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*Research Article*

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# Prevalence, Clinical Forms, and Exploratory Risk Modeling of Malnutrition among Children Aged 6 to 59 Months in the Commune of Aplahoué (Couffo, Benin) in 2020

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**ABSTRACT**

**Introduction:** Child malnutrition remains a major public health issue in Benin. This study assessed its prevalence, clinical forms, and modeled associated risk factors among children in Aplahoué.

**Methods:** An analytical, observational, and cross-sectional study was conducted in 2020 among 313 children aged 6 to 59 months, selected through two-stage cluster sampling. Anthropometric measurements were performed according to WHO (2006) standards. Statistical analyses, including multivariate logistic regressions and ROC curve assessment, were used to identify determinants of malnutrition. The final model integrated relevant sociodemographic and anthropometric variables, with collinearity control and validation through the Hosmer-Lemeshow test.

**Results:** The prevalence of acute, underweight, and chronic malnutrition was 29.4%, 31.7%, and 48.9%, respectively. Severe forms predominated (marasmus: 17.7%). The multivariate predictive modelincluding sex, age, birth weight, maternal BMI, and education levelshowed a modest but statistically significant discriminative ability (AUC = 0.581; p = 0.0206). At the optimal cutoff (0.263), sensitivity reached 76%, indicating a potential utility for early identification of children at risk in a screening context.

**Conclusion:** Child malnutrition remains a major concern in Aplahoué; integrated interventions targeting socio-economic and maternal determinants are essential.

**Keywords:** Malnutrition, Children, Risk Factors, Modeling, Benin

## Introduction

Child malnutrition remains one of the most persistent and multidimensional public health challenges worldwide, profoundly affecting the survival, growth, and cognitive development of children under five years of age [1]. In sub-Saharan Africa, nearly 148 million children are currently affected by stunting, and approximately 45 million suffer from wasting, reflecting a structural and chronic nutritional burden. This situation arises from a complex interplay of biological, environmental, socioeconomic, and institutional factors that shape access to food resources, healthcare services, and education [2,3]. Social determinants of health—particularly poverty, food insecurity, low maternal educational attainment,

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and limited access to safe drinking water and sanitation—play a critical role in the unequal distribution of malnutrition across the African continent [4].

Beyond individual-level determinants, food system dynamics and climatic variability exert a seasonal influence on both the availability and nutritional quality of food, exacerbating vulnerabilities during lean periods [5]. The cumulative effects of poverty, political instability, and climate change therefore contribute to the persistence of both acute and chronic forms of malnutrition [6]. Moreover, children living in fragile settings, such as internally displaced persons (IDP) camps, exhibit malnutrition rates that exceed regional averages, highlighting the health consequences of social disruption and restricted access to essential services [7,8]. Evidence from several meta-analyses further indicates that the convergence of low household income, inadequate feeding practices, and limited access to prenatal care is strongly associated with childhood undernutrition [9].

In response to this complexity, contemporary approaches emphasize the need to integrate socioeconomic and behavioral dimensions into the understanding of malnutrition. Analytical models grounded in social determinants theory and multivariate analysis have demonstrated a variable capacity to distinguish nutritionally at-risk children, depending on context and model calibration…" from those with adequate nutritional status, although their performance remains context-dependent [2,4]. Within this framework, the exploration of predictive factors combining anthropometric and sociodemographic variables represents a promising avenue for informing public policy, strengthening early detection strategies, and improving nutritional planning in low- and middle-income countries.

## Methods

### Study Design and Setting

This analytical, observational, cross-sectional study was conducted in 2020 in the municipality of Aplahoué, located in the Couffo Department in southwestern Benin. The area is characterized by a strong reliance on subsistence agriculture, high levels of monetary poverty, limited access to healthcare services, and suboptimal infant and young child feeding practices.

### Study Population

The study population consisted of all children aged 6 to 59 months residing in the municipality and present at the time of the survey. Parents or legal guardians served as respondents after providing informed consent. Children with major congenital malformations or chronic conditions likely to affect growth, those presenting with acute illness preventing reliable anthropometric measurements, and cases with incomplete or inconsistent data were excluded. These criteria were applied to minimize selection bias.

### Sample Size and Sampling Procedure

A sample of 313 children was selected based on the expected prevalence of stunting in Benin (approximately 33%), with a 5% margin of error and a 95% confidence level. A two-stage cluster sampling design was employed:

- **First stage:** simple random selection of administrative subdivisions (arrondissements) within the municipality of Aplahoué.
- **Second stage:** systematic selection of households with at least one eligible child.

When multiple eligible children were present within the same household, only one child was randomly selected to avoid intra-household correlation of observations.

### Weighting And Sampling Design Adjustment

Statistical weighting was applied to account for the complex sampling design and to correct for unequal probabilities of selection across clusters. All estimates incorporated a design effect coefficient (deff = 1.5) to adjust confidence intervals and enhance the population-level representativeness of the findings.

### Data Collection and Anthropometric Measurements

Data were collected using a structured questionnaire, a portable height board, a calibrated electronic scale, and a mid-upper arm circumference (MUAC) tape. All measurements were performed by specifically trained field investigators.

Anthropometric indices—weight-for-height (WHZ), weight-for-age (WAZ), and height-for-age (HAZ)—were calculated according to the World Health Organization (WHO) Child Growth Standards (2006) using ENA for SMART software, ensuring international comparability of nutritional indicators.

### Quality Control Procedures

A rigorous standardization and quality control protocol was implemented, including:

- systematic double weighing with calculation of the mean value;
- inter-observer reliability checks for height and MUAC measurements;
- daily calibration of weighing scales and zero verification before each measurement;
- on-site supervision by technical supervisors with random quality control checks.

### Statistical Analysis

Statistical analysis included both descriptive and analytical components. Descriptive statistics comprised frequencies, proportions, means, standard deviations, and 95% confidence intervals. Associations between explanatory variables and nutritional status were assessed using chi-square tests and bivariate and multivariable logistic regression analyses.

The final multivariable logistic regression model included relevant sociodemographic and anthropometric variables, notably the child's age and sex, birth weight, maternal age and body mass index (BMI), maternal educational level, and household socioeconomic status score.

Model goodness-of-fit was assessed using the Hosmer–Lemeshow test. Multicollinearity among independent variables was evaluated using the variance inflation factor (VIF), and the discriminatory performance of the model was examined through receiver operating characteristic (ROC) curve analysis and the area under the curve (AUC).

**Ethical Considerations**

All ethical requirements were met, including the acquisition of administrative authorizations, written informed consent from parents or legal guardians, confidentiality of collected data, and dissemination of findings to the community and local health authorities.

**Results**

The study sample included 313 children, with a balanced sex distribution: 50.2% boys and 49.8% girls. Children aged 6–17 months constituted the largest age group (24.0%).

**Table 1: Distribution of children under five years of age-by-age group and sex in the municipality of Aplahoué, 2020.**

| Âge (months) | Boys | | Girls | | Total | | Ratio |
|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | H/F |
| • 6-17 | 37 | 49.3 | 38 | 50.7 | 75 | 24.0 | 1.0 |
| • 18-29 | 36 | 52.9 | 32 | 47.1 | 68 | 21.7 | 1.1 |
| • 30-41 | 36 | 52.2 | 33 | 47.8 | 69 | 22.0 | 1.1 |
| • 42-53 | 28 | 44.4 | 35 | 55.6 | 63 | 20.1 | 0.8 |
| • 54-59 | 20 | 52.6 | 18 | 47.4 | 38 | 12.1 | 1.1 |
| Total | 157 | 50.2 | 156 | 49.8 | 313 | 100.0 | 1.0 |

**Prevalence of acute malnutrition**

Overall, acute malnutrition affected 29.4% of the children, including 7.4% with moderate acute malnutrition and 21.9% with severe acute malnutrition. bilateral pitting edema was observed in 4.2% of cases. The prevalence of acute malnutrition was slightly higher among girls (32.3%) than among boys (26.5%).

**Table 2: Prevalence of acute malnutrition according to weight-for-height z-scores and the presence of edema among children under five years of age in the municipality of Aplahoué, 2020.**

| Indicators | Total n = 310 | Boys n = 155 | Girls n = 155 |
|---|---|---|---|
| Overall malnutrition | (91) 29.4 | (41) 26.5 | (50) 32.3 |
| 95% CI | 24.6 – 34.7 | 20.1 – 33.9 | 25.4 – 40.0 |
| Moderate malnutrition | (23) 7.4 | (9) 5.8 | (14) 9.0 |
| 95% CI | 5.0 – 10.9 | 3.1 – 10.7 | 5.5 – 14.6 |
| Prevalence of severe malnutrition | (68) 21.9 | (32) 20.6 | (36) 23.2 |
| 95% CI | 17.7 – 26.9 | 15.0 – 27.7 | 17.3 – 30.5 |

Severe acute malnutrition was identified in 17.7% of children, while 7.4% presented with moderate acute malnutrition; 4.2% had bilateral pitting edema. Children aged 42–53 months were the most affected, with 24.2% presenting severe forms of acute malnutrition. Overall, 70.6% of children had a normal nutritional status.

**Table 3: Prevalence of acute malnutrition according to weight-for-height z-scores and/or presence of edema by age group among children under five years of age in the municipality of Aplahoué, 2020.**

| Âge (months) | N | Severe wasting | | Moderate wasting | | Normal | | Edema | |
|---|---|---|---|---|---|---|---|---|---|
| | | n | % | n | % | n | % | n | % |
| • 6-17 | 75 | 15 | 20.0 | 3 | 4.0 | 54 | 72.0 | 3 | 4.0 |
| • 18-29 | 68 | 11 | 16.2 | 6 | 8.8 | 49 | 72.1 | 2 | 2.9 |
| • 30-41 | 67 | 9 | 13.4 | 5 | 7.5 | 47 | 70.1 | 6 | 9.0 |
| • 42-53 | 62 | 15 | 24.2 | 7 | 11.3 | 40 | 64.5 | 0 | 0.0 |
| • 54-59 | 38 | 5 | 13.2 | 2 | 5.3 | 29 | 76.3 | 2 | 5.3 |
| Total | 310 | 55 | 17.7 | 23 | 7.4 | 219 | 70.6 | 13 | 4.2 |

**Clinical Forms of Severe Acute Malnutrition**

The majority of children (78.1%) did not present with severe acute malnutrition. Among severe forms, marasmus was the most prevalent (17.7%), followed by kwashiorkor (2.6%) and marasmic kwashiorkor (1.6%).

**Table 4: Distribution of clinical forms of severe acute malnutrition and presence of edema according to weight-for-height z-scores among children under five years of age in the municipality of Aplahoué, 2020.**

| | <-3 z-score | >=-3 z-score |
|---|---|---|
| Edema present | Marasmic kwashiorkor – 5 (1.6%) | Kwashiorkor – 8 (2.6%) |
| Edema absent | Marasmus – 55 (17.7%) | No severe malnutrition – 242 (78.1%) |

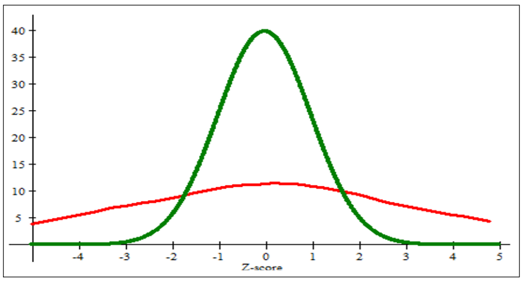


**Figure 1:** Distribution of the weight-for-height z-scores (WHZ) among children aged 6-59 months compared with the WHO reference normal distribution (ENA for SMART), Aplahoué, 2020.

**Prevalence of Underweight (Weight-For-Age)**

Underweight affected 31.7% of the children, including 14.0% with moderate underweight and 17.7% with severe underweight. Similar proportions were observed among boys (30.7%) and girls (32.7%).

**Gaussian distribution of weight-for-height (WHZ) among children**

The observed distribution of weight-for-height Z-scores, is shifted toward negative values. This shift reflects a substantial proportion of children affected by acute malnutrition, with a notable accumulation below the -2 and -3 z-score thresholds. Nevertheless, the presence of a peak near normal values remains consistent with the majority of children having an acceptable nutritional status.

**Table 5: Prevalence of underweight according to weight-for-age z-scores among children under five years of age in the municipality of Aplahoué, 2020.**

| | Total n = 300 | Boys n = 150 | Girls n = 150 |
|---|---|---|---|
| Prevalence of underweight | (95) 31.7 | (46) 30.7 | (49) 32.7 |
| 95% CI | 26.7 - 37.1 | 23.8 - 38.5 | 25.7 - 40.5 |
| Prevalence of moderate underweight | (42) 14.0 | (20) 13.3 | (22) 14.7 |
| 95% CI | 10.5 - 18.4 | 8.8 - 19.7 | 9.9 - 21.2 |
| Prevalence of severe underweight | (53) 17.7 | (26) 17.3 | (27) 18.0 |
| 95% CI | 13.8 - 22.4 | 12.1 - 24.2 | 12.7 - 24.9 |

Overall, 31.7% of children were underweight, with 17.7% presenting severe underweight and 14.0% moderate underweight. The prevalence increased with age, reaching 50.0% of severe forms among children aged 54–59 months. In contrast, 68.3% of children had a normal weight-for-age, while 4.3% presented with nutritional edema.

**Table 6: Prevalence of underweight according to weight-for-age z-scores and presence of edema by age group among children under five years of age in the municipality of Aplahoué, 2020.**

| Âge (months) | N | Underweight | | | | Normal weight | | Edema | |
|---|---|---|---|---|---|---|---|---|---|
| | | Severe | | Moderate | | | | | |
| | | n | % | n | % | n | % | n | % |
| • 6-17 | 72 | 03 | 4.2 | 01 | 01.4 | 68 | 94.4 | 3 | 4.2 |
| • 18-29 | 66 | 05 | 7.6 | 04 | 06.1 | 57 | 86.4 | 2 | 3.0 |
| • 30-41 | 63 | 09 | 14.3 | 11 | 17.5 | 43 | 68.3 | 6 | 9.5 |
| • 42-53 | 63 | 18 | 28.6 | 16 | 25.4 | 29 | 46.0 | 0 | 0.0 |
| • 54-59 | 36 | 18 | 50.0 | 10 | 27.8 | 08 | 22.2 | 2 | 5.6 |
| Total | 300 | 53 | 17.7 | 42 | 14.0 | 205 | 68.3 | 13 | 4.3 |

**Gaussian Distribution Of Weight-For-Age (Waz) Among Children**

The weight-for-age z-score (WAZ) distribution exhibits a general shift toward negative values, with a wide dispersion around the mean. This pattern reflects the combined burden of both acute and chronic forms of malnutrition, as WAZ captures the cumulative effects of recent weight loss and long-term growth failure.

The substantial proportion of children below −2 z-scores confirms a persistent nutritional burden, which increases with age, as evidenced by the rising prevalence of severe underweight among older children.

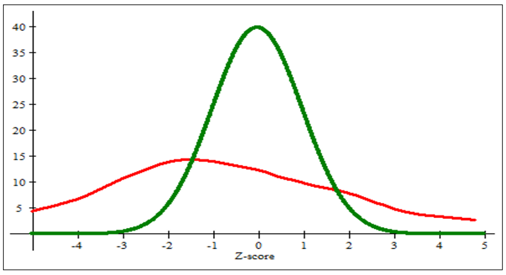


**Figure 2:** Distribution of the weight-for-age Z-scores (WAZ) among children aged 6-59 months compared with the WHO reference normal distribution (ENA for SMART), Aplahoué, 2020.

**Prevalence of Chronic Malnutrition (Stunting)**

Chronic malnutrition affected 48.9% of children, including 11.5% with moderate stunting and 37.4% with severe stunting. Comparable prevalences were observed among boys (50.3%) and girls (47.4%).

**Table 7: Prevalence of chronic malnutrition according to height-for-age z-scores among children under five years of age in the municipality of Aplahoué, 2020.**

| | Total n = 313 | Boys n = 157 | Girls n = 156 |
|---|---|---|---|
| Prevalence of chronic malnutrition | (153) 48.9 | (79) 50.3 | (74) 47.4 |
| 95% CI | 43.4 - 54.4 | 42.6 - 58.0 | 39.8 - 55.2 |
| Prevalence of moderate chronic malnutrition | (36) 11.5 | (19) 12.1 | (17) 10.9 |
| 95% CI | 8.4 - 15.5 | 7.9 - 18.1 | 6.9 - 16.8 |
| Prevalence of severe chronic malnutrition | (117) 37.4 | (60) 38.2 | (57) 36.5 |
| 95% CI | 32.2 - 42.9 | 31.0 - 46.0 | 29.4 - 44.3 |

Overall, 48.9% of children were affected by chronic malnutrition, with severe forms accounting for 37.4% and moderate forms for 11.5%. The prevalence increased markedly with age, reaching 78.9% of severe stunting among children aged 54–59 months. In contrast, 51.1% of children had a normal nutritional status.

**Table 8: Prevalence of chronic malnutrition according to height-for-age z-scores by age group among children under five years of age in the municipality of Aplahoué, 2020.**

| Âge (months) | N | Chronic malnutrition | | | | | |
|---|---|---|---|---|---|---|---|
| | | Severe | | Moderate | | Normal[16] | |
| | | n | % | n | % | n | % |
| • 6-17 | 75 | 04 | 05.3 | 03 | 04.0 | 68 | 90.7 |
| • 18-29 | 68 | 12 | 17.6 | 08 | 11.8 | 48 | 70.6 |
| • 30-41 | 69 | 27 | 39.1 | 16 | 23.2 | 26 | 37.7 |
| • 42-53 | 63 | 44 | 69.8 | 03 | 04.8 | 16 | 25.4 |
| • 54-59 | 38 | 30 | 78.9 | 06 | 15.8 | 02 | 05.3 |
| Total | 313 | 117 | 37.4 | 36 | 11.5 | 160 | 51.1 |

**Gaussian Distribution of Height-For-Age (Haz) Among**

The height-for-age z-score (HAZ) distribution displays a strong leftward deviation, with a high concentration of observations below −2 z-scores, indicating a very high prevalence of chronic malnutrition (stunting).

The flattened and widely spread shape of the curve reflects long-term and cumulative impairment of linear growth, resulting from sustained exposure to nutritional deficiencies, recurrent infections, and adverse living conditions early in life.

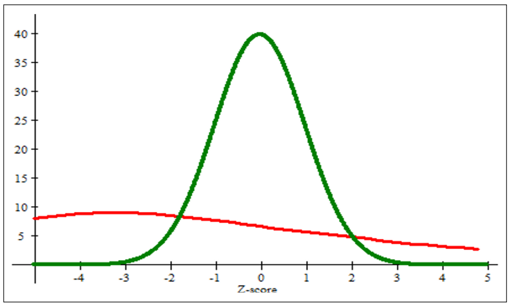


**Figure 3:** Distribution of the height-for-age Z-score (HAZ) among children aged 6-59 months compared with the WHO reference normal distribution (ENA for SMART), Aplahoué, 2020.

**Analysis of Predictors of Malnutrition**

Receiver operating characteristic (ROC) curve analysis of the combined predictive score indicated that the model incorporating sociodemographic and anthropometric variables showed statistically significant but limited discrimination between malnourished and non-malnourished children (AUC = 0.581; p = 0.0206)."

| Indicators | Statistics |
|---|---|
| Area under the ROC curve (AUC) | 0.581 |
| 95% confidence interval | 0.524 – 0.636 |
| Optimal cutoff value (associated criterion) | >0.263 |
| Sensitivity at optimal cutoff | 75.8% |
| Specificity at optimal cutoff | 42.3% |
| Youden index | 0.182 |

The predictive score was derived from the logistic regression model incorporating child sex and age, birth weight, maternal age, maternal body mass index (BMI), maternal educational level, and household socioeconomic status score, thereby capturing the cumulative effect of multiple risk factors. At the optimal cutoff value of 0.263, the model correctly identified nearly 76% of malnourished children, although specificity remained moderate (42%).

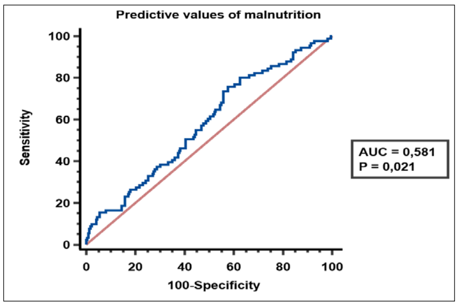


**Figure 4:** ROC curve of predictive factors for malnutrition among children under five years of age in the municipality of Aplahoué, 2020.

**Discussion**

This study highlights a substantial nutritional burden: 29.4% of children were acutely malnourished (7.4% moderate; 21.9% severe) with 4.2% exhibiting edema, 31.7% were underweight (17.7% severe), and 48.9% were chronically malnourished (37.4% severe). These figures depict an epidemiological profile in which severe malnutrition—particularly marasmus (17.7%)—remains the most concerning component, while approximately 70% of children retain normal nutritional indices.

Scientifically, this indicates that the problem is both frequent and heterogeneous: pockets of vulnerability, particularly among children aged 42–53 months and 54–59 months, concentrate the majority of severe cases, suggesting that targeted interventions may be more effective than universal approaches.

This profile is consistent with findings from recent African surveys. For instance, Mathosi et al. (2025) [10] reported a prevalence of acute malnutrition of ≈29% in KwaZulu-Natal, with strong associations between low dietary diversity, older age, and increased risk. Similarly, multi-country and regional analyses highlight the co-occurrence of undernutrition forms and the dominant influence of socioeconomic status and maternal education—observations that align with the current study, where maternal factors (age, BMI, education level) and household socioeconomic status emerged as major determinants of chronic malnutrition and underweight [2,3].

Regarding the ROC analysis and predictive score: the AUC of 0.581 ($p = 0.0206$) indicates statistically significant discrimination, although clinical performance is modest. The model performs better than chance but remains suitable primarily as a first-line screening tool. At the chosen cutoff (0.263), sensitivity is high (~76%), whereas specificity is moderate (42%).

These findings are consistent with the literature. A meta-analysis on the diagnostic accuracy of MUAC in Africa [7] demonstrated that a simple anthropometric marker could achieve a high AUC (≈0.85 for MUAC versus WHZ), but often with a trade-off in sensitivity and specificity depending on the cutoff, illustrating that well-calibrated single indicators (MUAC) can sometimes outperform a poorly calibrated composite score, as observed by Menber et al. (2025) [7]. Recent approaches using machine learning have achieved higher predictive performance by leveraging numerous variables and complex interactions [10], suggesting that the logistic regression-based score in this study could be improved by:

- including additional variables (e.g., access to water, distance to health facilities, dietary diversity);
- modeling interactions and non-linear relationships; or
- recalibrating cutoffs according to operational objectives (prioritizing sensitivity versus specificity).

Finally, reviews on determinants in fragile contexts emphasize the multiplicity of factors (age, socioeconomic status, prenatal care, dietary diversity), supporting the choice of predictors included in this score, while also indicating that incorporating environmental and maternal health measures could further enhance predictive performance.

**Conclusion**

Child malnutrition remains highly concerning in Aplahoué, with elevated rates of acute, underweight, and chronic forms. Key associated factors are related to maternal characteristics and socioeconomic conditions. The developed predictive model may serve as a useful screening tool for the early identification of children at risk. Integrated interventions focusing on nutrition, maternal education, and improved living conditions are essential to sustainably reduce malnutrition in the municipality.

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**Declaration of Conflict Of Interests**

The authors declare no conflicts of interest related to the conduct of this study, data analysis, or manuscript preparation.

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