Predictive Model of Stunting in Children 6-59 Months of Age in Kirundo Health District, Burundi

Nzigamasabo Aloys[1,2,*], Ndayikengurukiye Honoré[2], Nizigama Chris Tresor[3] and Nahimana Paterne[1,2]

[1]*Faculty of Agronomy and Bio-Engineering, Food Science and Technology Department, Food Science and Technology Research Center (CRSTA), Bujumbura, Burundi*

[2]*East African Nutritional Sciences Institutes, Bujumbura, Burundi*

[3]*University of Lake Tanganyika, Bujumbura, Burundi*

Abstract: An analytical cross-sectional study was conducted among a randomly selected sample of 374 households with at least one child aged 6 to 59 months in the Kirundo health district, Burundi. Sociodemographic, socioeconomic, socio-sanitary factors, food insecurity, behavioral, and environmental data were collected using a structured questionnaire. Children's weight was measured using a standard procedure (SECA scale), their height using a standard UNICEF height rod, and their age was obtained from the birth certificate. Anthropometric data were analyzed using Emergency Nutrition Assessment (ENA for Smart) software.

Modeling was performed using logistic regression to eliminate confounding factors, and all independent variables with a significance level less than or equal to 20% in the bivariate analysis were included to explore factors associated with stunting in children aged 6 to 59 months.

In this study, the prevalence of stunting is estimated at 61.5%. According to multivariate logistic regression, sex (AOR = 2.83; 95% CI:1.40-5.75), age (AOR= 10.40; 95% CI: 1.21-88.30), food insecurity (AOR = 10.47;95% CI: 3.58-30.61), latrine type (AOR = 6.83; 95% CI: 3.12-14.94), diarrhea (AOR = 2.56; 95% CI: 1.19-5.48), water source (AOR = 3.17; 95% CI: 1.54-6.52), media exposure (AOR = 0.24, 95% CI: 0.11-0.51), nutritional knowledge (AOR = 0.11; 95% CI: 0.05-0.25), birth spacing (AOR = 0.39, 95% CI: 0.16-0.93), complete vaccination (AOR = 0.06; 95% CI: 0.02-0.21), father's occupation (AOR = 0.25; 95% CI: 0.09-0.72), and mother's education (AOR = 0.21; 95% CI: 0.07-0.64) were significantly associated with stunting.

The predictive model showed an area under the curve (AUC) of 0.95, indicating excellent discrimination ability.

The high prevalence of stunting in this study highlights the importance of urgent action to end this problem.

Keywords: Stunting, predictive model, Kirundo health district, children 6 to 59 months.

1. INTRODUCTION

Stunting is defined as a height-for-age below -2 standard deviations from the median of the WHO reference population standard [1, 2]. It is a public health problem of worldwide concern, particularly in low- and middle-income countries, including Burundi [3]. It seriously affects the physical, cognitive, and economic development of children and society [4].

One of the global problems that impede human growth is stunting, which occurs in children with low height-for-age due to chronic malnutrition [5]. It is defined as height-for-age less than 2 times the standard deviation of the median of the World Health Organization (WHO) Child Growth Standard reference population resulting from chronic or recurrent undernutrition [2, 6]. Growth failure, which can occur from pregnancy until the age of 24 months, is a form of growth failure resulting from a prolonged accumulation of nutritional deficiencies. The short-term effects of malnutrition include increased morbidity and mortality, impaired cognitive, motor, and language development, and increased economic burdens related to the costs of caring for and treating sick children [7]. In the long term, it causes poor reproductive health, decreased concentration during learning, and reduced productivity at work [8, 9].

In 2019, the number of children under five years of age with stunting had been significantly reduced since 2000 in nearly all WHO regions, including Asia, where the prevalence had decreased by almost half [3, 4]. In Africa, however, the number of stunted children increased by more than 15% over the same period [10]. The prevalence of stunting was estimated at 35% of children under five years of age in sub-Saharan Africa, while the Eastern African region had the highest prevalence at 37% [11]. According to the WHO Nutrition Landscape Information System, stunting reflects the cumulative effects of undernutrition and infections since and even before birth [12]. Stunting is

*Address correspondence to this author at the Faculty of Agronomy and Bio-engineering, Food Science and Technology Department, Food Science and Technology Research Center (CRSTA), Bujumbura, Burundi;
E-mail: naloys@gmail.com

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caused by various interrelated factors that promote persistent or recurrent illness and/or inadequate dietary intake [13]. The UNICEF Conceptual Framework on the Determinants of Child Undernutrition places the conglomerate of facilitating factors in context and distinguishes between immediate causes, underlying causes, and fundamental causes [14, 15].

Despite the significant efforts made by the Burundian Government and its development partners to reduce the prevalence of stunting, the prevalence is among the highest in the world [16]. It has only slightly decreased over the last decade, from 58% to 56% to 54.2% in 2010, 2017, and 2019, respectively [17-20]. According to the SMART 2022 survey, the Kirundo Health District has experienced a significant increase in the prevalence of chronic malnutrition, rising from 45.3% in 2020 to 55.2% [19]. It is in a critical nutritional situation; its prevalence is far above the alert threshold of 40% set by the WHO [20]. To our knowledge, no specific study on growth retardation has been carried out in Kirundo, hence the interest of this study, which is to identify the predictors of growth retardation in children under five years of age to formulate a solution to these problems.

Research questions: What are the predictors of stunting in children aged 6 to 59 months in the Kirundo Health District of Burundi?

Research hypotheses: Socioeconomic, sociodemographic, sociocultural, food insecurity, socio-sanitary, behavioral, and environmental factors, as well as dietary practices, are linked to chronic malnutrition.

This study aims to inform decision-makers so they can adopt evidence-based strategies to combat this scourge. Understanding these factors could help improve health services for affected populations.

2. MATERIALS AND METHODS

2.1. Study Framework and Design

This study was conducted from February 26 to March 29, 2024. The study population consisted of households with at least one child aged 6 to 59 months. If multiple children in this age group lived in the same household, only one child was randomly selected. The sample size was determined using the "Open Epi" software, version 3, available online [21].

With 23,449 households with children under five years of age and based on a prevalence of chronic malnutrition of 55.2%, we arrived at a sample of 374 families with children aged 6 to 59 months.

2.2. Sampling Procedures and Sample Size Determination

To determine the sample size required to obtain a representative estimate of the population, we used the sampling technique as provided by the Open Epi software coupled with Raosoft's formula [22], taking into account the following assumptions: n = size of the sample to be interviewed, Z = reduced deviation corresponding to the 95% confidence level (1.96), N= size of the total target population for our study (N= 23449), E= width of the range expressing the margin of error, P= prevalence of stunting estimated according to SMART, 2022 [20].

$$n = \frac{N.Z^2.P.(1-P)}{E^2.(N-1)+Z^2.P.(1-P)}$$

$$= \frac{23449(1,96)^2 * 0.552(1-0.552)}{(0.05)^{2*}(23449-1)+(1,96)^2 * 0.552(1-0.552)}$$

$$= 373.96 \sim 374$$

The sampling method used in the research is a stratified random sampling [23] based on five randomly selected areas of responsibility in the Kirundo health district. A proportional allocation was used to distribute the number of children to be surveyed by stratum. The sampling frame consisted of lists provided by community health workers. Households were selected by simple random selection using the randomizer.org website [24].

2.2. Survey Procedures

2.2.1. Enumerators' Training

A training session for interviewers was held from February 20 to 24, 2024. Twelve interviewers were preselected to participate in this training, which was not only theoretical but also, above all, practical. The training focused on strict adherence to sampling methodology, cluster selection, household selection, and child selection. Particular emphasis was placed on questionnaire administration, interview techniques, the collection of reliable anthropometric data, and the use of the local calendar to estimate the age of sure children. The interviewers were also trained in entering anthropometric data into ENA for SMART.

2.2.2. Standardization and Pre-Survey Test

Two anthropometric measurement standardization tests were organized in parallel, following the recommendations of the SMART methodology. The agents worked in pairs to take two measurements each (weight, height) of ten children under five years old. The measurements were entered in the tablets via the Kobo-collect application and analyzed with the ENA software. The results obtained made it possible to evaluate the precision (difference observed between two measurements from the same measurer) and the accuracy of the measurements (difference observed between the interviewer's measurement and that of the reference measurements) for each interviewer. At the end of this test, 12 interviewers were identified for the survey. The survey tools were tested on February 25, 2024, in locations not included in the sample. This pre-test made it possible to improve the collection tools and to ensure the adequacy of the methodology and survey materials.

2.2.3. Anthropometric Data Collection

Anthropometric indicators were measured in children aged 6 to 59 months according to the SMART methodology protocol.

Weight: Children were measured naked using a SECA-type electronic mother-child scale with an accuracy of 0.1 kg. The scales were regularly checked and calibrated in the field.

Height: Measured using a standard UNICEF height rod [25]. Children measuring more than 87 cm were measured standing. Children measuring less than 87 cm were measured lying down. Height was measured with an accuracy of 0.1 cm.

Age: Collected from birth certificates.

Bilateral edema: Assessed by applying moderate thumb pressure for at least 3 seconds to both feet. The formation of a depression upon application of pressure confirmed the presence of bilateral edema.

2.2.4. Inclusion and Exclusion Criteria

(1) Households residing on the selected hills in the 2 communes of the district, with at least one child aged 6 to 59 months at the time of the survey; (2) Households that consented to participate in the study during the data collection period, and (3) households whose mother or guardian (in the case of the mother/female guardian) agreed to answer the survey questionnaire were included in the study. All children with malformations, those who were sick and/or those whose mothers refused to participate, were excluded from the study.

2.2.5. Sampling Techniques, Tools, and Data Collection

During data collection, only one child was considered; if multiple children aged 6 to 59 months were present in the same household, attention was focused on the eldest child for weight measurement and the maternal interview to reduce recall bias. The purpose of the study was explained to all respondents, and written informed consent was obtained before the interview.

The questionnaire included sociodemographic characteristics, child feeding practices (breastfeeding and complementary feeding), environmental and personal hygiene, as well as child weight and height measurements. Data were collected using a digital questionnaire administered on a smartphone via the Kobo Toolbox application. Questions were written in French and translated orally into Kirundi during the survey. The questionnaire was intended for the mother or guardian of the child who agreed to participate in the study.

2.3. Data Processing, Analysis, and Presentation of Results

The database was created by exporting the collected data from KoboToolbox to Excel 2016 for preliminary cleaning. The anthropometric data were processed using ENA for SMART (2020) software and then transferred to Stata 15.1 software for appropriate analysis. The process of dealing with missing values or incomplete data within a dataset was characterized in this study as data cleaning. Missing values were calculated with the k-nearest-neighbors imputer, which reduces data similarity when compared to the Euclidean distance.

The data are presented in tabular form. Univariate analysis was performed by describing the different qualitative variables and calculating the frequencies of their modalities. The description was done for quantitative variables using the mean and standard deviation when the distribution was normal. When the description was not normal, the median and interquartile range were used. A descriptive analysis of the relationship between the different independent variables and the dependent variable studied was performed using the chi-square (χ^2) test. The association between the independent and dependent variables was considered significant if the chi-square p-value was less than 0.05. In the bivariate analysis, the search for an association between sociodemographic, behavioral, environmental, economic, and child socio-sanitary factors and stunting was carried out by calculating the odds ratio (OR) and its 95% confidence interval (p = 0.05). Variables associated with stunting, as well as other independent variables with a significance threshold of less than 0.20 ($p < 0.20$), were retained for the multivariate analysis (modeling). This analysis was conducted in three stages:

1. Univariate analysis (description of respondent characteristics).
2. Bivariate analysis between each independent variable and underweight for all independent variables.
3. Multivariate analysis (modeling).

Modeling was performed using logistic regression to eliminate confounding factors. The bivariate analysis included all independent variables with a significance level less than or equal to 20% [26]. The variables retained after the multivariate analysis had a p-value less than 5% [27, 28]. The saturated model, containing only variables significantly associated with the dependent variable, was obtained by progressively eliminating (using the "backward" method) variables one by one, starting with those with the highest p-value, until only variables with a p-value < 0.05 remained. The discriminatory power of the final model was assessed using the ROC curve to test its reliability. The results are presented in tabular form using Word 2016 software. ENA-SMART software was used to obtain height-for-age Z-scores. This software also verified the prevalence of stunting and assessed the quality of the anthropometric data.

2.4. Ethical Approval

Before the start of this study, the survey protocol was submitted to the National Ethics Committee for approval and ethical validation (Ethical visa number 27/2024). The administrative authorities and technical structures involved in the survey were contacted and informed before the arrival of the survey teams in their respective locations, both for the preliminary phase and for data collection. Free and informed consent to participate in the survey was given to each head of household or, in their absence, to their representative.

3. RESULTS

This section focuses on three main points: univariate, bivariate, and multivariate analysis.

230 out of 374 children suffer from stunting (61.5%).

Table 1: Prevalence of Stunting in Children Aged 6-59 Months

Stunting	Frequency	Percentage (%)
Yes	230	61.50%
No	144	38.50%

3.1. Univariate Analysis

After data cleaning, the total sample included 374 children. Regarding age, the median was 18 months, with an interquartile range of 15 months. The median household size was 5 people, with an interquartile range of 3 people. The median number of children aged 6-59 months was 2, with an interquartile range of 1. Regarding the number of meals eaten per day, the median number was 2, with an interquartile range of 1. The median dietary diversity score was 3, with an interquartile range of 2. The most significant number of households were married, the most represented age group was 12-23 months, about half of the mothers had no education, and the majority of them lived in rural areas (Table **2**).

The Pearson test shows that there is a significantly associated relationship between sex, age of the child, mother's education level, and stunting ($p<0.05$) (Table **2**). About 60% of households lacked access to nutrition information through the media, and among them, 75% of children suffered from malnutrition. More than 80% of those surveyed (women and men) were engaged in agriculture. Table **3** reveals a significant relationship between media exposure, father's profession, and stunting ($p<0.05$). More than 60% of mothers had low nutrition knowledge. The results in Table **5** reveal that approximately 70% of households were experiencing either severe or moderate food insecurity. The Chi-square test shows that there is a significant association between food insecurity and stunting ($p<0.05$).

Socio-health factors, including vaccination status, diarrhea, child growth and development monitoring, and birth interval, were significantly associated with stunting, as illustrated in Table **6**. The same table shows that they lack access to an improved water source as well as hygiene facilities.

3.2. Bivariate Analysis

Bivariate logistic regression showed associations of stunting with sex, child age, education level, media exposure, occupation, exclusive breastfeeding,

Table 2: Characteristics of the Sample according to Sociodemographic Factors in the Kirundo Health District (n=374) in Burundi, 2024

Variable	n(%)	Stunting		Chi2	p-value
		Yes	No		
Sex				11.4161	0.001*
Female	203(4.28)	109(53.69)	94(46.31)		
Male	171(45.72)	121(70.76)	50(29.24)		
Number of children<5 years				0.8500	0.357
>=2 children	206(55.08)	131(63.59)	75(36.41)		
1	168(44.92)	99(58.93)	69(41.07)		
Child age in months				34.9239	0.000*
6-11 months	111(29.68)	49(44.14)	62(55.86)		
12-23 months	158(42.25)	96(60.76)	62(39.24)		
24-35 months	53(14.17)	38(71.7)	15(28.30)		
36-47 months	25(6.68)	22(88)	3(12.00)		
47-59 months	27(7.22)	25(92.59)	2(7.41)		
Household size				1.8661	0.172
<5 persons	122(32.62)	69(56.56)	53(43.44)		
>=5persons	252(67.38)	161(63.89)	91(36.11)		
Marital status				3.8981	0.142
Single	25(6.68)	16(64.00)	9(36.00)		
widow/separate	321(85.83)	192(59.81)	129(40.19)		
Mother's education level	28(7.49)	22(78.57)	6(21.43)	50.3464	0.000*
Without level/uneducated	184(49.2)	146(79.35)	38(20.65)		
Primary	129(34.49)	61(47.29)	68(52.71)		
Secondary and above	61(16.31)	23(37.70)	38(62.30)		
Religion				2.4163	0.121
Christian	193(51.6)	126(65.28)	67(34.72)		
Non-Christian	181(48.4)	104(57.46)	77(42.54)		
Place of residence				0.1040	0.747
Urban	62(16.58)	37(59.68)	25(40.32)		
Rural	312(83.42)	193(61.86)	119(38.14)		

Table 3: Distribution of Children Aged 6 to 59 Months in the Kirundo Health District according to Socioeconomic Factors in Burundi in 2024

Variable	n(%)	Stunting		Chi2	p-value
		Yes	No		
Media exposure				44.6747	0.000*
No	223(59.63)	168(75.34)	55(24.66)		
Yes	151(40.37)	62(41.06)	89(58.94)		
Mother's profession				0.8150	0.367
Farmer	317(84.76)	198(62.46)	119(37.54)		
Other	57(15.24)	32(56.14)	25(43.86)		
Father's profession				16.2990	0.000*
Farmer	312(83.42)	206(66.03)	106(33.97)		
Other	62(16.58)	24(38.71)	38(61.29)		

*: Variables significantly associated (p<0.05) with growth retardation.

Table 4: Description of Children Aged 6 to 59 Months in the Kirundo Health District according to behavioral Factors

Variable	n(%)	Stunting		Chi2	p-value
		yes	No		
Exclusive breastfeeding				11.9311	0.001*
<6 months	238(63.64)	162(68.07)	76(31.93)		
>=6 months	136(36.36)	68(50.00)	68(50.00)		
Weaning				6.5941	0.010*
<24 months	233(62.3)	155(66.52)	78(33.48)		
>=24 months	141(37.7)	75(53.19)	66(46.81)		
Number of meals/day				0.2299	0.632
<3 meals	249(66.58)	151(60.64)	98(39.36)		
>=3 meals	125(33.42)	79(63.2)	46(36.8)		
Knowledge of nutritional aspects				78.8138	0.000*
Weak	248(66.31)	192(77.42)	56(22.58)		
Sufficient	126(33.69)	38(30.16)	88(69.84)		

*: Variables significantly associated (p<0.05) with growth retardation.

Table 5: Description of Children Aged 6 to 59 Months in the Kirundo Health District according to Household Food Insecurity

Variable	n(%)	Stunting		Chi2	p-value
		Yes	No		
Dietary diversity score (6-23 months)				18.6800	0.000*
Inadequate	233(62.3)	163(69.96)	70(30.04)		
Adequate	141(37.70)	67(47.52)	74(52.48)		
Dietary diversity score (24-59 months)				2.0790	0.149
Inadequate	307(82.09)	194(63.19)	113(36.81)		
Adequate	67(17.91)	36(53.73)	31(46.27)		
Level of food insecurity				53.0957	0.000*
Acceptable	109(29.14)	52(47.71)	57(52.29)		
Moderate	149(39.84)	75(50.34)	74(49.66)		
Severe	116(31.02)	103(88.79)	13(11.21)		

*: Variables significantly associated (p<0.05) with growth retardation.

weaning, maternal knowledge, FCS, HHDS, vaccination, diarrhea, growth and development monitoring, birth spacing, latrine type, handwashing facility, and drinking water source with $p < 0.02$ (Table **7**).

3.3. Multivariate Analysis

After adjusting for the effect of confounding variables, the results of the multivariate logistic regression test indicate that male children are 2.83 times more likely to suffer from stunting than female children in the same area (OR = 2.83; 95% CI:1.40-5.75). The 36-47 month age group is 10.40 times more likely to be stunted than the 6-11 month age group, and the 47-59 month age group is 6.75 times more likely to be stunted (OR= 10.40; 95% CI:1.21-88.30). Children from food-insecure households were more likely to be stunted than those from food-secure households (OR = 10.47; 95% CI:3.58-30.61). Children from households using unimproved latrines were 6.83 times more likely to be stunted than children from families with improved latrines (OR = 6.83; 95% CI: 3.12-14.94).

The notion of diarrhoea in the two weeks preceding the survey increases the risk of developing stunting; their odds ratios exceed 1, and their 95% confidence intervals do not contain 1 (OR = 2.56, 95% CI: 1.19-5.48). Children from households using an unimproved

Table 6: Description of Children Aged 6 to 59 Months in the Kirundo Health District according to Socio-Health Factors

Variable	n(%)	Stunting		Chi2	p-value
		Yes	No		
Vaccination				40.7329	0.000*
Incomplete	83(22.19)	76(91.57)	7(8.43)		
Complete	291(77.81)	154(52.92)	137(47.08)		
Iron supplementation				0.1828	0.669
Yes	313(83.69)	191(61.02)	122(38.98)		
No	61(16.31)	39(63.93)	22(36.07)		
Micronutrient Powder				1.7668	0.184
Yes	7(1.87)	6(85.71)	1(14.29)		
No	367(98.13)	224(61.04)	143(38.96)		
Fever				0.0032	0.955
No	307(82.09)	189(61.56)	118(38.44)		
Yes	67(17.91)	41(61.19)	26(38.81)		
Cough				8.8584	0.003*
No	260(69.52)	147(56.54)	113(43.46)		
Yes	114(30.48)	83(72.81)	31(27.19)		
Diarrhea				6.0265	0.014*
No	165(44.12)	90(54.55)	75(45.45)		
Yes	209(55.88)	140(66.99)	69(33.01)		
Growth and development monitoring				9.8809	0.002*
No	198(52.94)	107(54.04)	91(45.96)		
Yes	176(47.06)	123(69.89)	53(30.11)		
Interbirth interval				4.3457	0.037*
< 24months	240(64.17)	157(65.42)	83(34.58)		
>= 24months	134(35.83)	73(54.48)	61(45.52)		

*: Variables significantly associated (p<0.05) with growth retardation.

Table 7: Description of Children Aged 6 to 59 Months in the Kirundo Health District according to Environmental Determinants

Variable	n(%)	Stunting		Chi2	p-value
		Yes	No		
Types of latrine				22.8893	0.000*
Improved	148(39.57)	69(46.62)	79(53.38)		
Unimproved	226(60.43)	161(71.24)	65(28.76)		
Washing device				4.8078	0.028*
Yes	70(18.72)	35(50.00)	35(50.00)		
No	304(81.28)	195(64.14)	109(35.86)		
Availability of washing soap				0.6321	0.427
Yes	103(27.54)	60(58.25)	43(41.75)		
No	271(72.46)	170(62.73)	101(37.27)		
Source of drinking water				7.4198	0.007*
Improved	172(45.99)	93(54.07)	79(45.93)		
Unimproved	202(54.01)	137(67.82)	65(32.18)		
Arrival time at the water source				0.1111	0.739
<30min	76(20.32)	48(63.16)	28(36.84)		
>=30min	298(79.68)	182(61.07)	116(38.93)		

*: Variables significantly associated (p<0.05) with growth retardation.

Table 8: Final Model of Factors Linked to Growth Retardation

Explanatory variables	n(%)	OR (IC95%)	P
Sex			
Female	109(53.69)	1	
Male	121(70.76)	2.83(1.40-5.75)	0.004*
Child's age in months			
6-11months	49(44.14)	1	
12-23months	96(60.76)	1.83(0.82-4.06)	0.139
24-35months	38(71.70)	2.32(0.55-9.79)	0.251
36-47months	22(88,00)	10.40((1.22-88.34)	0.032*
47-59months	25(92.59)	6.75(2.04-22.34)	0.002*
Mother's education level			
Uneducated	146(79.35)	1	
Primary	61(47.29)	0.18(0.08-0.40)	0.000
Secondary and above	23(37.7)	0.21(0.07-0.64)	0.006
Level of food insecurity			
Acceptable	52(47.71)	1	
Moderate	75(50.34)	0.81(0.35-1.88)	0.621
Severe	103(88.79)	10.47(3.58-30.62)	0.000*
Vaccination status			
Incomplete	76(91.57)	1	
Complete	154(52.92)	0.06(0.02-0.21)	0.000
Birth interval			
< 24months	157(65.42)	1	
>= 24months	72(54.14)	0.39(0.16-0.93)	0.033
Knowledge of nutritional aspects			
Weak	192(77.42)	1	
Sufficient	38(30.16)	0.11(0.05-0.25)	0.000
Types of latrines			
Improved	69(46.62)	1	
Unimproved	161(71.24)	6.83(3.12-14.94)	0.000*
Recurrent diarrhea			
No	107(54.04)	1	
Yes	123(69.89)	2.56(1.19-5.48)	0.016*
Source of drinking water			
Improved	93(54.07)	1	
unimproved	137(67.82)	3.17(1.54-6.52)	0.002*
Media exposure			
No	168(75.34)	1	
Yes	62(41.06)	0.24(0.11-0.51)	0.000
Father’s profession			
Father	206(66.03)	1	
Other	24(38.71)	0.25(0.09-0.72)	0.010

*: Predictors of stunting, Kirundo health district, Burundi, 2024.

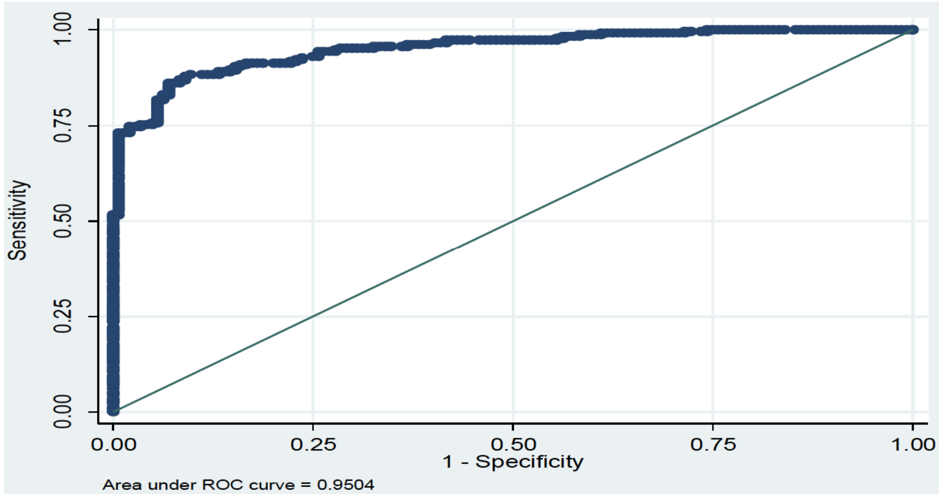

Figure 1: ROC Curve of the predictive model for stunting in children aged 6-59 months in Kirundo district.

X-axis: False Positive Rate (1-specificity).

Y-axis: True Positive Rate (sensitivity).

The area under the curve (AUC) is 0.95, indicating an excellent discriminative ability of the model.

drinking water source were 3.17 times more likely to be stunted than those with an improved water source (OR= 3.17; 95% CI: 1.54-6.52). Media exposure, adequate nutritional knowledge, birth spacing, mother's secondary education and above, and full immunization were identified as protective factors ($p<0.05$) (Table **8**).

3.4. Model Validity Study

To determine the validity of the final model for growth retardation in children aged 6 to 59 months in our study population, a ROC curve was performed. Figure **1** shows the ROC curve obtained from the results of the saturated logistic model. The model's ability to correctly classify observations was 95.04%. It can be concluded that this model has predictive power, with excellent discrimination.

4. DISCUSSION

The aim of the study was to assess the prevalence and factors influencing stunting in children aged 6-59 months in the Kirundo health district.

The study revealed a very high prevalence of stunting, reaching 61.5% (95% CI: 54.9-67.1). This rate far exceeds the critical threshold of 40% set by WHO in 2006, as well as that reported in Ethiopia by Bogale *et al.* (48%) in 2020 [29]. This result corroborates the data observed in Lubumbashi by Musimwa in 2017 (62.8%) [30]. Still, it remains higher than Burundi's national prevalences observed in the 2016-2017 EDSB (56%) [18] and during the 2022 SMART survey, where a prevalence of 55.8% was observed [20]. This prevalence is also high compared with that observed in other countries, such as Chad (49%, 2021) [31] and Benin (32%, 2018) [32]. This alarming situation could be explained by the high proportion of food-insecure households and the lack of access to latrines and improved water sources, factors that increase the risk of infectious diseases and compromise child growth.

(1) Child age is a predictor of stunting. Children in the four age categories of 12–59 months were more likely to be stunted than children aged 6–11 months, indicating that stunting increases with age [27]. Our results are consistent with studies conducted in Ghana [33-35], Ethiopia [36], and Burkina Faso [37]. This hypothesis could be explained by the fact that older children have higher energy needs, which they cannot meet with the given foods.

The proportion of children with stunting in the 12–23 months age group is dominant, it is 60.76% in our study. This age group, according to WHO, corresponds to the period of 1000 days during which the foundations of an individual's physical size and physiological and intellectual capacities at a very advanced stage of life are laid [38, 39]. In studies conducted in Uganda and Kenya have proven that this age group is associated with growth retardation [40, 41].

(2) Sex influences stunting, boys are 2.83 times more likely to suffer from growth retardation (OR= 2.83, IC à 95 %: 1.40-5.75) compared to

girls in our study. This is confirmed by studies conducted in sub-Saharan Africa in 36 countries [42] and in India [43].

Our findings are similar to a variety of studies worldwide [44, 45]. A systematic review that examined the causes of sex differences in chronic malnutrition in sub-Saharan Africa (SSA) identified both social and biological reasons [46]. In contrast to these findings, some studies conducted in Pakistan and Ethiopia found no significant difference between child sex and stunting in children under five years of age [47, 48].

(3) The likelihood of suffering from stunting was 10.47 times higher among children living in severely food-insecure households than those living in food-secure households. This result is consistent with a cross-sectional study conducted in 2013 by Ali *et al*. in three low- and middle-income countries: Bangladesh, Ethiopia, and Vietnam, which showed that children from severely food insecure households were more likely to be stunted [49]. It is also consistent with a study conducted in Malaysia by Ali Naser *et al*. in 2014 and another in Rwanda by Agho *et al*. in 2019, which indicated that children from severely food-insecure households were significantly associated with stunting [28, 50, 51]. Similarly, a recent study in rural central Benin observed that food insecurity was associated with all nutritional deficiencies (chronic, acute malnutrition, and underweight) in children [52]. Food-insecure households tend to prioritize satisfying their energy needs over meeting their micronutrient or trace element needs, which can paradoxically lead to an increase in overweight and obesity [15, 53].

(4) Children from households without improved toilets were 6.83 times more likely to be stunted than those who had improved latrines at home (p=0.000). The results of the present study corroborate with those found in Tanzania and South Asia [44, 54]. Similarly, Hasan Md Mehedi *et al*. in their studies on the association between access to water, sanitation, and handwashing facilities and undernutrition in children under 5 years of age in Bangladesh, revealed that not having access to an improved sanitation facility increases the probability of suffering from stunting [55]. This situation could be explained by the fact that the absence of enhanced toilets increases the risk of exposure of children to fecal bacteria that can cause diarrheal diseases and intestinal worm infections, and thus increases the susceptibility to stunting.

(5) In our study, children with diarrheal infections in the last two weeks before the survey had a high risk of suffering from stunting compared to those who did not have diarrhea. Our results are similar to multiple studies conducted in several geographical areas that have revealed the existence of a statistically significant relationship between diarrhea and stunting in children [56, 57]. This finding was also noted by other studies conducted in Ghana [34], Burkina Faso [37], Nigeria [58] and India that children with diarrhea were more likely to develop undernutrition than those without it [59]. This situation could be explained by the fact that diarrhea potentially affects the nutritional status of children by causing anorexia, increasing fluid losses, and impairing nutrient absorption.

(6) Drinking water source is another predictor; there is a statistically significant relationship (OR=3.17, IC at 95%: 1.54-6.52) with stunting. Our results are consistent with those of Takele *et al*., among whom children from households that did not have improved water sources had a 7% higher risk of stunting compared to children from families that had an improved drinking water source [11]. The present study is consistent with a systematic review and meta-analysis of 171 DHS from 70 low- and middle-income countries worldwide from 1984 to 2007 and a study conducted in Ethiopia [60]. Poor sanitation and the quality of drinking water sources, such as those polluted by Escherichia coli, can impact the health and nutritional status of children through various mechanisms, including repeated episodes of diarrhea, parasites, environmental enteropathy, and other factors that prevent nutrient assimilation and absorption.

(7) In addition, inadequate feeding practices, infections, and exposure to environmental pathogens [36, 38] are contributing factors to stunting.

5. STRENGTHS AND LIMITATIONS OF THE STUDY

This study is the first to have been carried out specifically in this locality, based on a rigorous methodology and a representative sample, which reinforces the validity of its results and their usefulness in guiding the strategic decision-makers of the health authorities and their partners. However, the study does have certain limitations that should be highlighted. The use of a cross-sectional design makes it impossible to establish causal relationships between the factors studied and stunting. In addition, memory bias is possible due to the self-reported nature of some data, such as disease history and dietary practices. The absence of critical contextual variables, such as income, also limits the explanatory power of the results. Finally, despite statistical adjustments, residual confounding factors may persist and influence the interpretation of observed associations. These limitations highlight the need for further research to strengthen our understanding of the causes of stunting.

6. CONCLUSION

The prevalence of stunting among children aged 6 to 59 months in the Kirundo health district of Burundi is alarming at 61.5%, making it a significant public health problem. According to this research; after data collection and analysis, it was observed that the main variables such as recurrent diarrhoea, household food insecurity, age, low level of education of mothers, short inter-gestational interval, unimproved toilets, poorly followed vaccination, gender and unimproved water source have a significant impact on stunting with a probability threshold of less than 5%. Finally, we recommend the implementation of an integrated community program combining access to food security, drinking water and sanitation, maternal education and family planning to strengthen household resilience and support human capital development.

CONFLICT OF INTEREST

None.

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