Burns J, Hothorn T, et al. Understanding child stunting in India: a comprehensive analysis of socio-economic, nutritional and environmental determinants using additive quantile regression. *PloS One.* 2013;8:e78692.
- [16] Rah JH, Cronin AA, Badgaiyan B, et al. Household sanitation and personal hygiene practices are associated with child stunting in rural India: a cross-sectional analysis of surveys. *BMJ Open.* 2015;5:e005180.
- [17] Chandrasekhar S, Aguayo VM, Krishna V, et al. Household food insecurity and children's dietary diversity and nutrition in India. Evidence from the comprehensive nutrition survey in Maharashtra. *Matern Child Nutr.* 2017;13 Suppl 2. Epub 2017/10/17. PubMed PMID: 29032621. DOI:10.1111/mcn.12447
- [18] Menon P, Bamezai A, Subandoro A, et al. Age-appropriate infant and young child feeding practices are associated with child nutrition in India: insights from nationally representative data. *Matern Child Nutr.* 2015;11:73–87.

- [19] Sinhababu A, Mukhopadhyay DK, Panja TK, et al. Infant- and young child-feeding practices in Bankura District, West Bengal, India. *J Health Popul Nutr.* 2010;28:294–299. PubMed PMID: 518039218; 20635641.
- [20] Ahmad I, Khalique N, Khalil S, et al. Dietary diversity and stunting among infants and young children: a cross-sectional study in Aligarh. *Indian J Community Med.* 2018;43:34–36. PubMed PMID: 128005164. Language: English. Entry Date: 20180307. Revision Date: 20180307. Publication Type: Article.
- [21] Chyne DAL, Meshram II, Rajendran A, et al. Nutritional status, food insecurity, and biodiversity among the Khasi in Meghalaya, North-East India. *Matern Child Nutr.* 2017;13:1. PubMed PMID: 127501110. Language: English. Entry Date: 20180206. Revision Date: 20180206. Publication Type: Article.
- [22] Moffitt R, Schoeni RF, Brown C, et al. Assessing the need for a new nationally representative household panel survey in the United States. (Author abstract). *J Econ Social Meas.* 2015;40:1.
- [23] International Institute for Population Sciences (IIPS), ICF. National Family Health Survey (NFHS-4)-reports. Mumbai (India): IIPS; 2015. Available from: 98%; <http://rchiips.org/NFHS/NFHS-4Reports/India.pdf>
- [24] International Institute for Population Sciences (IIPS), ICF. National Family Health Survey (NFHS-4) - national report. Mumbai (India): IIPS; 2017.
- [25] Ogbo FA, Agho KE, Page A. Determinants of suboptimal breastfeeding practices in Nigeria: evidence from the 2008 demographic and health survey. *BMC Public Health.* 2015;15:259.
- [26] Akombi BJ, Agho KE, Hall JJ, et al. Stunting and severe stunting among children under-5 years in Nigeria: A multilevel analysis. *BMC Pediatr.* 2017;17:15. PubMed PMID: PMC5237247.
- [27] De Onis M, Borghi E, Arimond M, et al. Prevalence thresholds for wasting, overweight and stunting in children under 5 years. *Public Health Nutr.* 2019;22:175–179.
- [28] Nkurunziza S, Meessen B, Korachais C. Determinants of stunting and severe stunting among Burundian children aged 6–23 months: evidence from a national cross-sectional household survey, 2014. *BMC Pediatr.* 2017;17:176.
- [29] De Onis M, Blössner M, Borghi E, et al. Estimates of global prevalence of childhood underweight in 1990 and 2015. *JAMA.* 2004;291:2600–2606.
- [30] Onis M, Frongillo EA, Blössner M. Is malnutrition declining? An analysis of changes in levels of child malnutrition since 1980. *Bull World Health Organ.* 2000;78:1222–1233.
- [31] UNICEF. Strategy for improved nutrition of children and women in developing countries. New York (NY): UNICEF; 1990.
- [32] World Health Organisation. Nutrition health topics 2019. Available from: https://www.who.int/nutrition/topics/moderate_malnutrition/en/
- [33] De Onis M, et al. WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age. Geneva (Switzerland): WHO Press; 2006.
- [34] Keino S, Plasqui G, Etyyang G, et al. Determinants of stunting and overweight among young children and adolescents in sub-Saharan Africa. *Food Nutr Bull.* 2014;35:167–178. Epub 2014/08/01. PubMed PMID: 25076764.
- [35] Jiang Y, Su X, Wang C, et al. Prevalence and risk factors for stunting and severe stunting among children under three years old in mid-western rural areas of China. *Child Care Health Dev.* 2015;41:45–51. Epub 2014/ 05/07. PubMed PMID: 24797895.
- [36] Singh A, Upadhyay A, Kumar K. Birth size, stunting and recovery from stunting in Andhra Pradesh, India: evidence from the young lives study. *Maternal Child Health J.* 2017;21:492–508. PubMed PMID: 121919518. Language: English. Entry Date: 20170323. Revision Date: 20180301. Publication Type: Article.
- [37] Corsi DJ, Mejía-Guevara I, Subramanian S. Risk factors for chronic undernutrition among children in India: estimating relative importance, population attributable risk and fractions. *Soc Sci Med.* 2016;157:165–185.
- [38] Ahmad Kiadaliri A. Global, regional, and national age-sex specific mortality for 264 causes of death, 1980–2016: a systematic analysis for the global burden of disease study 2016. *Lancet.* 2017;390:1151–1210.
- [39] Kumar D, Goel N, Mittal PC, et al. Influence of infant-feeding practices on nutritional status of under-five children. *Indian J Pediatr.* 2006;73:417–421.
- [40] Owais A, Schwartz B, Kleinbaum DG, et al. Minimum acceptable diet at 9 months but not exclusive breastfeeding at 3 months or timely complementary feeding initiation is predictive of infant growth in Rural Bangladesh. *PloS One.* 2016;11:e0165128. Epub 2016/ 10/25. PubMed PMID: 27776161; PubMed Central PMCID: PMC5077142.
- [41] World Health Organisation. WHA global nutrition targets 2025: stunting policy brief 2014. Available from: https://www.who.int/nutrition/topics/moderate_malnutrition/en/
- [42] World Health Organisation. Nutrition - complementary feeding, 2019. Available from: https://www.who.int/nutrition/topics/complementary_feeding/en/
- [43] Abuya B, Onsomu E, Kimani J, et al. Influence of maternal education on child immunization and stunting in Kenya. *Matern Child Health J.* 2011;15:1389–1399.
- [44] Khattak UK, Iqbal SP, Ghazanfar H. The role of parents' literacy in malnutrition of children under the age of five years in a semi-urban community of Pakistan: a case-control study. *Cureus.* 2017;9:6.
- [45] Khan GN, Turab A, Khan MI, et al. Prevalence and associated factors of malnutrition among children under-five years in Sindh, Pakistan: a cross-sectional study. *BMC Nutr.* 2016;2:69.
- [46] National Health Survey of Pakistan (NHSP, 1990–1994). Health Profile of the People of Pakistan. Islamabad (Pakistan): Pakistan Medical Research Council; 1998. p. 24.
- [47] Ogbo F, Page A, Idoko J, et al. Population attributable risk of key modifiable risk factors associated with non-exclusive breastfeeding in Nigeria. *BMC Public Health.* 2018;18:1.
- [48] Ogbo FA, Page A, Idoko J, et al. Trends in complementary feeding indicators in Nigeria, 2003–2013. *BMJ Open.* 2015;5:e008467.
- [49] Ogbo FA, Page A, Agho KE, et al. Determinants of trends in breast-feeding indicators in Nigeria, 1999–2013. *Public Health Nutr.* 2015;18:3287–3299.
- [50] Kassa T, Meshesha B, Haji Y, et al. Appropriate complementary feeding practices and associated factors among mothers of children age 6–23 months in Southern Ethiopia, 2015. *BMC Pediatr.* 2016;16:131. Epub 2016/08/21. PubMed PMID: 27542833; PubMed Central PMCID: PMC5092197.

- [51] Mamabolo RL, Alberts M, Mbenyane GX, et al. Feeding practices and growth of infants from birth to 12 months in the central region of the Limpopo Province of South Africa. *Nutrition*. 2004;20:327–333.
- [52] Issaka AI, Agho KE, Burns P, et al. Determinants of inadequate complementary feeding practices among children aged 6–23 months in Ghana. *Public Health Nutr*. 2015;18:669–678.
- [53] Batal M, Boulghourjian C, Akik C. Complementary feeding patterns in a developing country: a cross-sectional study across Lebanon. *East Mediterr Health J*. 2010;16:180–186. DOI:10.26719/2010.16.2.180M
- [54] Basnet S, Sathian B, Malla K, et al. Reasons for early or late initiation of complementary feeding: a study in Pokhara. *Am J Public Health Res*. 2015;3:69–75.
- [55] Abuya BA, Ciera J, Kimani-Murage E. Effect of mother's education on child's nutritional status in the slums of Nairobi. *BMC Pediatr*. 2012;12:80.
- [56] Rohner F, Woodruff BA, Aaron GJ, et al. Infant and young child feeding practices in urban Philippines and their associations with stunting, anemia, and deficiencies of iron and vitamin A. *Food Nutr Bull*. 2013;34:S17–S34. Epub 2013/09/21. PubMed PMID: 24049993.
- [57] The DHS program - Demographic and Health Surveys. DHS model Questionnaires. Available from: https://dhsprogram.com/What-We-Do/Survey-Types/DHS-Questionnaires.cfm#CP_JUMP_16179
- [58] Chirande L, Charwe D, Mbwana H, et al. Determinants of stunting and severe stunting among under-fives in Tanzania: evidence from the 2010 cross-sectional household survey. *BMC Pediatr*. 2015;15:165.
- [59] Akombi BJ, Agho KE, Merom D, et al. Multilevel analysis of factors associated with wasting and underweight among children under-five years in Nigeria. *Nutrients*. 2017;9:44.
- [60] Rayhan MI, Khan MSH. Factors causing malnutrition among under five children in Bangladesh. *Pak J Nutr*. 2006;5:558–562.
- [61] Tiwari R, Ausman LM, Agho KE. Determinants of stunting and severe stunting among under-fives: evidence from the 2011 Nepal demographic and health survey. *BMC Pediatr*. 2014;14:239.
- [62] World Health Organization. World's largest nutrition education program launches in India, courtesy of the mobile phone. New Delhi (India); 2015. Available from: <http://www.who.int/pmnch/media/news/2015/mobile/en/>
- [63] Government of India. Mother and child nutrition-mother, infant and young child nutrition & malnutrition: India's primary policy response: The Integrated Child Development Services (ICDS) program. The Mother and Child Health and Education Trust; 1975 [updated 2017 Dec 16; cited 2019]. Available from: <http://motherchildnutrition.org/india/program-outline.html>
- [64] Government of India. POSHAN Abhiyaan - PM's overarching scheme for holistic nourishment. National Portal of India, Government of India; 2018. Available from: <https://www.india.gov.in/spotlight/poshan-abhiyaan-pms-overarching-scheme-holistic-nourishment>
- [65] National Health Mission, Ministry of Health and Family Welfare, Government of India. Janani Suraksha Yojna. 2018 [cited 2019]. Available from: <http://nhm.gov.in/nrhm-components/rmnc-a/maternal-health/janani-suraksha-yojana/background.html>
- [66] World Health Organization. Global targets 2025 - to improve maternal, infant and young child nutrition. 2018 [cited 2018]. Available from: <https://www.who.int/nutrition/global-target-2025/en/>
- [67] USAID. Partnership for water sanitation and hygiene (wash). 2018. Available from: <https://www.usaid.gov/india/water-and-sanitation>
- [68] Johri M, Subramanian S, Koné GK, et al. Maternal health literacy is associated with early childhood nutritional status in India. *J Nutr*. 2016;146:1402–1410.
- [69] Borooh VK. The role of maternal literacy in reducing the risk of child malnutrition in India. *J Quant Econ*. 2004;2:186–202.
- [70] Mittal A, Singh J, Ahluwalia S. Effect of maternal factors on nutritional status of 1–5-year-old children in urban slum population. *Indian J Community Med*. 2007;32:264.
- [71] Panigrahi A, Das SC. Undernutrition and its correlates among children of 3–9 years of age residing in slum areas of Bhubaneswar, India. *Sci World J*. 2014;2014:1–9. DOI:10.1155/2014/719673
- [72] Gupta A, Sarker G, Rout AJ, et al. Risk correlates of diarrhea in children under 5 years of age in slums of Bankura, West Bengal. *J Glob Infect Dis*. 2015;7:23.