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A predictive modelling approach to illustrate factors correlating with stunting among children aged 12–23 months: a cluster randomised pre-post study

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ABSTRACT

Objective The aim of this study was to construct a predictive model in order to develop an intervention study to reduce the prevalence of stunting among children aged 12–23 months.

Design The study followed a cluster randomised pre-post design and measured the impacts on various indicators of livelihood, health and nutrition. The study was based on a large dataset collected from two cross-sectional studies (baseline and endline).

Setting The study was conducted in the north-eastern region of Bangladesh under the Sylhet division, which is vulnerable to both natural disasters and poverty. The study specifically targeted children between the ages of 12 and 23 months.

Main outcome measures Childhood stunting, defined as a length-for-age z-score <−2, was the outcome variable in this study. Logistic and probit regression models and a decision tree were constructed to predict the factors associated with childhood stunting. The predictive performance of the models was evaluated by computing the area under the receiver operating characteristic (ROC) curve analysis.

Results The baseline survey showed a prevalence of 52.7% stunting, while 50.0% were stunted at endline. Several factors were found to be associated with childhood stunting. The model's sensitivity was 61% and specificity was 56%, with a correctly classified rate of 59% and an area under the ROC curve of 0.615.

Conclusion The study found that childhood stunting in the study area was correlated with several factors, including maternal nutrition and education, food insecurity and hygiene practices. Despite efforts to address these factors, they remain largely unchanged. The study suggests that a more effective approach may be developed in future to target adolescent mothers, as maternal nutrition and education are age-dependent variables. Policy makers and programme planners need to consider incorporating both nutrition-sensitive and nutrition-specific activities and enhancing collaboration in their efforts to improve the health of vulnerable rural populations.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study used a combination of parametric and non-parametric predictive models to estimate the effect size of the independent variables and identify significant correlates of childhood stunting.
⇒ The study was designed to mitigate the potential impact of seasonal factors by conducting the baseline and endline surveys at the same time of the year.
⇒ A binary indicator of stunting based on a single length-for-age z-score cut-off point (<−2) may not provide a complete evaluation of the severity of malnutrition among children as it does not consider micronutrient deficiencies.
⇒ Use of recall data from the previous 24 hours for dietary diversity, household food insecurity, domestic violence and maternal healthcare may be subject to recall bias.
⇒ Biological data have not been collected such as enteropathogen and environmental enteric dysfunction, which could have been related to childhood stunting.

Trial registration number RIDIE-STUDY-ID-5d5678361809b.

INTRODUCTION

Childhood stunting, which is defined as length-for-age z-score (LAZ) <−2, is a major concern for public health and has been widely used as an indicator of chronic malnutrition in children.[1 2] Although childhood stunting scenarios have much improved globally, the prevalence of childhood stunting is still very high in low-resource settings, including countries such as Bangladesh. According to the 2018 Global Nutrition Report, 150.8 million children (22.2%) under 5 years of age are stunted globally, compared with 198.4

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million (32.6%) and 165 million children in 2000 and 2011, respectively.[3 4] Between 2000 and 2018, Asian countries have experienced a decrease in the rate of stunting among children under 5 years of age from 38.1% to 23.2%. However, South Asia still has the highest prevalence of stunting in the region, with a rate of 38.9% in 2018.[3] In Bangladesh, about 5.5 million (36%) children under 5 years of age were stunted in 2014,[5] however by 2018, childhood stunting has reduced to about 31%.[2] As WHO considers a childhood stunting rate of 15% to be an emergency situation, the current prevalence of childhood stunting in Bangladesh reflects an alarming situation of chronic undernutrition.[6]

Literature suggests that children are at a higher prevalence of stunting if their mothers do not receive adequate antenatal care (ANC), fail to rest sufficiently, do not consume additional food and neglect to take iron-folic acid (IFA) tablets during pregnancy.[7–9] Additionally, maternal and child health are correlated with mass media exposure, receiving a vitamin A capsule, having a skilled birth attendant and maternal education.[6 8 10–12] Children in poor households in Bangladesh are more likely to experience stunted growth if their mothers are employed, as there are inadequate day care centres available for the children, leading to insufficient breast feeding.[13] Moreover, evidence suggests that a number of characteristics at the household level, which relate to both children and mothers, can influence childhood stunting. The characteristics of the household head, household food insecurity and lower dietary diversity, household lower-income, household involvement in several earning activities, availability of sanitation facility at home, hand-washing status, family size, religion and receive several types of allowance from government are most often reported to be associated with stunting in the literature.[6 8 11 14–16]

Based on child characteristics, several indicators are associated with stunting. This status is associated with two basic characteristics: a child's gender and age.[8] Children are commonly affected by the co-occurrence of illness in low-income and middle-income countries, which is one of the most common causes of stunting.[17] Inadequate infant and young child feeding (IYCF) practices also reduce child growth.[8 15] However, these findings are mostly based on nationally representative cross-sectional and cohort studies, or studies conducted in urban settings.[18 19] Therefore, a knowledge gap exists on whether similar results would be obtained when nationwide data are compared with data for study populations from poor or very poor rural households in specific vulnerable regions.

Sylhet is one such vulnerable region of north-east Bangladesh, comprising diverse terrains such as plain land, hilly land, *Haor* (wetland) and flash flood-prone areas. This region is reported to perform poorly for all important maternal healthcare indicators,[20] despite the fact that Bangladesh has made substantial progress in improving the overall health of the population.[21] Moreover, the socio-economic profile of the inhabitants in Sylhet region includes both very rich and extremely poor people. This scenario may worsen without the implementation of appropriate strategies in the near future. Sylhet region is also performing poorly compared with the national averages for a number of health and nutritional indicators. Critical indicators such as the infant mortality rate and unemployment status of women are high.[19] In comparison to the overall situation of Bangladesh, where stunting among children under 5 years of age has decreased, the Bangladesh Demographic and Health Survey (BDHS) 2014 indicates the prevalence of childhood stunting in Sylhet is astonishingly high, at 50%.[19] This alarming figure provided the rationale for implementation of a comprehensive intervention programme in this region. A large-scale nutrition programme, *Suchana: Ending the Cycle of Undernutrition in Bangladesh; a multisectoral nutrition programme*, was undertaken with the aim to prevent chronic malnutrition in Sylhet.

In general, *Suchana* nutrition interventions can be divided into two types: nutrition-sensitive and nutrition-specific.[22] The concept of nutrition-sensitive intervention refers to an intervention that benefits the beneficiaries in terms of food and nutrition security, and also influences the underlying determinants of nutrition. This type of intervention is largely delivered through the agricultural sector (homestead vegetable and fruit production, pro-poor nutrition-sensitive aquaculture), improved technology (mono-sex tilapia and carp-tilapia polyculture, subsistence fishing, fish drying), demonstrations (village model farms and demo ponds, livestock, food security, promotion of climate-smart technologies) and supported income-generating activities (skill development in business management, engagement with the private sector and other sectors). As nutrition-specific interventions were delivered through nutrition-sensitive interventions, their coverage, effectiveness and scale can be increased. It can meet the targets by lowering them and implementing nutrition-specific interventions. A nutrition-specific intervention addresses the immediate cause of malnutrition. Direct determinants of nutrition are the focus of this intervention. There is a strong focus on nutrition-specific interventions in the health sector. Whether implemented alone or jointly, nutrition-specific interventions improve health outcomes. Some examples of nutrition-specific interventions are: counselling for mothers at the household level, community-based nutrition education for spouses and in-laws, growth monitoring and promotion sessions integrated with *Expanded Programme on Immunisation* in communities, *Government of Bangladesh* health facilities equipped with *severe acute malnutrition* service delivery and support for *National Nutrition Services* service delivery through community clinics, Union Health and Family Welfare Centres and Upazila health complexes.

The primary objective of the *Suchana* programme was to reduce the prevalence of childhood stunting in the intervention areas. The secondary objectives were to assess the changes in *Suchana* beneficiaries' households, in terms of an increase and diversification of household income, food security status, optimal IYCF practices,

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haemoglobin status of children, the empowerment of women and adolescents' nutritional knowledge and practices.[22]

The *Suchana* programme substantially improved nutritional behaviour, maternal healthcare practices, women's empowerment, household income and household food security in the intervention area compared with the control area.[23] Contrary to predictions, however, *Suchana* did not result in any significant reduction in the prevalence of childhood stunting. Therefore, although most other factors related to childhood stunting improved, this raises the question of why the prevalence of stunting did not reduce after the intervention. An important observation from the *Suchana* survey was that the proportion of households in this study population using hygienic latrines was quite low. This factor was associated with stunting in children,[8] and did not significantly improve by endline in the intervention areas compared with the control areas.

In this study, we aimed to construct a predictive model to attempt to explain whether any improvements in associated factors may promote a significant reduction in stunting among children aged 12–23 months from poor and extremely poor households in the Sylhet region.

METHODS

Study design and setting

The *Suchana* programme was implemented in 157 *Unions* over 20 subdistricts in the Sylhet region in the north-east of rural Bangladesh. The *Suchana* programme's protocol has been thoroughly explained elsewhere.[22] *Union*, the smallest local government and administrative entity in rural Bangladesh, was considered as a cluster and divided into four phases at random. Phase I was designated as the intervention group, while phase IV was the control group, and the other phases were treated as learning phases.[22] For implementation purposes, vulnerable villages were selected within phase I and phase IV areas. The staff of the programme chose vulnerable villages in each *Union* based on their vulnerability (eg, frequent floods or submerging, little or no intervention from other development programmes, poverty or household living circumstances, remoteness and accessibility issues, a high prevalence of superstitions and social taboos). After consultation with the local government representatives, elected officials and local elites as well as field visits, this selection method was decided on. The impacts of the intervention on livelihood, health and nutrition were measured using a pre-post design. A large dataset was collected from two cross-sectional surveys (baseline and endline) under this study. The baseline survey was conducted in November 2016 and February 2017, followed by the endline survey in the same months 3 years later among the same population and different participants (online supplemental figure 1).

Outcome variable

The outcome variable in this study was childhood stunting, which was defined as LAZ <−2.[2]

Independent variables

Initially, a list of independent variables was finalised through results obtained from descriptive and bivariate analyses, as well as a comprehensive literature review (table 1). These included at least four ANC visits by a skilled service provider, additional resting during pregnancy, additional food consumption during pregnancy, consumption of at least 100 IFA tablets during pregnancy, receiving vitamin A capsule after last delivery, birth attendant/facility, mother involved in income-generating activities, maternal body mass index, maternal education, household food insecurity, household monthly income >15 000 Bangladesh taka (BDT), involved with aquaculture, hygienic latrine, water and soap available in handwashing place, household size, household dietary diversity, sex of household head, religion, received any grant/allowance/stipend from the government, access of mass media, child's age, child's sex, childhood illness in the last 15 days, minimum dietary diversity, early initiation of breast feeding and received colostrum. Household food insecurity access scale was measured using the Food and Nutrition Technical Assistance's Guideline, which categorises household food insecurity into four levels: (a) food secure, (b) mildly food insecure, (c) moderately food insecure and (d) severely food insecure.[24] In the analysis herein, this indicator was redefined as a binary indicator: severely food insecure or not severely food insecure.

Sample size

The sample size for this study was calculated with the STATA '*clustersampsi*' command module, considering the number of clusters in the surveys and considering the expected prevalence of childhood stunting in the control group (online supplemental appendix 1). It was estimated that the expected prevalence of stunting was 47%, which was hypothesised to be reduced to 41% after 3 years of intervention. A sample size of 1520 per arm was calculated based on a 5% level of significance, 80% power, 40 clusters per arm and an intracluster correlation coefficient of 0.01. After rounding, the estimated sample size per arm was 1620, and the total sample size was 3200 at baseline, with an equal number of participants in the control and intervention groups. For evaluation purposes, the sample size at endline was doubled to ensure a stratified intervention component, resulting in a total sample size of 9600 mother-child pairs (baseline: 3200 and endline: 6400).[22]

Sampling

The baseline and endline surveys were conducted in a total of 8 and 12 villages respectively, which were randomly selected from each *Union* using a list of vulnerable villages provided by Save the Children. The most vulnerable households were identified and verified using

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Table 1 List of all independent variables

Indicators	Code	Stunting status*	Selection in the model
At least four ANC visits by a skilled service provider			Selected
At least four ANC visits by a skilled service provider	0		
Less than four ANC visits by a skilled service provider	1	Higher prevalence[8]	
Additional resting during pregnancy			Not selected
Took more rest	0		
Did not take more rest	1	Higher prevalence[8]	
Additional food consumption during pregnancy			Not selected
Consumed more food	0		
Did not consume more food	1	Higher prevalence[7 8]	
Consumption of at least 100 IFA tablets during pregnancy			Not selected
Consumed at least 100 IFA tablets	0		
Did not consume at least 100 IFA tablets	1	Higher prevalence[9]	
Received vitamin A capsule after last delivery			Not selected
Received	0		
Did not receive	1	Higher prevalence[8]	
Birth attendant/facility			Selected
Skilled	0		
Unskilled	1	Higher prevalence[10]	
Mother involved in income-generating activities			Selected
No	0		
Yes	1	Higher prevalence[6 13]	
Maternal BMI			Selected
≥18.5	0		
<18.5	1	Higher prevalence[6 11]	
Maternal education			Selected
At least 1 year formal education	0		
No schooling	1	Higher prevalence[6 11]	
Access of mass media			Selected
Access	0		
No access	1	Higher prevalence[12]	
Household food insecurity			Selected
Below severe	0		
Severe	1	Higher prevalence[8]	
Household monthly income ≥15 000 BDT			Selected
≥15 000	0		
<15 000	1	Higher prevalence[11]	
Involved with aquaculture			Selected
Involved	0		
Did not involve	1	Higher prevalence[14]	
Hygienic latrine			Selected
Hygienic latrine	0		
Unhygienic latrine	1	Higher prevalence[6 11 15]	
Water and soap available in handwashing place			Selected
Available	0		
Unavailable	1	Higher prevalence[15]	

Continued

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Table 1 Continued

Indicators	Code	Stunting status*	Selection in the model
Household size			Selected
Below seven	0		
Seven or above	1	Higher prevalence[11]	
Household dietary diversity score			Selected
≥7	0		
<7	1	Higher prevalence[8]	
Sex of household head			Not selected
Female	0		
Male	1	Higher prevalence[8]	
Household head education			Not selected
At least 1 year formal education	0		
No schooling	1	Higher prevalence[6]	
Religion			Not selected
Muslim	0		
Non-Muslim	1	Lower prevalence[6]	
Received any grant/allowance/stipend from the government			Not selected
Received	0		
Did not receive	1	Higher prevalence[16]	
Child's age (months)			Selected
<18	0		
>18	1	Higher prevalence[8]	
Child's sex			
Female	0		
Male	1	Higher prevalence[8]	
Childhood illness in the last 15 days			Selected
No	0		
Yes	1	Higher prevalence[17]	
Minimum dietary diversity			Not selected
Received	0		
Did not receive	1	Higher prevalence[8 15]	
Early initiation of breast feeding			Not selected
Received	0		
Did not receive	1	Higher prevalence[8]	
Received colostrum			Not selected
Received	0		
Did not receive	1	Higher prevalence[8]	

*Expected effects based on findings of the literature.
ANC, antenatal care; BDT, Bangladesh taka; BMI, body mass index; IFA, iron-folic acid.

the inclusion criteria of the *Suchana* programme (online supplemental table 1). These households were then given an identification number to prepare the sampling frame and required households were systematically selected for the surveys from the frame. The method of data collection is explained in detail in the online supplemental appendix 2.

STATISTICAL ANALYSIS

General characteristics

Stata V.14 software (StataCorp, College Station, Texas, USA) and R V.4.2.2 (*rpart*)[25] were used to analyse the data. Bar diagram was used for data visualisation. Descriptive statistics, such as frequency and proportions for categorical variables and mean and SD for quantitative

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variables, were used to summarise the data at baseline and endline. Cross-tabulation was used to present that outcome variable segregated by intervention and control group at baseline survey as well as the endline survey. The *difference-in-difference* method was used to estimate the contrast of an intervention by comparing the difference in the outcomes between an intervention group and a control group before and after the intervention.[26]

Predictive model

Three statistical models were used as predictive models. Two parametric models, such as logistic and probit regression models, and decision tree as a non-parametric model. Logistic and probit regression models were used as predictive models as well as classifier models. The models were also used to investigate which factors were significantly associated with childhood stunting, and estimate their effect size, in order to predict whether changes in behavioural practices might potentially help to achieve targeted reductions in stunting. Using those variables, a decision tree was applied, and the predictive performance was compared with other models.

For the parametric models, first, χ^2 test was used to examine the bivariate associations between stunting and all possible explanatory variables. In the second step, variables with p values <0.25 in the simple model were included in the multiple regression models.[27] In the final step, any independent variables thought to be likely predictors were added to the multiple regression model using the stepwise forward selection method. Some indicators, for example, age, sex and maternal nutritional status were added regardless of their p value due to their scientific plausibility. The mathematical equation of logistic and probit regression models are given in the online supplemental appendix 3. As a cluster variable, *Union* was used to adjust the SEs. Furthermore, for the explanation of the regression model, a p value <0.05 was considered as statistically significant, and 95% CI was also reviewed. From the fitted model, the adjusted effect size (adjusted prevalence difference) against all predictors was estimated using the '*adjrr*' package in Stata. The list of independent variables with the value labels used in the model is given in table 1.

Model evaluation

The predictive performance of the three statistical models was evaluated by computing model sensitivity and specificity, and calculating the area under the receiver operating curve (ROC) analysis. To ensure accurate results, the data were randomly split into a training set (75%) and a test set (25%) using a random-number seed 113 843. The same training and test datasets were used for evaluating the performance of all algorithms to ensure consistency in the results. The sensitivity and specificity values, as well as the area under the ROC curve, were used to determine the overall accuracy of the algorithms in predicting childhood stunting.[28 29]

Patient and public involvement

Patients and public were not actively involved in formulating the research question and or protocol development, including the outcome measures. To expedite the field implementation, however, local elites, for example, teachers, religious persons and local government council members were informed about the study.

RESULTS

General characteristics

Out of 9600 cases, 9501 cases were found to be available. The refusal rate was around 1%. With respect to the outcome indicator, stunting in children aged 12–23 months, 52.7% of children were stunted at the baseline survey (intervention group: 52.6%; control group: 52.8%), whereas the proportion of children exhibiting stunting at endline was 50.0% (intervention: 49.9%; control: 50.1%; figure 1). At both the baseline and endline surveys, there was no significant difference in proportion between intervention and control areas. The *difference-in-difference* in outcomes over time was also insignificant.

Figure 2 describes several other indicators related to maternal and child health, including the status of consuming a minimum acceptable diet (intervention: 35.2%; control: 14.9%), minimum dietary diversity (intervention: 42.8%; control: 20.4%), maternal decision-making (intervention: 45.0%; control: 31.0%), at least four maternal ANC visits by a skilled service provider (intervention: 36.1%; control: 17.7%), minimum dietary diversity for women (intervention: 52.6%; control: 33.5%), a household dietary diversity score of at least 7 (intervention: 88.9%; control: 78.3%) and household food security status (intervention: 26.6%; control: 20.2%). Results from the endline survey showed that these indicators were significantly improved in the intervention group compared with the control group. However, the availability of hygienic latrines did not increase in the intervention group (intervention: 44.0%; control: 44.0%). Table 2 shows the households' sociodemographic characteristics, women's general characteristics and children's characteristics at baseline and endline.

Correlated factors

The study used two parametric predictive models to determine the correlates of childhood stunting. The results, presented in table 3, showed the adjusted ORs (aOR) computed from multiple logistic regression and the adjusted coefficients computed from multiple probit regression. These results provide important insights into the factors that increase the odds of stunting in childhood, and can inform public health interventions aimed at reducing stunting and improving child health. The aORs provide a quantitative measure of the relationship between different factors and childhood stunting, adjusting for *Union* as cluster variable. Understanding the correlates of childhood stunting is critical for addressing this important public health issue and improving the health and well-being of children globally.

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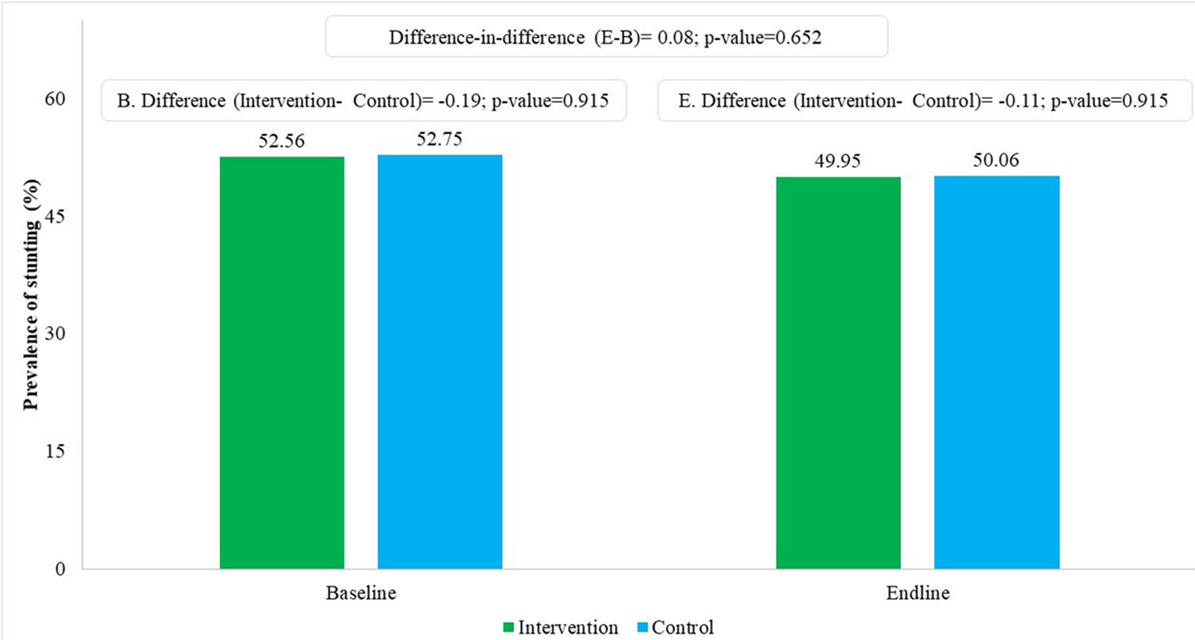

Figure 1 Prevalence of childhood stunting in the intervention and control areas at baseline compared with endline. The p value of the *difference-in-difference* was estimated using interaction analysis in the multiple logistic regression model.

The results of this study show that a number of maternal, household and children factors were correlated with an increased prevalence of stunting in children. Children of mothers who did not receive at least four ANC visits from a skilled service provider had 1.16 times higher odds of stunting (95% CI 1.05 to 1.30; p=0.005). Children of mothers who gave birth with an unskilled birth attendant or facility had 1.11 times higher odds of stunting (95% CI 1.02 to 1.20; p=0.012). The odds of stunting were 1.18 times higher in children whose mothers were involved in income-generating activities (95% CI 1.02 to 1.37; p=0.030), 1.23 times higher in children of underweight mothers (95% CI 1.12 to 1.36; p<0.001) and 1.31 times higher in children of low-educated mothers (95% CI 1.20 to 1.42; p<0.001). Furthermore, the lack of exposure to mass media was also found to be associated with stunting, with odds of 1.15 (95% CI 1.02 to 1.30; p=0.025) times higher. Children from households with severe food insecurity, lower-income households, households not involved in aquaculture and households with low dietary diversity were more likely to be stunted, with odds increasing by 1.12 (95% CI 1.00 to 1.24; p=0.041), 1.12 (95% CI 1.01 to 1.25; p=0.037), 1.19 (95% CI 1.03 to 1.38; p=0.018) and 1.17 (95% CI 1.07 to 1.29; p=0.001) times, respectively. The results also showed that the odds of stunting increased with increasing household size (95% CI 1.11 to 1.31; p<0.001), the absence of a hygienic latrine (95% CI 1.10 to 1.30; p<0.001), the absence of water and soap in the handwashing place (95% CI 1.08 to 1.30; p<0.001), increasing child age (95% CI: 1.39 to 1.67; p<0.001) and being male (95% CI 1.11 to 1.34; p<0.001). The odds of stunting were also 1.20 times higher in children with acute illness (95% CI 1.06 to 1.36; p=0.003). The logistic and probit regression models were employed to predict stunting in a sample of 9501 individuals. Both models were found to be significant, with log-likelihoods of −6387.94 and −6388.02, respectively, and significant Wald χ^2 statistics (p<0.001). Predictive ability of various indicators for the adjusted prevalence of stunting and adjusted prevalence difference (effect size) are given in online supplemental tables 2a and 2b). The factors correlating with childhood stunting, as determined by using a decision tree as a non-parametric predictive model, are also presented in figure 3. The decision tree result suggests that maternal education was the most important variable in predicting childhood stunting, as it was the main root node. The other variables, such as maternal nutrition, hand washing indicators and hygienic latrine, were also important, as they were next root node variables. This tree model can be used to predict the childhood stunting status with relative ease.

Predictive performance

Table 4 describes the model validation based on sensitivity, specificity and whether the model was correctly classified for the overall dataset, as well as the training and test datasets. The sensitivity and specificity of the model were around 60% and 55%, respectively for all models. The correctly classified rate was 59%, and the area under the ROC curve was around 61%. We found that these values were approximately equal among the three datasets (main, training and test datasets); however, the predictive performance of the model was low.

DISCUSSION

In an effort to understand why the *Suchana* programme was not effective in reducing the prevalence of childhood stunting, this study analysed data from both the baseline and endline surveys of the programme. The analysis aimed to identify the factors that were significantly

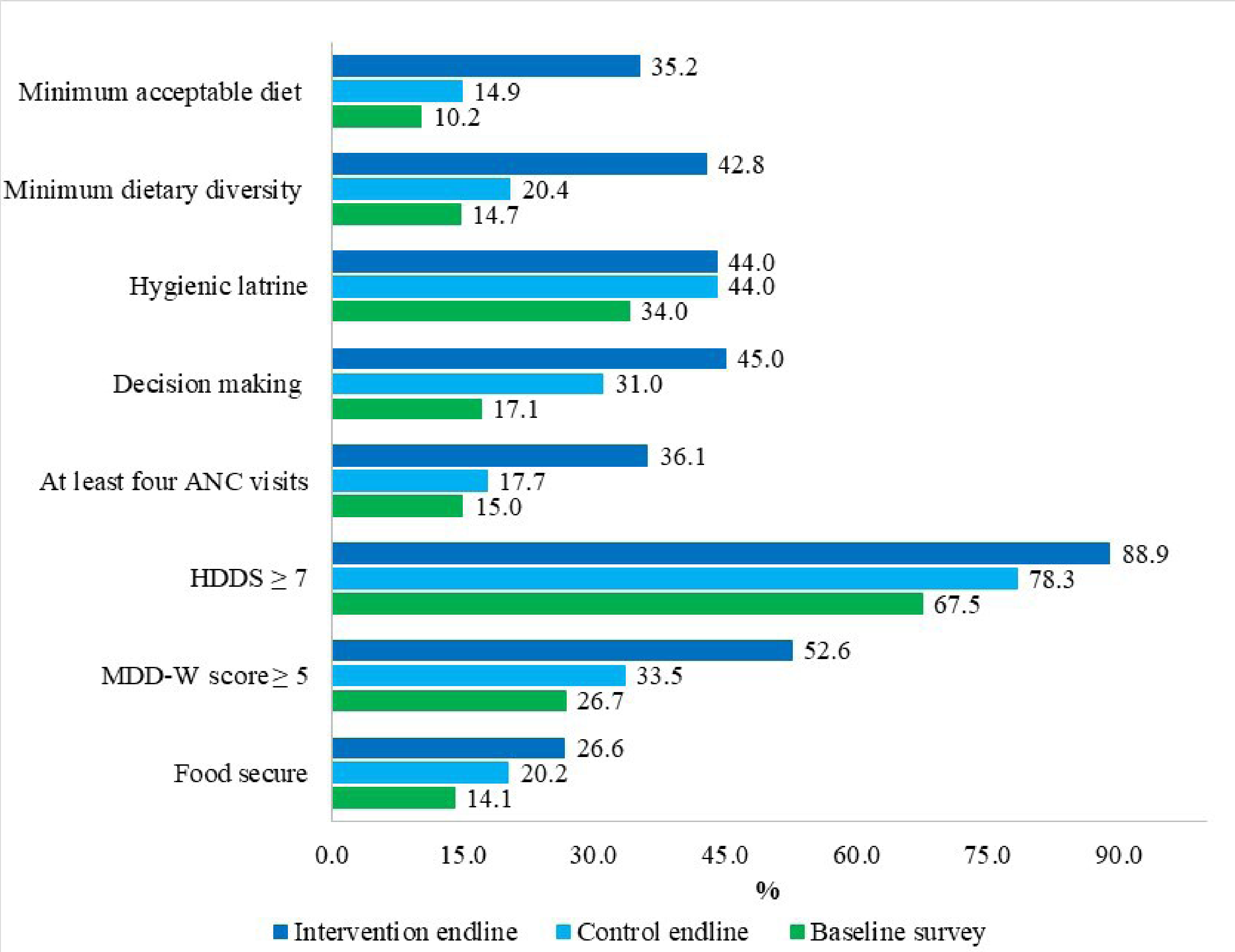

Figure 2 Results framework and *Suchana* log frame indicators. ANC, antenatal care; HDDS, household dietary diversity score; MDD-W, minimum dietary diversity for women.

correlated with stunting and to evaluate the model's predictive performance. After controlling for the *Union* as a cluster variable, the study found several indicators that were significantly related to stunting. These included the number of ANC visits by a skilled service provider, household dietary diversity, household food security and household monthly income, all of which improved after the intervention. However, it was noted that the household food security status did not reach the target value of 50%, despite being an important factor associated with childhood stunting.[8 30 31] On the other hand, other outcome indicators of the *Suchana* programme, such as the dietary diversity of children, maternal dietary diversity and maternal empowerment, despite reaching their target values, were not found to be associated with stunting in this study.

The study found that while the *Suchana* programme showed improvement in certain programme indicators, it did not lead to a significant reduction in childhood stunting. Despite efforts to address key factors such as maternal nutrition and education, household food security and hygiene practices, these factors remained largely unchanged. However, the study suggests that interventions aimed at adolescent mothers may be more effective in improving maternal nutrition and education, since these are age-dependent variables. Additionally, the results of the study were also impacted by natural disasters in 2017, including heavy rains and flooding in the Sylhet region, which resulted in widespread damage to agriculture, aquaculture and homes in the study population.[32 33]

The study found a contradictory relationship between stunting and maternal involvement in income-generating activities, with a higher prevalence of stunting observed among children whose mothers were engaged in various earning activities. Although there was a slight increase in the proportion of mothers involved in income-generating activities after the intervention, the lack of childcare support for working mothers resulted in a marked rise in childhood stunting among low-income households. It is important to address this issue by providing adequate childcare support measures for working mothers from poor families to ensure that the child's essential needs

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Table 2 General characteristics of the *Suchana* beneficiaries

Indicators, n (%)	Baseline n=3200	Endline n=6301	Total n=9501
At least four ANC visits by a skilled service provider			
Yes	408 (12.8)	1530 (24.3)	1938 (20.4)
No	2792 (87.2)	4771 (75.7)	7563 (79.6)
Delivery at skilled birth attendant/facility			
Yes	1000 (31.2)	2769 (44.0)	3769 (39.7)
No	2200 (68.8)	3532 (56.0)	5732 (60.3)
Access of mass media			
Access	563 (17.59)	1169 (18.55)	1732 (18.23)
No access	2637 (82.41)	5132 (81.45)	7769 (81.77)
Mother involved in income-generating activities			
No	3102 (96.9)	5665 (89.9)	8767 (92.2)
Yes	98 (3.1)	639 (10.1)	737 (7.8)
Maternal BMI			
>18.5	1859 (58.1)	4073 (64.6)	5932 (62.4)
<18.5	1341 (41.9)	2231 (35.4)	3572 (37.6)
Mother completed primary education			
Yes	1721 (53.8)	3808 (60.4)	5529 (58.2)
No	1479 (46.2)	2496 (39.6)	3975 (41.8)
Maternal age (years)			
<30	2145 (67.0)	3559 (56.5)	5704 (60.0)
>30	1055 (33.0)	2745 (43.5)	3800 (40.0)
Type of delivery			
Normal	2879 (90.0)	5529 (87.8)	8408 (88.5)
Caesarean	321 (10.0)	772 (12.3)	1093 (11.5)
PNC			
No	2152 (67.3)	4128 (65.5)	6280 (66.1)
Yes	1048 (32.8)	2173 (34.5)	3221 (33.9)
Household severely food insecure			
Yes	912 (28.5)	1016 (16.1)	1928 (20.3)
No	2288 (71.5)	5285 (83.9)	7573 (79.7)
Household monthly income >15 000 BDT			
Yes	424 (13.2)	1015 (16.1)	1439 (15.1)
No	2776 (86.8)	5289 (83.9)	8065 (84.9)
Household involved with aquaculture			
Yes	161 (5.0)	561 (8.9)	722 (7.6)
No	3039 (95.0)	5740 (91.1)	8779 (92.4)
Hygienic latrine			
Yes	1121 (35.0)	2782 (44.1)	3903 (41.1)
No	2079 (65.0)	3519 (55.9)	5598 (58.9)
Water and soap available in handwashing place			
Yes	862 (26.9)	3170 (50.3)	4032 (42.4)
No	2338 (73.1)	3131 (49.7)	5469 (57.6)
Household savings			
No	1080 (33.8)	2876 (45.6)	3956 (41.6)
Yes	2120 (66.2)	3425 (54.4)	5545 (58.4)

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Table 2 Continued

Indicators, n (%)	Baseline n=3200	Endline n=6301	Total n=9501
Sex of household head			
Female	110 (3.4)	501 (8.0)	611 (6.4)
Male	3090 (96.6)	5799 (92.0)	8889 (93.6)
Source of drinking water			
Tube well	2748 (85.9)	5713 (90.7)	8461 (89.0)
Others	452 (14.1)	588 (9.3)	1040 (11.0)
Household dietary diversity score			
≥7	2182 (68.2)	5322 (84.5)	7504 (79.0)
<7	1018 (31.8)	979 (15.5)	1997 (21.0)
Household monthly income (thousand BDT)*	6.7 (5, 10)	7.5 (5.1, 10.8)	7.1 (5, 10.4)
Per capita income (thousand)*	2.6 (1.8, 3.7)	2.9 (2, 4.1)	2.8 (2, 4)
Household size*	6.2±2.4	5.9±2.1	6±2.2
Child's age in month†	17.9±3.5	17.3±3.6	17.5±3.6
Length-for-age z-score†	−2.1±1.2	−2±1.1	−2±1.1
Weight-for-age z-score†	−1.7±1.1	−1.5±1.0	−1.5±1.0
Weight-for-length z-score†	−0.9±1.0	−0.7±0.9	−0.7±1.0
Child's age (months)			
<18	1745 (54.5)	3710 (58.9)	5455 (57.4)
≥18	1455 (45.5)	2594 (41.1)	4049 (42.6)
Child's sex			
Female	1567 (49.0)	3044 (48.3)	4611 (48.5)
Male	1633 (51.0)	3257 (51.7)	4890 (51.5)
Childhood illness in the last 15 days			
Yes	2867 (89.6)	5763 (91.5)	8630 (90.8)
No	333 (10.4)	538 (8.5)	871 (9.2)

*Median (IQR).
†Mean±SD.
BDT, Bangladesh taka; BMI, body mass index; PNC, postnatal care.

are not impacted by the mother's employment status.[13] Additionally, efforts should be made to increase awareness among working mothers regarding the importance of child health and nutrition. This can be achieved through targeted education and outreach programmes that provide information on proper child feeding practices, hygiene and health-seeking behaviours.

The literature suggests that environmental enteropathy may contribute to poor growth among children in rural Bangladesh and may represent an important factor affecting the study population in the *Suchana* programme.[34] Although it was not specifically assessed in this study, indicators such as unsanitary latrines, unimproved floors, a lack of handwashing practices and low education levels were available.[18 35] Improving Water, Sanitation and Hygiene (WaSH) variables, particularly latrine facilities and handwashing practices, may help reduce the burden of stunting in young children. One of the components of the intervention was poultry, but our qualitative findings revealed that many households shared living spaces with poultry, ducks or other animals, which could increase the risk of infections with *Campylobacter* species, a leading foodborne pathogen.[18 36] Previous studies have shown a strong association between stunting and enteropathy among children who do not respond to nutritional interventions, and findings from rural Bangladesh have linked environmental conditions and stunting in children.[37–39] While assessing environmental enteropathy was beyond the scope of the *Suchana* evaluation, collecting data on indicators of enteropathy in the intervention and control areas could help evaluate the impact of appropriate interventions in the future. The failure to achieve the desired outcome may have been due to several factors, including food insecurity and a lack of aquaculture involvement due to natural disasters, poor WaSH status, a lack of focus on maternal education and nutrition and a lack of focus on the risk of enteropathogen burden.

Another important finding based on the postestimation findings as well as the value of the area under the ROC

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Table 3 Factors correlating with stunting in children aged 12–23 months, computed using logistic and probit regression analyses

	Logistic		Probit	
Indicators	**Adjusted OR (95% CI)**	**P value**	**Adjusted coefficient (95% CI)**	**P value**
At least four ANC visits by a skilled service provider				
Yes	Reference		Reference	
No	1.16 (1.05 to 1.30)	0.005	0.09 (0.03 to 0.16)	0.005
Birth attendant/facility				
Skilled	Reference		Reference	
Unskilled	1.11 (1.02 to 1.20)	0.012	0.06 (0.01 to 0.11)	0.012
Mother involved in income-generating activities				
No	Reference		Reference	
Yes	1.18 (1.02 to 1.37)	0.030	0.10 (0.01 to 0.19)	0.030
Maternal BMI				
≥18.5				
<18.5	1.23 (1.12 to 1.36)	0.000	0.13 (0.07 to 0.19)	0.000
Maternal education was primary completed				
Yes	Reference		Reference	
No	1.31 (1.20 to 1.42)	0.000	0.17 (0.12 to 0.22)	0.000
Access of mass media				
Yes	Reference		Reference	
No	1.15 (1.02 to 1.30)	0.025	0.09 (0.01 to 0.16)	0.025
Household food insecurity				
Below severe				
Severe	1.12 (1.00 to 1.24)	0.041	0.07 (0.00 to 0.13)	0.042
Household monthly income >15 000 BDT				
Yes	Reference		Reference	
No	1.12 (1.01 to 1.25)	0.037	0.07 (0.00 to 0.14)	0.035
Involved with aquaculture				
Yes	Reference		Reference	
No	1.19 (1.03 to 1.38)	0.018	0.11 (0.02 to 0.20)	0.018
Household size				
Below seven	Reference		Reference	
Seven or above	1.20 (1.11 to 1.31)	0.000	0.12 (0.06 to 0.17)	0.000
Hygienic latrine				
Yes	Reference		Reference	
No	1.20 (1.10 to 1.30)	0.000	0.11 (0.06 to 0.16)	0.000
Water and soap available in handwashing place				
Yes	Reference		Reference	
No	1.19 (1.08 to 1.30)	0.000	0.11 (0.05 to 0.16)	0.000
Household dietary diversity				
>7	Reference		Reference	
<7	1.17 (1.07 to 1.29)	0.001	0.10 (0.04 to 0.16)	0.001
Child's age (months)				
<18	Reference		Reference	
>18	1.52 (1.39 to 1.67)	0.000	0.26 (0.2 to 0.32)	0.000

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Table 3 Continued

Indicators	Logistic		Probit	
	Adjusted OR (95% CI)	P value	Adjusted coefficient (95% CI)	P value
Child's sex				
Female	Reference		Reference	
Male	1.22 (1.11 to 1.34)	0.000	0.13 (0.07 to 0.18)	0.000
Childhood illness in the last 15 days				
No	Reference		Reference	
Yes	1.20 (1.06 to 1.36)	0.003	0.11 (0.04 to 0.19)	0.003
Sample size and regression diagnostic values for logistic and probit regression analyses	N=9501 Log-likelihood=−6387.94 Wald χ^2 (17)=427.79 P<0.001 Pseudo R^2=0.0298		N=9501 Log-likelihood=−6388.02 Wald χ^2 (17)=441.18 P<0.001 Pseudo R^2=0.0298	

Unions were adjusted as clusters. Baseline and endline were adjusted as time variables.
BDT, Bangladesh taka; BMI, body mass index.

curve was that the predictive performance of the model was low. Thus, we need to identify other indicators from similar research contexts that correlated with childhood stunting but were not included in our model. Future research in the field of childhood stunting should give priority to the development of more suitable methods for monitoring and identifying effective interventions. It is also essential to collect data that considers biological and environmental factors related to childhood stunting, following the literature. By considering these diverse factors, we can improve the accuracy and predictive performance of statistical models. This, in turn, can help draw more reliable conclusions about the effectiveness of interventions aimed at reducing childhood stunting in similar contexts. Additionally, evaluating the model on an independent dataset or conducting external validation could help to determine the generalisability of the model to new data.

This study will aid programme managers in prioritising their focus and designing effective interventions to reduce childhood stunting. Sustainable solutions should be based on the needs of the beneficiaries. Implementing short-term initiatives such as attendance at healthcare-led workshops and campaigns can increase ANC visits, skilled birth attendance and handwashing practices. Establishing women's healthcare services that focus on maternal and child health and nutrition will also help reduce the incidence of stunting.[23] Improved access to media can help vulnerable communities benefit from government welfare programmes. Food security, income, sanitation, aquaculture and illness are all time-sensitive factors. Increasing food production through self-production or purchasing can improve household food security and nutrition. However, household wealth and access to nearby markets can impact their ability to buy nutritious food. Climate change adaptation in agriculture is crucial to minimise current risks and prepare for future uncertainties. Using organic fertilisers instead of chemicals in agriculture has environmental benefits, reducing the need for pesticides and protecting human health and biodiversity. Aquaculture can provide a source of protein and improve nutrition, but establishing these facilities takes time. Improving sanitation requires improving socioeconomic status, which is also a time-intensive process. It takes time to improve stunting, as shown by national surveys such as the BDHS and the Food Security and National Surveillance Project.[2 40] Improving maternal nutrition and education is crucial for promoting the optimal growth and development of children. Adequate food, good environmental conditions and access to schooling facilities during adolescence are necessary for women to maintain their own health and to positively impact the health of their children. Emphasising the education of female children can break the cycle of poverty and stunting, as it can lead to improved knowledge and decision-making skills related to nutrition and health.[6 11] To reduce childhood stunting in low-income and middle-income countries, comprehensive interventions that include nutritional support, food security, maternal education, income-generating activities for women with childcare support and addressing domestic violence against women should be implemented. These interventions should be tailored to the specific needs and cultural context of the community in which they are implemented, and community participation and engagement are essential for their success. By addressing the underlying factors contributing to childhood stunting, we can make significant progress towards reducing its prevalence and improving the health and well-being of children in low-income and middle-income countries. Furthermore, continued monitoring and evaluation of these interventions is essential to ensure their effectiveness and to identify areas for improvement.

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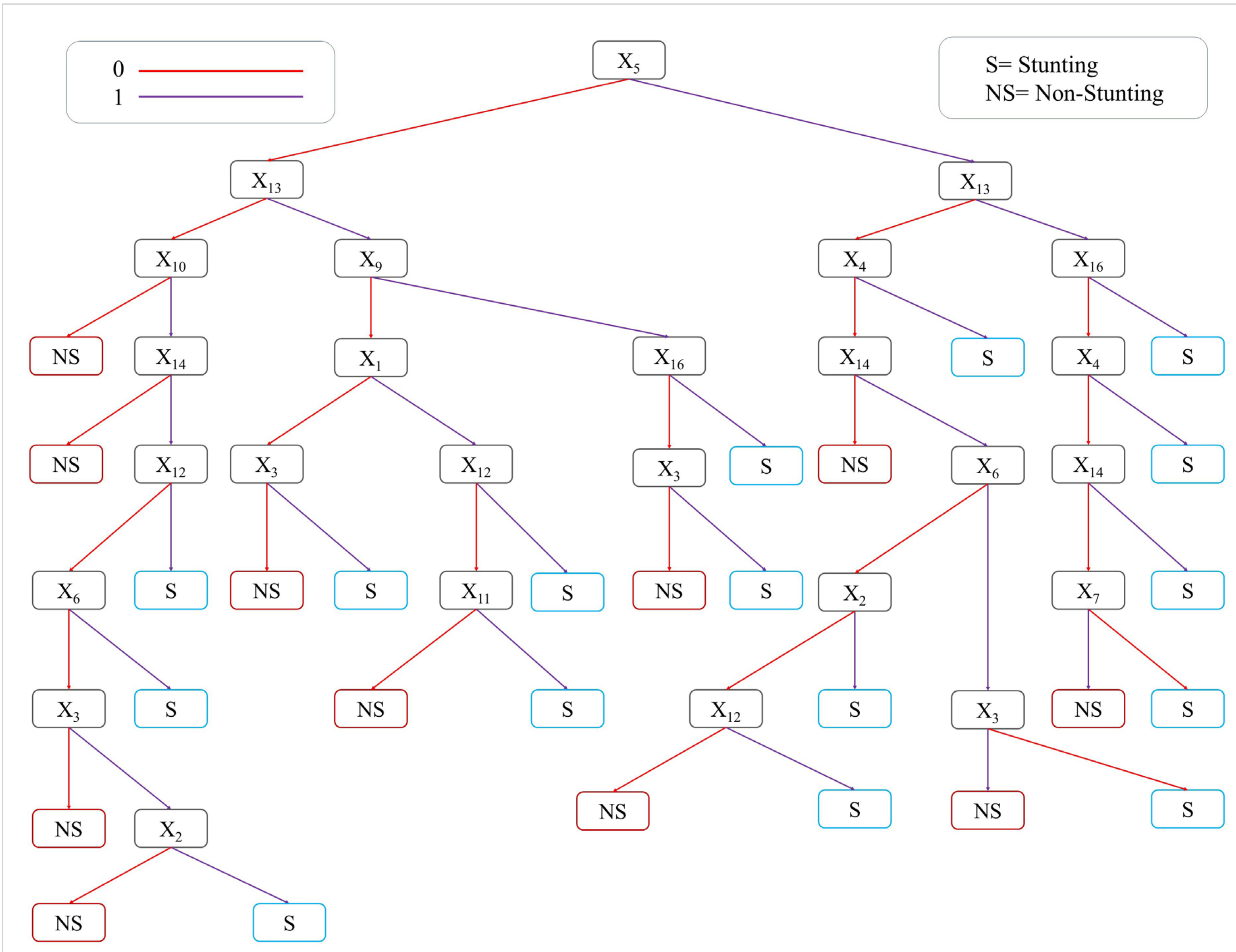

Figure 3 Factors correlating with stunting in children aged 12–23 months, computed using decision tree analysis (X_1: less than four ANC visits by a skilled service provider, X_2: unskilled birth attendant/facility, X_3: mother involved in income-generating activities, X_4: maternal body mass index <18.5, X_5: maternal education: no schooling, X_6: household severe food insecurity, X_7: monthly income <15 000 Bangladesh taka, X_8: did not involve with aquaculture, X_9: having unhygienic latrine, X_{10}: soap was unavailable in hand washing place, X_{11}: household size ≥7, X_{12}: household dietary diversity score <7, X_{13}: child's age >18 months, X_{14}: child's sex was male, X_{15}: childhood illness in the last 15 days, X_{16}: lacked access to mass media).

Recommendation

The *Suchana* model offers a holistic and integrated approach to addressing food and nutrition security, recognising undernutrition as a complex problem caused by multiple factors. The endline survey of *Suchana* showed significant improvement in programme indicators. The multisector approach of *Suchana* is a meaningful solution to addressing undernutrition. However, policy makers should consider implementing additional nutrition-sensitive and nutrition-specific activities, such as promoting climate-resilient agriculture and increasing water and sanitation coverage. It is also important to have a sustainable mechanism for improving food security and to promote awareness of seasonal diseases associated with livestock and poultry. To further improve the programme, indicators such as child sex, maternal education and nutrition could be adjusted during the design stage. The *Suchana* programme is one of the largest global nutrition interventions, leading to positive changes in critical indicators, with long-term benefits expected for the health and livelihoods of the beneficiaries.

Strength and limitation

The study had several strengths, including a large sample size, randomization and appropriate sampling techniques. A dedicated quality control team was involved in checking the data, and the use of precise anthropometry instruments and separate training for the measurement team helped ensure accurate data collection. The study was also designed to avoid seasonality by conducting the baseline and endline surveys at the same time of the year. However, the study results may have been impacted by a lack of selection effect in the implementation of the programme, as well as by the short time horizon of the

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Table 4 Predictive performance of the model for stunting based on classification, sensitivity and specificity in the full, training and test datasets with area under the receiver operating characteristic curve analysis

	Logistic regression	Probit regression	Decision tree
Full dataset			
Overall accuracy	58.46	58.38	56.51
Sensitivity	61.21	61.25	61.15
Specificity	55.61	55.41	51.70
Area under the curve	61.54	61.54	56.72
Training dataset			
Overall accuracy	58.83	58.62	57.66
Sensitivity	61.59	61.70	63.93
Specificity	55.36	55.42	51.61
Area under the curve	61.37	61.37	58.44
Test dataset			
Overall accuracy	58.11	58.19	56.67
Sensitivity	60.23	60.23	61.58
Specificity	55.90	56.07	51.94
Area under the curve	61.76	61.77	58.01

study. The short duration of the study may not have been enough to see a significant impact on stunting. Additionally, changes in the study population between the baseline and endline surveys could also have contributed to the lack of differences observed in the results. Another limitation of this study is that we did not collect food intake data but only recall data from the previous 24 hours. These data may be subject to recall bias; thus, caution is necessary when drawing conclusions, especially for indicators such as dietary diversity, household food insecurity, domestic violence and maternal healthcare. Finally, using a binary indicator of stunting based on a single LAZ cut-off point, which was defined as <–2, may not provide a comprehensive assessment of the severity of malnutrition among children, as it fails to account for micronutrient deficiencies

CONCLUSION

Our study revealed that childhood stunting was significantly correlated with a multitude of factors, and majority of the factors were found in poor status in our study area. Despite the implementation of an intervention programme, the situation remained unchanged due to factors such as food insecurity, lack of involvement in aquaculture, poor access to WaSH facilities and a lack of focus on maternal education and nutrition. The study did not include important indicators such as enteropathogen and environmental enteric dysfunction, which might have contributed to the failure to achieve the desired outcome. The results suggest that policy makers and programme planners should consider enhancing collaboration and coordination between nutrition-sensitive and nutrition-specific activities to address nutritional deficiencies and family health programmes in vulnerable rural populations.

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Patient consent for publication Consent obtained directly from patient(s).

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Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. Data are available upon reasonable request. All data relevant to the study are included in the article or uploaded as supplemental information. The data of this study on which the findings are based upon, are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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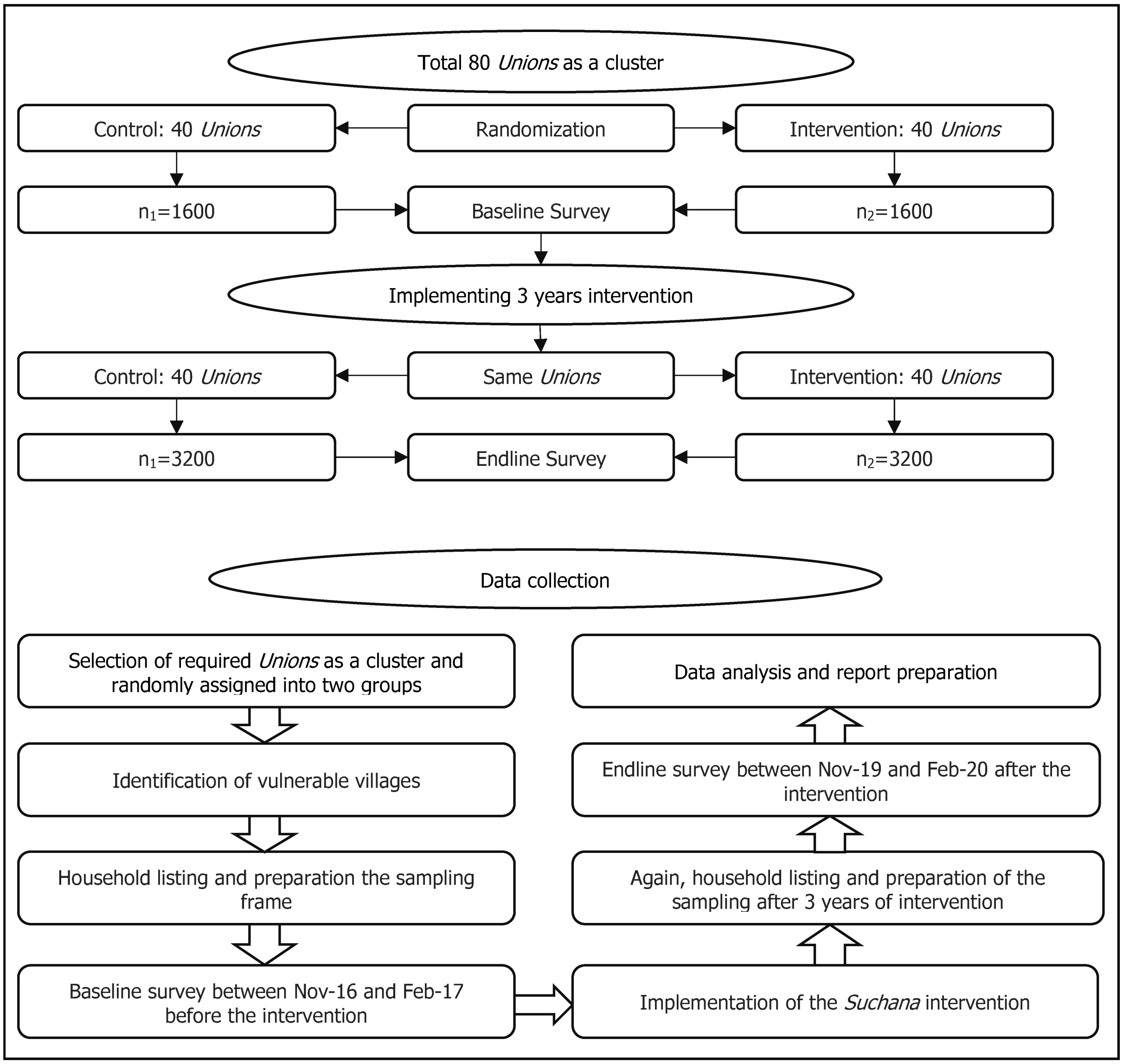
Appendix 1. Sample size calculation

```
clustersampsi, binomial samplesize p1(0.47) p2(0.41) k40) rho0.01)alpha(0.05) beta(0.8)
```

Output of the STATA command for sample size calculation

```
Sample size calculation to determine number of observations required per cluster, for a two-
sample comparison of proportions (using normal approximations) without continuity correction.

For the user specified parameters:
      p1: 0.4700
      p2: 0.4100
      significance level:  0.05
      power:  0.80
      number of clusters available:  40
      intra cluster correlation (ICC):  0.0100
clustersampsi estimated parameters:
      Firstly, assuming individual randomisation: sample size per arm: 1071
      Then, allowing for cluster randomisation: average cluster size required:  38
      sample size per arm:   1520
```



Supplementary Figure 1. The evaluation diagram of *Suchana* programme

Appendix 2. Data collection

The Suchana data collection software contained built-in validation rules. As the data were entered at the interviewer level and the records were uploaded to a server at the icddr,b using the built-in internet connectivity of the devices, maximum validation rules were set in the data system to prevent errors during data entry, which reduced the data entry burden. This allowed the data analysis team to review the consistency of the data every day. Data were synchronized to the central server "Web Service" developed in Asp.Net based on the C# (C Sharp) code. Activities such as editing (after receiving any feedback from field staff members), updating, range checks, duplication checks, consistency checks, frequency checks and cross tabulation were regularly performed during the data entry period. In case of any unusual observations, the issues were discussed and resolved.

Appendix 3. Equation of logistic and probit regression

$logit(y)= \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + \beta_{12}X_{12} + \beta_{13}X_{13} + \beta_{14}X_{14} + \beta_{15}X_{15} + \beta_{16}X_{16}$

$probit(y)= \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + \beta_{12}X_{12} + \beta_{13}X_{13} + \beta_{14}X_{14} + \beta_{15}X_{15} + \beta_{16}X_{16}$

Where,

x1: Less than four ANC visits by a skilled service provider
x2: Unskilled birth attendant/facility
x3: Mother involved in income-generating activities
x4: Maternal BMI <18.5
x5: Maternal education: no schooling
x6: HH severe food insecurity
x7: Monthly income <15000 BDT
x8: Did not involve with aquaculture
x9: Having unhygienic latrine
x10: Soap was unavailable in hand washing place
x11: HH size≥7
x12: HH dietary diversity score <7
x13: Child's age>18
x14: Child's sex was male
x15: Childhood illness in the last 15 days
x16: Lacked access to mass media

and

$logit(y) = log[y/(1-y)]$

Supplementary Table 1. *Suchana* inclusion criteria for registration of enrolling as vulnerable households

Vulnerable household verification questions	Inclusion criteria
Step 1 • Households currently participating/member of any livelihood, food security or asset transfer program	If "NO" go ahead for next questions
Step 2 • Ability to afford three (3) full meals per day for all family members round the year • Households monthly income BDT 7,500 or more • Household productive asset value worth BDT 15,000 or more (excluding land, pond and homestead) • Ownership of homestead land 10 decimals or more • Ownership of cultivable land 50 decimals or more (excluding homestead or pond)	If anyone is "NO" go ahead for next questions
Step 3 • Households have married women with in child bearing age (15 to 45 years) • Households have pregnant women (including abandoned or widowed woman) • Households have 0-23 months old children • Households have adolescent girls (15-19 years)	If anyone is 'Yes' go ahead for registration of enrolling as vulnerable Household
Sampling frame was prepared for collecting data from mother-child pair if the households had 0-23 months old children	

Supplementary Table 2a. Predictive ability of various indicators for the adjusted prevalence of stunting and adjusted prevalence difference (effect size) in the fitted multiple logistic regression model.

	Prediction of adjusted stunting [% (95% CI)]	Prediction of adjusted prevalence difference as effect size*	p-value
At least four ANC visits by a skilled service provider			
Yes	51.64 (50.05, 53.23)	Reference	
No	47.99 (45.46, 50.53)	3.65 (1.07, 6.22)	0.006
Birth attendant/facility			
Skilled	51.87 (50.23, 53.51)	Reference	
Unskilled	49.42 (47.48, 51.36)	2.45 (0.55, 4.35)	0.012
Mother involved in income-generating activities			
No	54.55 (50.90, 58.19)	Reference	
Yes	50.59 (49.08, 52.11)	3.95 (0.40, 7.51)	0.029
Maternal BMI			
BMI ≥18.5	54.04 (52.01, 56.07)	Reference	
BMI <18.5	49.01 (47.21, 50.81)	5.03 (2.66, 7.41)	<0.001
Maternal education was primary completed			
Yes	54.66 (52.58, 56.74)	Reference	
No	48.21 (46.67, 49.75)	6.45 (4.49, 8.40)	<0.001
HH food insecurity			
Below severe	53.03 (50.91, 55.15)	Reference	
Severe	50.36 (48.63, 52.09)	2.66 (0.11, 5.22)	0.041
HH monthly income ≥15000 BDT			
Yes	51.31 (49.79, 52.84)	Reference	
No	48.58 (45.86, 51.30)	2.73 (0.17, 5.30)	0.037
Involved with aquaculture			
Yes	51.22 (49.72, 52.72)	Reference	
No	46.99 (43.30, 50.69)	4.23 (0.73, 7.73)	0.018
Hygienic latrine			
Yes	52.67 (50.94, 54.4)	Reference	
No	48.36 (46.5, 50.23)	4.31 (2.34, 6.28)	<0.001
Water and soap available in handwashing place			
Yes	52.64 (50.71, 54.58)	Reference	
No	48.54 (46.74, 50.33)	4.10 (1.83, 6.38)	<0.001
HH size			
Below seven	53.86 (51.98, 55.74)	Reference	
Seven or above	49.41 (47.70, 51.13)	4.44 (2.43, 6.46)	<0.001
HH dietary diversity			
HDDS ≥7	53.92 (51.25, 56.60)	Reference	
HDDS <7	50.10 (48.70, 51.50)	3.83 (1.63, 6.02)	<0.001
Child's age			
Age ≤18 months	56.72 (54.77, 58.67)	Reference	
Age >18 months	46.59 (44.82, 48.35)	10.1 (7.94, 12.32)	<0.001
Child's sex			
Female	53.25 (51.17, 55.34)	Reference	
Male	48.40 (46.78, 50.03)	4.85 (2.59, 7.10)	<0.001
Childhood illness in the last 15 days			
No	54.90 (52.04, 57.77)	Reference	
Yes	50.49 (48.94, 52.05)	4.41 (1.48, 7.34)	0.003
Access of mass media			
Yes	51.51 (49.88, 53.15)	Reference	
No	48.13 (45.39, 50.88)	3.38 (0.42, 6.34)	0.028

*Differences in the predicted values of stunting between the two groups were calculated using the Stata "*adjrr*" package

Supplementary Table 2b. Predictive ability of various indicators for the adjusted prevalence of stunting and adjusted prevalence difference (effect size) in the fitted multiple probit regression model.

	Prediction of adjusted stunting [% (95% CI)]	Prediction of adjusted prevalence difference as effect size*	p-value
At least four ANC visits by a skilled service provider			
Yes	51.64 (50.05, 53.23)	Reference	
No	47.99 (45.46, 50.53)	3.65 (1.08, 6.22)	0.007
Birth attendant/facility			
Skilled	51.87 (50.23, 53.51)	Reference	
Unskilled	49.42 (47.48, 51.36)	2.45 (0.54, 4.35)	0.011
Mother involved in income-generating activities			
No	54.55 (50.90, 58.16)	Reference	
Yes	50.59 (49.08, 52.11)	3.93 (0.39, 7.48)	0.024
Maternal BMI			
BMI ≥18.5	54.04 (52.01, 56.07)	Reference	
BMI <18.5	49.01 (47.21, 50.81)	5.03 (2.66, 7.40)	<0.001
Maternal education was primary completed			
Yes	54.66 (52.58, 56.74)	Reference	
No	48.21 (46.67, 49.75)	6.45 (4.49, 8.41)	<0.001
HH food insecurity			
Below severe	53.01 (50.89, 55.12)	Reference	
Severe	50.37 (48.64, 52.10)	2.64 (0.09, 5.19)	0.042
HH monthly income ≥15000 BDT			
Yes	51.32 (49.79, 52.84)	Reference	
No	48.56 (45.84, 51.28)	2.75 (0.19, 5.32)	0.035
Involved with aquaculture			
Yes	51.22 (49.73, 52.71)	Reference	
No	46.99 (43.28, 50.69)	4.24 (0.73, 7.74)	0.018
Hygienic latrine			
Yes	52.67 (50.94, 54.4)	Reference	
No	48.36 (46.5, 50.23)	4.31 (2.34, 6.28)	<0.001
Water and soap available in handwashing place			
Yes	52.64 (50.71, 54.58)	Reference	
No	48.53 (46.74, 50.33)	4.11 (1.83, 6.39)	<0.001
HH size			
Below seven	53.86 (51.98, 55.73)	Reference	
Seven or above	49.41 (47.70, 51.13)	4.44 (2.43, 6.46)	<0.001
HH dietary diversity			
HDDS ≥7	53.90 (51.23, 56.57)	Reference	
HDDS <7	50.10 (48.71, 51.50)	3.79 (1.60, 5.98)	<0.001
Child's age			
Age ≤18 months	56.72 (54.76, 58.67)	Reference	
Age >18 months	46.59 (44.83, 48.35)	10.1 (7.93, 12.3)	<0.001
Child's sex			
Female	53.25 (51.17, 55.33)	Reference	
Male	48.41 (46.78, 50.03)	4.85 (2.60, 7.10)	<0.001
Childhood illness in the last 15 days			
No	54.90 (52.04, 57.75)	Reference	
Yes	50.50 (48.94, 52.05)	4.40 (1.47, 7.33)	0.003
Access of mass media			
Yes	51.51 (49.88, 53.15)	Reference	
No	48.13 (45.40, 50.86)	3.38 (0.42, 6.34)	0.028

*Differences in the predicted values of stunting between the two groups were calculated using the Stata "*adjrr*" package