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Tracking Progress in Anthropometric Failure among Children in India: A Geospatial Analysis

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MAA national breastfeeding program, supplementation of Iron-folic acid tablets (IFA), National Food Security Mission and Poshan Abhiyan for holistic nourishment. Among all these programs, one of the earliest interventions to break the vicious cycle of under-nutrition by adopting a lifecycle approach and by reaching the critical age groups is the Integrated Child Development Services (ICDS) Scheme, India's flagship program for nutrition. It was started in 1975 by the Government of India to achieve better health and nutrition of children, pregnant women, and lactating mothers. Children below age six years are eligible to get the benefits of ICDS services. Under this scheme, beneficiaries receive services like supplementary nutrition for children, health check-up, growth monitoring of children, and their immunization. Besides, pregnant women and lactating mothers receive intensified counseling on nutritional and health information for mothers and their children.

Emphasizing on the broad consensus that, investments in nutrition-specific and nutrition-sensitive programs to ensure healthy living conditions are required to reduce the anthropometric failures substantially. Priorities were always accorded to nutrition-specific interventions that aim to modify individual-level behaviors such as complementary foods and feeding practices and breastfeeding [12-15]. When the findings of NFHS-3 were announced in 2005-06, and it was found that the prevalence of anthropometric failure among children in India was one of the highest in the world, the issue attracted the focused attention of policymakers and program managers. The results highlighted that nearly half of the children under age five were stunted (48%), and (43%) were underweight. Also, it called attention to the fact that the ICDS program in India covered only 110 out of 160 million children under the age of 6 years. With these two sets of information, it is believed that the ICDS scheme is yet to lead a substantial improvement in the nutritional status of children. Also, it can be argued that it is not always food insecurity that affects the level of anthropometric failure in India. There are many other proximate risk factors behind this scenario viz. socioeconomic conditions and maternal characteristics [16]. In addition to this, studies have pointed out that anthropometric failure varies by geographical location because of its altitude, rainfall, crop production, population density and diseases related to the specific area [17-20]. Socio-economic inequality plays a significant role in affecting the three components of anthropometric failure, i.e., stunting, wasting, and underweight in most developing countries like India. There is a pool of the researchers who stringently bolster that the reduction of poverty and strengthening of health infrastructure will assist in improving child health conditions, especially dealing with such failure. However, the causal relationship between socio-economic inequality and anthropometric failure is not explicit. These points toward the need to understand the importance of other known correlates [21]. The fourth round of National Family Health Survey provides the first opportunity in more than a decade to conduct an up-to-date, complete evaluation of the importance of various factors concerning child anthropometric failures in India. It cannot be denied that the nutritional transition in India depicts a significant decline in the prevalence of these failures among children below age five during the last decade, except for childhood wasting. However, several eminent experts have talked about how the problem of anthropometric failure is still severe, with almost two-fifths of the world's under-nourished children living in India [22]. In the existing nutritional transition among children in India, some critical research questions that emerge from the evolution seen in anthropometric failures are (1) what are the essential contributors to socio-economic and spatial inequalities in anthropometric failures among children in India? (2) How is the spatial heterogeneity in the prevalence of anthropometric failures among under-five children? The results of the spatial analysis will help recognize the role of diverse risk factors in anthropometric failures. This will have pivotal implications for policy-makers, planners, and organizations seeking to meet national and international development targets and help policymakers in planning as per the need of the geographical location.

Data and Method

Dataset

The basic data used in this analysis have been taken from the last three rounds of National Family Health Survey, NFHS-2 (1998-99), NFHS-3 (2005-06), and NFHS-4 (2015-16). NFHS 3 used multistage stratified sampling and was conducted in all 29 states of India. For the first time, the NFHS-4 included all 36 states, union territories, and 640 districts in India [22]. Survey respondents were selected following a stratified two-stage sampling frame by states and urban and rural areas within each state. The data used to pertain to 89,199 eligible women age 15-49 and their children born in the last three years preceding NFHS 2; 124,385 women and their children under five in NFHS-3 and 699,686 women and their children under age five in NFHS-4. The unit of analysis of the study was district; there were 640 districts in India in 2015-16, with each district having an average of 940 households surveyed. The anthropometric measures used were stunting, wasting, and underweight among children born in the last three years for NFHS-2 and the last five years for NFHS 3 and 4.

Description of Variable

The predictor variables used in the study were; sex, age of the child, educational level of the mother, place of residence, wealth quintile, belonging to a particular caste, belonging to a particular religion, Body Mass Index (BMI) of the mother, time of initiation of breastfeeding, cesarean section delivery, birth order of the child, birth weight of the child and ICDS usage. All children younger than five years of age were selected for anthropometric measurements. In some of the analyses, we coded age into several groups: 0–5, 6–11, 12–23, 24–35, 36, and above months. BMI of the mother was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Mothers were categorized according to three risk factors, 'underweight" were classified as having a BMI <18.5 k/m^2 "normal" was classified as having BMI 18.5-24.95 k/m^2 and "overweight/obese" was classified as those having BMI 25-29.9 kg/m^2 and above. Wealth index was divided into quintiles, and for anthropometric failures, so the suitability of Spatial Error Model (SEM) and Spatial Lag Models (SLM) were examined using diagnostic tests. e fundamental di erence between the two models is that the spatial lag model, unlike the spatial error model does not consider the spatial dependence in the error term. Diagnostics tests for spatial relationships were carried out, and the value of the Lagrange Multiplier is found signi cant in both the models ($p < 0.001$). Next, we compared the Akaike Information Criterion (AIC) value for both the models to know the best spatial t. erefore, a larger value of LM (error) than the LM(lag) and relatively larger value of adjusted R^2 explained the better model adequacy and lower values of Akaike info criterion and Schwarz criterion, this further explained better suitability of the model, which led us to apply LM(error) model. A detail description of Spatial Error and Spatial Lag models can be found in various literature [23,24].

Finding

Over the last decade, there has been a decline in the level of anthropometric failures among children, except for wasting. e adjusted Tf(tests. e fundamental digT2 Td)Tj/Tp nomodel.0ng. j/Tp n aTr term. Diagnostics tests for spatial

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of stunting may be attributed to the on-going programs and services to address micronutrient de ciencies and improving child-feeding practices in the country, even among those coming from the poorest wealth quintile. Further, increased nutritional awareness among mothers coming from wealthier households may be the reason behinds the drastic reduction in the estimated probability of stunting among children of mothers from more a uent households.

Similarly, the predicted probabilities of being underweight among the children below age three from the poorest wealth quintile declined slightly (only 1%) from 1998-99 to 2005-06. In contrast, the decline in the estimated probability of underweight during the same period was more pronounced among children below age three from the richest quintile (20%). e reduction in predicted probabilities of children being underweight among the most deprived quintiles during the last decade (during NFHS-3 to 4) among children below age 5 was minuscule, ranging from 2% from among those coming from the poorest wealth quintiles to 3% among those coming from the wealthiest wealth quintiles. Besides, Table 2a portrays children below age three; belonging to the poorest quintile, the estimated probability of being wasted increased from 0.260 in 1998-99 to 0.282 in 2005-06, an increase of over 8%. Over the same period, the likelihood of wasting among children below age three from the richest wealth quintile increased from 0.123 in 1998-99 to 0.150 in 2005-06, an increase of 22%. e corresponding increase in the prevalence of wasting among children below age ve among those from the poorest and richest wealth quintiles between 2005 and 2016 was 2% and 23%, respectively. ese results portray that variation in the estimated probability of stunting as well as underweight were relatively higher among those coming from the poorest households during 1998-99 to 2005-06 in comparison to the recent period of 2005-06 and 2015-16. However, the changes in the estimated probability of wasting remain by and large the same. is may be primarily due to higher values of anthropometric failures during 1998-98, and hence achieving decline might have been more straightforward. Another reason may be the changed age cohort. e prevalence of anthropometric failures in 1998-99 was computed among those below age three, which has the potential to produce faster improvements due to any vertical interventions in comparison to children in the age cohort of under ve years.

Table 2b presents the predicted probabilities of stunted, underweight, and wasted children using logistic regression analysis for di erent categories of mother's education in India, 1998-2016. e estimated predicted probability of stunting among children below age three among the mothers with no education declined by 16% point during 1998-99 to 2005-06, while the same among those educated up to higher secondary or above declined by 15% during the same period. e corresponding changes in the predicted probability of stunting among children below age ve during 2005-06 and 2015-16 were 9% and 6%, respectively. us, there is an enormous change in the estimated probability of stunting among women with no education, which gradually declines with time, and hence making is relatively complex to achieve a rapid decline in the future.

For underweight, the changes in the estimated predicted probability among children below age three of the mothers who were having no education were 10%, and for children of those having a higher level of education was only in igher ability increuni anmativ in were in poorer states like Odisha, Gujarat, Maharshtra, Chattisgarh, Rajasthan, West Bengal, Uttar Pradesh, Bihar, Jharkhand etc. Around 145 districts show clustering of low maternal BMI and childhood underweight. Some of these districts are Gaya, Lakhisarai, Arwal, Aurangabad, Samastipur, Samastipur, Jabalpur, Sheopur, Guna, Sidhi, Datia, Gwalior, Puruliya, Bankura, Birbhum, Kolkata, Murshidabad. Additionally, the map shows a high prevalence for the bene ciary of ICDS services and underweight mothers, in which total 183 districts were identi ed as the hot spots. Some of these districts are Narayanpur, Bastar, Uttar bastar kanker, Dakshin bastar kanker, Malkangiri, Nabarangapur, Birbhum, Paschim Medinipu, Bankura, Kolkata, Banka, Gaya, Sheikhpura, Arwal, Madhepura, Lakhisarai, shahjahanpur, Budaun, Lucknow, Lalitpur, Jaunpur.

Figure 2 depicts the bivariate Moran's I statistics for two measures of anthropometric failures among children across 640 districts of India using the scattered plot. e univariate Moran's I value for stunting among children is 0.62 (statistically signi cant), which shows that stunting among children is spatially clustered across Indian districts. Amongst all the factors, the bivariate Moran's I value for stunting was the highest for utilization of ICDS services by children in the last 12 months (0.57, p<=0.001), followed by low BMI of mothers (0.50, p<=0.05). Concerning univariate and bivariate Moran's I values for underweight, it was found that the univariate Moran's I was (0.72, p<=0.01) and the spatial autocorrelation was the highest with the utilization of ICDS in the last 12 months (0.65, p <= 0.01) and birth weight (0.60, p<=0).

e spatial autocorrelation with the application of bi-variate LISA maps and Moran's I put forward the need for analyzing the spatial dependence in the prevalence of stunting and underweight among children aged 0-59 months across di erent districts of India. To decide the suitability of the model to analyze spatial relationships, two sets of tests on Log Ranges Multipliers (LM) and Robust LM were used with the help of the White test in the OLS model. e White test produces the signi cance of LM (lag) as well as LM (error). As a result, Robust LM (lag) and Robust LM (error) have been compared. A relatively larger value of LM (error) than the LM (lag) and relatively larger value of adjusted R^2, (explaining the better model adequacy) and lower values of Akaike info criterion and Schwarz criterion, (explaining better suitability of the model), guided us to apply LM (error) model to analyze the spatial dependence of stunting and underweight among children with various predictors included in the model. Results of the spatial error model on the spatial relationship of stunting and underweight among under- ve children are presented in Table 3.

e ndings portray that in the prevalence of anthropometric failure among children. Poor maternal nutrition, low birth weight, C-section deliveries, and higher birth order were found to be the key predictors significantly explaining the spatial dependence of stunting and underweight among children age 0-59 months. The use of ICDS services in the last 12 months significantly affected the spatial variation in the prevalence of stunting but in a negative direction, which may be primarily due to selection bias for participation in the ICDS. This brings out the issue of selectivity as most of the children who were availing ICDS services either for supplementary nutrition, health check-ups or for immunization services, hail from the socio-economically deprived section of society. Rural place of residence was not significantly affecting the stunting of children, but it has emerged as a considerably affecting predictor of underweight in the spatial model. This finding affirms the findings explained in the earlier section that rural children are at a disadvantageous position in terms of anthropometric failures, which varies by space. It is worth mentioning that the inclusion of spatial weights in the model has increased the predicting power of the model from 69% in case of OLS to nearly 76% in the spatial regression model for the prevalence of stunting, while the corresponding values for underweight were 71% and 81% respectively.

Discussion and Conclusion

Anthropometric measures are the most routinely used objective indicators of nutritional status in children [25]. Nevertheless, having the biggest anti-anthropometric failure program and a prolonged history of the fight towards ending it, in 2015-16, more than 38% of children were stunted, 20% were wasted, and 36% were underweight, which is the stark reality. Such high numbers show our failure in securing our children. The relationship between maternal level factors and child's anthropometric failure has also been documented in several other studies [6,12,16,26]. The study underscores the importance of improving the overall environmental and socioeconomic conditions at the child, maternal and household levels. Children who were more than 12 months of age were more likely to be stunted or underweight; age correlated positively with both, these findings are not surprising and are in line with previous assessments. In the initial months, children are wholly dependent on mother's milk for food and hence are adequately fed and nourished. However, at a later stage, the child becomes more dependent on other sources of food for his nutrition needs; this could hamper his nourishment levels [27,28].

Our results underscore that factors such as sex of the child, birth order, BMI of the mother, education, and household wealth were highly related to anthropometric failures. Our findings go in line with other authors who talk about maternal education playing a significant role in influencing the anthropometric failure [7,29]. Highly educated wo l T4 727 the ncingen mater11 Hig0, bir5rabDti28 Tm[(. A we)Tj
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underweight, and wasting across the districts of India. The anthropometric failure (stunting and underweight) showed significant clustering in the districts belonging to the states of Uttar Pradesh, Bihar, Jharkhand, Gujarat, Madhya Pradesh, and Rajasthan. The Moran's I statistics suggested strong spatial dependence in variation in levels of various anthropometric failures among the states among children aged 0-59 months in India, this highlights that geography plays a substantial role in the levels of stunting and underweight in an area [17-19]. Districts with a higher percentage of underweight women with a BMI of less than 18.5 kg/m^2 were significantly more likely to have a higher prevalence of stunting and underweight among their children, and findings were consistent with previous studies. This point towards an intergenerational transfer of poor health from mother to child, studies suggest that a mother's social and nutritional environment during early life is a significant factor of her children's subsequent health outcomes [13,20,26].

The districts with a higher incidence of usage of ICDS in the last 12 months are at higher risk of increased prevalence of stunting and underweight. This antagonistic relationship is mainly due to selection bias for the beneficiaries participating in the ICDS program. Strengthening of anganwadis and balwadis will be helpful as they are instrumental in taking care of the child, and educating the child along with providing meals which complement the child's diet, thus improving their nutritional status. When spatial weights were taken into consideration, the spatial regression model could predict the prevalence of anthropometric failure among children quite substantially. The spatial models suggested a statistically significant association of anthropometric failures (stunting and underweight) with factors such as BMI status of mothers, birth order, caesarean section births, place of residence, BMI of the mother, and ICDS usage. These findings are similar to the results of various studies.

The results of spatial analysis have highlighted that there are variations in the anthropometric failure levels across the country. It is, therefore, vital to plan the combating of the failure in a manner that is suitable for the trends and context of each hotspot and cold spots. The finding that maternal nutrition and maternal education are significant predictors of anthropometric failure among children below age 5 indicate an urgent need to strengthen policy efforts and programs addressing these dimensions of women's empowerment. Continuous efforts would help reduce disparity in elevating nutrition problems in India and would help in achieving sustainable development goals, particularly those related to the eradication of extreme poverty, hunger, and child survival. Such efforts are the need of the hour given that we have one of the worst anthropometric failure levels worldwide.

Recommendation

These findings demonstrate that multiple factors affect anthropometric failures among children in India. Results on the potential impact of the ICDS indicate that the current efforts of India's nutrition program, POSHAN Abhiyan, in addressing anthropometric failures can be more productive by enhancing the coverage and efficiency of the ICDS scheme in the country. However, given the multiple social determinants of anthropometric failure, efforts are needed to address those social determinants (wealth, education, etc.) through synergy between the programs and services being implemented by different ministries of Government of India. The government should increase the magnitude of efforts done to combat the anthropometric failure.

Limitation

The study used a number of factors of anthropometric failure among children in India and estimated the contribution of a number of biosocial factors. However, this study did not consider a number of unobserved confounders, including medical factors, which were not investigated as part of the survey.

Authors' Contributions

SKS conceived the idea and designed the experiment. PM reviewed the paper and gave her inputs. SKS and AA analysed the data, interpreted the results, and drafted the manuscript.

The authors reviewed the manuscript and approved the final manuscript for submission for publication.

Conflict of Interest

The authors do not have any conflict of interest to declare.

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