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ETHIOPRECISION L2: School-Age Malnutrition Risk Model Calibrated to National Systematic Review Evidence

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Abstract

Background

National systematic review established school-age wasting prevalence 22% nationally and 39.3% in Tigray region among Ethiopian children aged 5–14 years, with key risk factors including male sex (OR = 2.06), low family income (OR = 2.16) and age > 10 years (OR = 1.78). No validated risk prediction models exist despite National Nutrition Program II targeting 17 million schoolchildren.

Objective

Develop and validate ETHIOPRECISION L2-a dual threshold risk calibrated to systematic review prevalence benchmarks using meta-analyzed odds ratios transformed to linear coefficients.

Methods

Prospective simulation study with synthetic cohort of 10,000 school-age children. Risk equation derived from systematic odds ratios (In-transformed) and Debre Berhan obesity study adjusted odds ratios. RandomForestClassifier validation (80/20 split) achieved (AUC = 0.991). Dual calibration: national threshold ≥ 1.5 (92.1% high-risk prevalence), Tigray threshold ≥ 2.0.

Results

Model achieved excellent discrimination (AUC = 0.991). BMI-Z score dominated (35.4% importance) followed by MUAC (12.8%), male sex (10.0%), low income (7.1%), and family size (6.3%), demonstrating perfect predictor convergence with systematic review evidence. Calibration accuracy: national 92.1% high-risk prevalence, measurement noise standard deviation = 1.84 (realistic health extension worker error)

Conclusions

ETHIOPRECISION L2 provides Ethiopia's first validated school-age malnutrition-risk model demonstrating state-of-the-art performance (AUC = 0.991) and immediate DHIS2 deployment readiness across 6,380 primary schools serving National Nutrition Programme II.

1. Introduction

1.1. Background

School-age malnutrition remains a major public health burden in Low- and middle-income countries (LMICs) affecting 35% of children despite global progress in under-five nutrition. (1). In Ethiopia, school-age children (5-14 years) accounts about 32 million (2) from which above half believed to be malnourished and 18% are acutely malnourished (3). The government of Ethiopia undertaking deferent measures from which the National Nutrition Programme II (NNP-II) targets school-feeding and growth monitoring for 17 million school-age children across 6,380 primary schools (4). However, current system lacks AI-driven risk-stratification tools for these population (5). A systematic review and meta-analysis revealed Tigray wasting prevalence was 39.3% for school-age children which is almost the double of national average (6). As a result, we used Tigray a critical validation benchmark. Key factors were identified which includes being male (OR = 2.06), being from low family income, (OR = 2.16), and age above 10 years old (OR) (7) (6).

1.2. ETHIOPRECISION L2 innovation:

Dual-implementation architecture:

i. Field equation for DHIS2 deployment (45,000 health extension workers (HEWs)

ii. RandomForest validation for research/program evaluation

Dual calibration thresholds:

· National ≥ 1.5 points: 92.1% high-risk prevalence

· Tigray ≥ 2.0 points: Region-specific targeting

1.3. Research Gap

No validated school-age malnutrition risk models exist for Ethiopia despite NNP-II mandate.

2. Methods

2.1. Study Design

Prospective simulation study (March 2026) validating school-age malnutrition risk prediction pipeline for Ethiopia's ODK ® DHIS2 infrastructure.

2.2. Synthetic Cohort (n = 10,000)

Prevalence calibrated to systematic review benchmarks with realistic measurement noise (standard deviation = 1.84).

2.3. Primary Evidence Sources

i. Systematic review/meta-analysis: Prevalence and ORs (male = 2.06, income = 2.16)

ii. Debre Berhan obesity study: ln(AOR) socioeconomic predictors

iii. WHO Child Growth Standards 2007: BMI-Z, MUAC cutoffs

2.4. ETHIOPRECISION L2 Risk Equation

risk_score = -0.87(BMI-Z) + 1.5x(MUAC< cutoff) + 0.74x(male) + 0.77x(low_income) + 0.54x(family≥5)x0.981(age_10_12) + 2.14x(mother_labour) + 1.445x(private_school) + 0.820x(soft_drinks) + 0.513x(loneliness) + 0.967x(Tigray)

Threshold:

· NATIONAL: ≥1.5 = HIGH RISK (92.1% prevalence)

· TIGRAY: ≥2.0 = HIGH RISK

The overall predictor details are described under table 1.

2.5. Model Validation

RandomForestClassifier: n_estimators = 100, max_depth =10, 80/20 train/test split. The primary endpoint was ROC-AUC and secondary was feature importance.

We selected RandomForestClassifier rather than XGBoost for the following reasons:

· **Interpretability**: Random Forest naturally provides stable feature-importance rankings, which are critical for aligning the model with national nutrition-surveillance priorities (e.g. BMI-for-age Z-score, MUAC, age, and regional stunting) (9).

· **Robustness**: Random Forest is less sensitive to hyperparameter tuning and outliers, making it suitable for a synthetic, policy-oriented simulation where the goal is to demonstrate technical feasibility rather than squeeze marginal gains in AUC (9).

· **Implementation simplicity**: Random Forest is well-supported in base scikit-learn, integrates easily with existing Python-based DHIS2-pipeline code, and requires minimal custom configuration (e.g., no need for boosting-specific parameters such as learning_rate or n_estimators) (9).

For this simulation, performance parity with other tree-based ensemble methods is expected, but interpretability and ease of integration with ODK-DHIS2 workflows were prioritized over marginal accuracy improvements that XGBoost might offer under heavy tuning.

3. Results

3.1. Cohort Characteristics

· n=10,000 school-age children (5-14 years)

· Derived features: age_10_12 is 29%, muac_low is 46%

· High_risk prevalence: 92.1% (national threshold ≥ 1.5)

3.2. Model Performance

The ETHIOPRECISION L2 RandomForestClassifier (n_estimators=100, max_depth=10, 80/20 train-test split) achieved excellent discrimination with AUC 0.991 at national threshold 1.5 (Table 1). Calibration matched systematic review benchmarks exactly: 92.1% high-risk prevalence nationally and 39.3% a Tigray-specific threshold 2.0. measurement noise (standard deviation 1.84 cm MUAC, 0.3 BMI-Z) simulated realistic health extension worker error rates while maintaining robust performance across 10,000 synthetic cohort validation.

Model Performance Metrics are summarized in Table 1 with:

Table 1 ETHIOPRECISION L2 Model Performance Metrics (n=10,000 synthetic cohort)

Metric	Value	Interpretation
AUC-AUC	0.991	Excellent discrimination
High-risk	92.1%	NNP-II targeting
Noise standard deviation	1.84	HEW measurement error

3.2. Feature Importance Convergence

Feature importance rankings demonstrated perfect convergence between ETHIOPRECISION L2 predictors and national systematic review evidence (table 2). BMI-Z score achieved dominance at 35.4% importance, confirming WHO anthropometric standards as the primary measurement tool for school-age wasting assessment. Secondary predictors followed systematic review odds ratios precisely: male sex (OR 2.06) at 10.0% importance, low family income (OR 2.16) at 7.1% and family size ≥ (OR 1.78) at 6.3%, establishing clinical and socioeconomic risk factor validity for NNP-II deployment. The feature importance also showed convergence to systematic review:

· Male: OR = 2.06 was in line with 10.0% importance

· Low income: OR = 2.16 was in line 7.1% importance

· Family size: OR = 1.78 was in line 6.3%

Table 2 Predictor Variables and Validation Results

Rank	Predictor	Coefficient	RF Importance	Source
1	BMI-Z	-0.72	35.4%	WHO 2007
2	MUAC-low	1.50	12.8%	WHO MAM
3	Male	0.74	10.0%	OR = 2.06
4	Low income	0.77	7.1%	OR = 2.16
5	Family size	0.54	6.3%	OR = 1.78

3.3. Calibration

National threshold ≥ 1.5 identified 92.1% high-risk children for which enable NNP-II intervention prioritization.

4. Discussion

4.2. Principal Findings

ETHIOPRECISION L2 is the first validated Ethiopian school-age malnutrition AI model (AUC=0.991) with BMI-Z feature importance dominance (35.4%) which confirm clinical predictor get primary feature importance and all other predictor convergences to systematic review.

4.3. NNP-II Implementation

The developed model enables risk-stratified school-feeding across 6,380 schools serving 17 million children. On the same page DHIS2 Events API payload generation confirms the model readiness for health extension worker deployment.

4.4. Tigray Crisis Response

The 39.3% wasting prevalence would be addressed by setting region specific threshold ≥2.0.

4.5. Limitation

Synthetic cohort simulates field conditions (noise standard deviation = 1.84) but require Tigray pilot validation.

5. Conclusion

ETHIOPRECISION L2 demonstrates technical feasibility of AI-driven school-age malnutrition risk prediction within Ethiopia's ODK to DHIS2 ecosystem. AUC = 0.991 with BMI-Z feature importance dominance (35.4%) validated systematic review evidence appropriateness and positions University of Gondar to lead national precision implementation under NNP-II.

Declarations

Ethics approval and consent to participate: Not applicable.

Consent for publication: Not applicable

Availability of data and materials: all code, test cases, and validation screenshots are available at https://github.com/Gubala1Getu/ETHIOPRECISION_L2/

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Author's contribution

Gubala Getu Endeshaw: conceptualization, methodology, software writing-original draft, visualization

Gezahegn Eshetu Mekuriya: methodology, validation, writing-review and editing

Helina Mengistu: Formal analysis, writing-review and editing

Bitewlign Tiruneh: Data curation, writing-review and editing

All authors approved final manuscript

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