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Original Research Article

Machine learning algorithms for predicting the determinants of minimum dietary diversity among Bangladeshi children

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ABSTRACT

Background: In developing countries, the minimum dietary diversity (MDD) measure of dietary quality is widely used to define the dietary habits of infants between the ages of 6 and 23 months. However, the particular situation in Bangladesh shows that just 34% of kids have access to a food that complies with the bare minimum acceptable norms. The main aim of this study was to predict the determinants of minimum dietary diversity (MDD) among Bangladeshi children.
Methods: This study was based on data from the Bangladesh Demographic and Health Survey (2017-2018 BDHS). Statistical analysis involving a χ^2 test alongside machine learning (ML) algorithms was employed to identify the factors associated with MDD and to predict the factors influencing MDD outcomes within the context of Bangladesh.
Results: The random forest (accuracy =0.854, specificity =0.639, sensitivity =0.927, precision =0.883, F1-score = 0.905, area under the curve: AUC = 0.711) show the best performance than others machine learning model. The random forest model shows the "division", "mother age", "wealth index", "partner education", "total number of children" and "mother education" play an important role to predict the determinants of MDD in Bangladesh.
Conclusions: To enhance newborn and young child feeding practices, it is strongly advised to boost women's empowerment and mother's education. To protect the health of infants, government healthcare authorities should implement public education programs and awareness campaigns in addition to enforcing the appropriate laws and regulations.

Keywords: Bangladesh, Children, Food, Machine learning, MDD

INTRODUCTION

Diversity of diet has been acknowledged as a prime element of high quality of diets for long. The WHO and UNICEF recently updated the MDD definition from consumption of ≥4 of 7 food groups in the previous 24 hours (MDD-7) to ≥5 of 8 food groups (MDD-8), adding a breastmilk group.[1] Malnutrition is a major issue in underdeveloped nations, where it either directly or indirectly accounts for half of all worldwide fatalities among children under the age of five.[2] Globally, most of the children are not receiving adequate nutritious and diversified food. During the first two years of life, there are more than two-thirds of malnutrition related child deaths due to inappropriate feeding practice.

An estimated 6% of under-five deaths can be prevented by ensuring optimal complementary feeding among which dietary diversity and meal frequency are the most important ones, significantly contributing to the realization of millennium development goal 4.[3] According to the World Health Organization (WHO), indicators of proper complimentary feeding are starting of solid, semi-solid or soft foods, minimum meal frequency,

minimum dietary diversity, minimum acceptable diet, and consumption of iron-rich or iron-fortified foods.[4] For better growth WHO suggested to initiate breastfeeding within one hour of birth, exclusive breastfeeding for the first six months of life, introducing complementary food at six months of age, continuing breastfeeding up to two years, no prelacteal feeding, no bottle feeding, and maintaining minimum dietary diversity (MDD). In south-east Asia Bangladesh, achievement of the MDD is necessary for better growth and proper nutrition of the children as chronic malnutrition significantly associated with dietary diversity.[5] According to the Food and Agriculture Organization (FAO), qualitative measure of food consumption is known as dietary diversity that reflects household access to a variety of foods and subsequent for nutrient adequacy of the diet of individuals. Dietary diversity can be assessed by using tools such as dietary scores which sum the number of food groups consumed over a reference period and these are good proxies of overall dietary quality and are useful indicators of household food security.[6]

One of the criteria for complementary feeding developed by the WHO is minimum dietary diversity or giving foods from four or more complementary food groups (grains; legumes/nuts; dairy products; flesh foods; eggs; fruits; and vegetables) to infants 6-23 months. Mother's educational attainment and a higher household monthly income were positively associated with the minimum dietary diversity practice.[7] In Asia, minimum dietary diversity ranges from 15% in India, to 34% in Nepal and 71% in Sri Lanka.[8] However, minimum dietary diversity drops to 19.8% in 6-11-month-olds and nearly triples to 59.7% in 18-23-month-olds.[9]

In developing countries, meeting this minimum standard for nutrition is a challenge, where comprehensive educational programs are often lacking that would educate caretakers on appropriate quality of complementary nutrition. The number of children, media exposure, and wealth quintile all had an impact on feeding behaviors. In order to enhance baby feeding behaviors in Ethiopia, it is crucial to improve economic status, the custom of eating meals together, and media exposure.[3] Furthermore, financial and food insecurity is prevalent. Bangladesh has some of the highest malnutrition rates in the world in part due to a lack of appropriate, complementary nutrition. Given the high rates of malnutrition, stunting, underweight, and wasting in Bangladesh, better understanding factors influencing minimum dietary diversity can be critical for improving child health and well-being.[10]

METHODS

Data

This study was based on data from the Bangladesh Demographic and Health Survey (2017-2018 BDHS), the eighth nationwide survey to provide information on the demographics and health status of women and children. The BDHS (2017-2018) is a national survey that includes a sample of about 20,250 randomly chosen households that is nationally representative. Personal interviews were offered to every previously married woman aged 15 to 49, who permanently resides in the selected households or who stayed overnight in those selected residences prior to the survey.

In the study, children aged 6-23 months were included to predict the determinants of minimum dietary diversity (MDD) among Bangladeshi children. After addressing missing values, a total of 7146 observations were utilized in the study. The study was conducted from March 2023 to September 2023.

Study variables and measurements

In this study, the outcome variable was minimum dietary diversity (MDD)- was measured as a binary outcome. The children were expected to consume at least four of the seven food groups in addition to breastmilk. These were included (i) grains, roots, and tubers; (ii) legumes and nuts; (iii) dairy products (milk, yogurt, cheese); (iv) flesh foods (meat, fish, poultry, liver, or other organs); (v) eggs;(vi) vitamin A-rich fruits and vegetables; and (vii) other fruits and vegetables. To estimated, we summed all the food groups together with scores ranging from 0 to 7. Any child who consumed any of the food groups was assigned a score of one (1) and zero (0) for not consuming a food group. The children who consumed at least four (≥4) of the food groups were said to have an adequate MDD and this was coded as "1" while the remaining children who consumed lower than four food groups were coded as "0 = inadequate".

The independent variables for this study were mother age, division, type of place of residence, mother education, religion, sex of household head, exposure of media, wealth index, total no. of children, breastfeeding status, partner's education, mother working status, and sex of children.

Statistical analysis

Descriptive statistics were employed to calculate the number and frequency of the relevant study variables. A χ^2 test was used to detect the variables related to minimum dietary diversity (MDD). The SPSS V.23 software was operated to perform the data processing and chi-square test. Several widely used machine learning (ML) algorithms- logistic regression (LR), a random forest (RF), decision tree (DT), support vector machine (SVM) models, K-nearest neighbor (KNN), gradient boosted tree and Naïve Bayes- were used to predict minimum dietary diversity (MDD) determinants in Bangladesh. The selection of these machine learning model was based on information from existing literature on the subject.[11]

Ethical consideration

Utilizing secondary data from BDHS, the research drew its foundations; hence, ethical endorsement wasn't necessary. The data was obtained through https://dhsprogram.com/ by adhering to guidelines and fulfilling the stipulated conditions for data confidentiality.

RESULTS

Exploratory data analysis on minimum dietary diversity (MDD)

Table 1 shows the percentage distribution of respondent according to their regional place and also show that maximum number of respondents are from Chittagong (18.0%) then Sylhet (16.2%) and Dhaka (13.7%) division. From Table 1, more than (68.1%) of women were living in rural area whereas only (31.9%) live in urban area that means almost two third of the women live in rural areas. 44.07% of women had secondary level education and (32.9%) of women were in primary education level that means most of the respondent were in primary and secondary level of education category. The maximum (93.7%) of women's religion was Islam and (6.0%) of respondent's religion is Hinduism. The maximum (87.6%) of household head were male and (12.4%) were female. Then also showed that (52.1%) of women were not exposed in watching television and (47.9%) of women were exposed in watching television. Again, the sample respondents come from different family are almost equal.

We can say from Table 2 that respondents have (51.1%) of ≥3 child, (31.5%) of two children in household and (17.4%) of one child in household. And (96%) have breastfeeding status were positive. The percent distribution of respondent partner's education level was (36.5%) of husband in primary level, (29.7%) of secondary level, (17.7%) of no education and (15.8%) of higher education level. So most of the respondent husband's education level were primary and secondary. It was observed that (61.4%) of women are currently not employed whereas only (38.6%) of women were engaged with some kind of work. So most of the women were currently jobless in Bangladesh. Then the sex of child was evenly distributed with (50.9%) of female and (49.1%) of male.

The age of mother, regional place of respondent, type of place of residence, highest educational level of respondent, respondent's wealth index status, exposure of media, highest educational level of respondent's partner, breastfeeding status of respondent, total number of children, currently working condition, and surprisingly respondent's religion was statistically significant predictor for MDD. Sex of household head in household, regional place, and sex of child was not statistically significant (Table 2).

Table 3 illustrates various realized confusion matrices of different ML models. The confusion matrix compares the actual target positive 1602 and negative 543 cases with those predicted by the different ML models. The logistic regression model has true positive (TP) =1581, true negative (TN) =20, false positive (FP) =523, false negative (FN) =21, i.e., 1581 positive and 20 negative classes data points were correctly classified by the logistics regression model and 523 negative and 21 positive classes data points were incorrectly classified by the logistic regression model. The decision tree model had true positive (TP) =1591, true negative (TN) =11, false positive (FP) =532, false negative (FN) =11, i.e., 1591 positive and 11 negative classes data points were correctly classified by the decision tree model and 532 negative and 11 positive classes data points were incorrectly classified by the decision tree model. The maximum 1485 positive and 347 negative classes data points are correctly classified by the RF model, whereas the SVM model failed to correctly classify any negative class data points though classified correctly all positive class data points.

Table 4 shows that the RF model was the efficient one to predict the determinant of minimum dietary diversity (MDD) among Bangladeshi children based on the higher value of the performance parameters in all cases. For instance, the RF model provided 85.4% of accurate prediction (accuracy =0.854), 92.7% of positive cases that were predicted as positive (sensitivity =0.927), 63.9% of negative cases that were predicted as negative (specificity =0.639), 88.3% of positive predictions that were correct (precision =0.883) and 90.5% of F1-score indicating moderate precision and recall (F1-score =0.905). Though commonly used LR model provides the accuracy score (accuracy =0.743) and sensitivity score (sensitivity =0.986) were high but specificity score (specificity =0.037), precision score (precision =0.751) and (F-score =0.853) were less than the RF model. The Table 4 also shows that the SVM model were completely failed to predict the negative case because specificity score (specificity =0.000) and DT has specificity score (specificity =0.020) which is less than the score of RF model. The KNN model provided 75.9% of accurate prediction (accuracy =0.759), 93.3% of positive cases that were predicted as positive (sensitivity =0.933), 24.9% of negative cases that were predicted as negative (specificity =0.249), 78.6% of positive predictions that were correct (precision =0.786) and 85.3% of F1-score indicating moderate precision and recall (F1-score =0.853). Then gradient boosted tree model provided 73.6% of accurate prediction (accuracy =0.736), 91.6% of positive cases that were predicted as positive (sensitivity =0.916), 20.3% of negative cases that were predicted as negative (specificity =0.203), 77.2% of positive predictions that were correct (precision =0.772) and 83.8% of F1-score indicating moderate precision and recall (F1-score =0.838).

Table 1: The percentage distribution of exposure variables along with their categorizations.

Variables names	Variable type	Descriptions	Categorization	Percentage
Age (years)	Nominal	Age in 5-year groups	15-19	10.6
			20-24	28.1
			25-29	29.4
			30-34	21
			35-39	9.1
			40-44	1.7
			45-49	0.1
Division	Nominal	Regional place of respondent	Barisal	10.5
			Chittagong	18
			Dhaka	13.7
			Khulna	9.1
			Mymensingh	12.4
			Rajshahi	9
			Rangpur	11
			Sylhet	16.2
Residence	Nominal	Type of place of residence	Urban	31.9
			Rural	68.1
Education	Ordinal	Highest educational level of respondent	No education	9.5
			Primary	32.9
			Secondary	44.1
			Higher	13.5
Wealth index	Ordinal	Respondent's wealth index status	Poorest	24.9
			Poorer	21.5
			Middle	17.8
			Richer	18.6
			Richest	17.2
Exposure media	Nominal	Frequency of media exposure	Non-exposure	52.1
			Exposure	47.9
Partner education	Ordinal	Highest educational level of respondent's partner	No education	17.7
			Primary	36.5
			Secondary	29.7
			Higher	15.8
Working	Nominal	Respondent currently working condition	No	61.4
			Yes	38.6
Sex head	Nominal	Sex of household head	Male	87.6
			Female	12.4
Breastfeeding Status	Numerical	Currently breastfeeding	No	4
			Yes	96
Children	Numerical	Total number of children in household	One child	17.4
			Two children	31.5
			≥3 children	51.1
Sex child	Nominal	Sex of child	Male	49.1
			Female	50.9
Religion	Ordinal	Respondent's religion	Islam	93.7
			Hinduism	6
			Buddhism	0.2
			Christianity	0.1
MDD	Numerical	MDD	Inadequate	74.4
			Adequate	25.6

Table 2: Minimum dietary diversity (MDD) outcome by study characteristics, BDHS 2017-18 (N=7146).

Variables names	Categorization	MDD		Total (%)	P value
		<4	≥4		
Age (years)	15-19	8	2.6	10.6	0.010
	20-24	20.4	7.7	28.1	
	25-29	22.2	7.2	29.4	
	30-34	15.9	5.1	21	
	35-39	6.7	2.4	9.1	
	40-44	1.1	0.6	1.7	
	45-49	0.1	0	0.1	
Division	Barisal	7.6	2.9	10.5	0.531
	Chittagong	13.2	4.8	18	
	Dhaka	10.1	3.6	13.7	
	Khulna	6.7	2.4	9.1	
	Mymensingh	9.5	3	12.4	
	Rajshahi	6.8	2.2	9	
	Rangpur	8.2	2.9	11	
	Sylhet	12.3	3.9	16.2	
Residence	Urban	22.7	9.2	31.9	<0.001
	Rural	51.7	16.4	68.1	
Education	No education	8	1.5	9.5	<0.001
	Primary	26.1	6.8	32.9	
	Secondary	32.1	12	44.1	
	Higher	8.2	5.3	13.5	
Wealth index	Poorest	20.2	4.8	24.9	<0.001
	Poorer	16.6	5	21.5	
	Middle	13.6	4.2	17.8	
	Richer	13.2	5.3	18.6	
	Richest	10.9	6.3	17.2	
Breastfeeding status	No	2.2	1.8	4	<0.001
	Yes	72.3	23.8	96	
Partner education	No education	18.9	8.7	14	<0.001
	Primary	39.9	26.7	33.5	
	Secondary	30.7	35.6	33.1	
	Higher	10.5	29.1	19.5	
Working status	No	46.5	14.9	61.4	0.001
	Yes	27.9	10.7	38.6	
Religion	Islam	70.1	23.6	93.7	0.010
	Hinduism	4.1	1.9	6	
	Buddhism	0.2	0	0.2	
	Christianity	0	0	0.1	
Sex of head	Male	65.6	22.1	52.1	0.290
	Female	8.9	3.5	12.4	
Exposure media	Non-exposer	41	11.1	52.1	<0.001
	Exposer	33.5	14.4	47.9	
Total number of children	One child	11.8	5.6	17.4	<0.001
	Two children	23.6	7.8	31.5	
	≥3 children	39	12.1	51.1	
Sex of child	Male	36.4	12.6	49.1	0.357
	Female	38	12.9	50.9	

Table 3: Realized confusion matrices of different machine learning models.

Classifier	Predicted	Actual	
		Positive	Negative
LR	Positive	1581	523
	Negative	21	20
SVM	Positive	1602	543
	Negative	0	0
RF	Positive	1485	196
	Negative	117	347
DT	Positive	1591	532
	Negative	11	11
KNN	Positive	1495	408
	Negative	107	135
Gradient boosted tree	Positive	1468	433
	Negative	134	110
Naïve Bayes	Positive	1512	464
	Negative	90	79

Table 4: Accuracy, sensitivity, specificity, precision and F1-score of machine learning models.

Models	Accuracy	Sensitivity	Specificity	Precision	F1-score
LR	0.743	0.986	0.037	0.751	0.853
SVM	0.747	1.000	0.000	0.747	0.855
RF	0.854	0.927	0.639	0.883	0.905
DT	0.747	0.993	0.020	0.749	0.854
KNN	0.759	0.933	0.249	0.786	0.853
GBT	0.736	0.916	0.203	0.772	0.838
NB	0.742	0.944	0.145	0.765	0.845

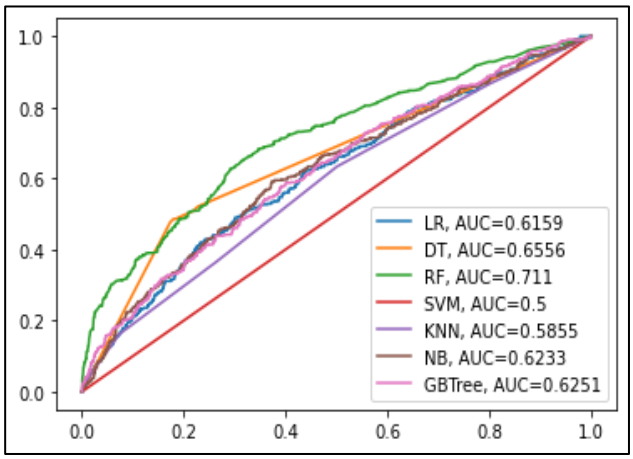

Figure 1: The ROC curve to predict the determinants of MDD among Bangladeshi children using LR, DT, RF, SVM, KNN, NB, and GB tree.

Figure 1 depicts that to predict the determinants of MDD among Bangladeshi children the estimated AUC scores. It was found that the area under the ROC curve (AUC) for logistic regression was 0.6159, for decision tree was 0.6556, for random forest was 0.711, for support vector machine was 0.5, for K-nearest neighbor was 0.5855, for Naïve Bayes was 0.6233 and gradient boosted tree was 0.6251. So, comparing all the score of AUC, we can say that random forest provides the highest score of AUC among all examined ML models. Therefore, random forest model performs great with respect to other models.

DISCUSSION

Inadequate feeding practices, which play a major role in the emergence of malnutrition in early children, represent one of the key obstacles to sustained socioeconomic progress and the decrease of poverty. Motivated by such an obvious public health issue, this research helps to predict the determinants of minimum dietary diversity (MDD) among Bangladeshi children using different ML algorithms. These ML algorithms were applied by using 70% of the individuals in each group (training data set) and approved in the remaining 30% (test data set). All models were trained based on 10-fold cross-validation. We used 10-fold cross-validation on the training set, and the performance was estimated on the testing set.

The predictive performance of these five ML algorithms was compared based on the score of accuracy, precision, sensitivity, specificity, F1-score, and ROC curve. Based on various performance parameters, the best results have been accomplished by the RF algorithm, which demonstrated an accuracy of 85.4%, a sensitivity of

92.7%, a specificity of 63.9%, a precision of 88.3% and F1-score of 90.5%. Along these lines, we can presume that the RF algorithm was moderately superior to any other ML algorithms used in this study to predict the determinants of MDD among children. By other studies similarly findings that the RF algorithm was moderately superior to any other ML algorithms used to predict malnutrition status among under-five children in Bangladesh and they consider only three parameters (accuracy, sensitivity, specificity). When the main objective was to forecast malnutrition, they suggested using RF classification with RF feature selection. And another study conducted by Khare et al showed that an ML approach such as logistic regression identifies some important features when used to predict nutritional status of children in India.[2] This may be due to the data set that was used. Our study revealed that using RF models is the best practice for predicting the determinants of minimum dietary diversity (MDD) among Bangladeshi children.

In Bangladesh, specifically, minimum dietary diversity was low, at 41.9%, which was lower than in Sri Lanka (71%) but higher than India (15%) and Nepal (34%).[8] A study suggests that a mother's educational attainment was positively associated with the practice of minimum dietary diversity.[7]

Similarly, our study's findings align with this observation. Another study reveals that socioeconomic status also plays a significant role in ensuring dietary diversity, with the wealthiest quintiles having a better opportunity to access and afford a more diverse diet than the poorest, a pattern that our study also reflects.[12] MDD is significantly associated with the mother's age, the total number of children, partner's education, and breastfeeding practices, as observed in previous studies, which is consistent with our study findings.[13-15]

CONCLUSION

Minimum dietary diversity (MDD) is an important public health concern in all developing countries. This paper presents a comprehensive study for predicting the determinants of MDD among Bangladeshi children. Our findings show that nine factors were selected. These selected factors were used as input features in seven ML-based classifiers to predict the determinants of MDD. Our experimental results indicate that the RF-based system provided the highest accuracy. Our proposed RF system may be used for predicting the determinants of MDD among Bangladeshi children at a lower cost and in less time. To minimize serious consequences and the financial burden on the healthcare system, this study will be useful for healthcare professionals and policy-makers in developing a framework for implementing necessary interventions and healthcare procedures. The practice of feeding young children properly needs improvement, especially for children from low socioeconomic status families and mothers with no formal education.

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