Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Comparison of WHO, IOTF, CDC Global BMI Reference Standards and Sociodemographic Factors Associated with Nutritional Status among Rural South African Schoolchildren: A Cross-Sectional Study

Violet Kankane Moselakgomo

violet.moselakgomo@univen.ac.za

University of Venda

Paola Silvia Wood

University of Pretoria

Research Article

Keywords: global reference standards, socio-demographic factors, nutritional status, growth and development, rural South African children

Posted Date: November 17th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11735270/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

Global reference standard variations introduce significant discrepancies in child health and nutritional diagnostics. This study evaluated the diagnostic concordance of the WHO 2007, IOTF, and CDC growth references and examined sociodemographic factors associated with nutrition status in rural South African children.

Methods

A cross-sectional survey evaluated 556 school-going children (aged 9–14 years) in rural schools in Limpopo, South Africa. Anthropometric data were collected following ISAK protocols. Sociodemographic and household information was self-reported by participating children using a structured questionnaire under researcher supervision. Agreement between the WHO 2007, IOTF and CDC classifications was assessed using Cohen's kappa. Pearson chi-square tests examined associations between nutritional status categories and age and sex. Multinomial logistic regression was used to examine sociodemographic factors associated with WHO 2007 nutritional status, with normal weight as the reference category.

Results

The reference system produced different nutritional-status estimates. IOTF classified the highest prevalence of thinness (19.4%), while the CDC classification captured the highest prevalence of obesity (8.3%) and showed a significant association between nutritional status classification and sex (p = .017). Agreement was highest between WHO and IOTF (kappa=.933; p=.001) and the lowest between WHO and CDC (kappa=.875; p=.001). Multinomial regression revealed that overnutrition risks decreased significantly with child's age (p=.002). Crucially, primary care by a pensioner caregiver status was associated with high odds of overweight by more than 21-fold (aOR = 21.98, 95% CI: 2.26-213.67, p = .008), whereas grandparents' co-residence was associated with 82% lower offs of obesity (aOR = 0.18, 95% CI: 0.05–0.69, p = .012).

Conclusions

A substantial double burden of malnutrition exists in rural Limpopo. While international references show high statistical agreement, their clinical diagnostic thresholds vary systematically. These findings highlight the importance of consistent selection of BMI reference values and consideration of age and household characteristics when interpreting nutritional status among rural school-going children.

1. Background

Late childhood and early adolescence represent an important developmental period characterised by rapid physiological growth and the onset of pubertal growth spurts [1]. During this phase, adequate nutritional status is essential for normal growth and development. In low- and middle-income countries (LMICs) [2–3], particularly within rural South African settings, school-aged children and early adolescent cohorts face a complex "double burden of malnutrition"-the co-occurrence of undernutrition (stunting and wasting) alongside escalating rates of overnutrition (overweight and obesity) [4]. In rural South Africa, historically marginalised provinces like Limpopo face profound socio-demographic challenges. Structural vulnerabilities, including high unemployment, low educational attainment among household primary caregivers, and large multi-generational households, may constrain access to nutrient-dense foods. Furthermore, limitations in rural infrastructure reduce opportunities for structured physical activity [5–6], while dietary shifts toward affordable, energy-dense processed items introduce new health challenges. While the Limpopo province serves as a key agricultural and mining hub, it grapples with a high poverty headcount index and severe socioeconomic gaps, leading to generational malnutrition [7]. Childhood nutritional status is influenced by interacting socioeconomic, household and dietary factors, including poverty, food and nutrition insecurity, caregiver education, infrastructure and access to health services. In South Africa, the coexistence of undernutrition and increasing overweight and obesity complicates nutritional surveillance [8–10]. However, comparatively little is known about how nutritional status estimates vary according to the BMI reference applied among socioeconomically vulnerable school-aged children in rural Limpopo, or how household characteristics are associated with these classifications. The socioeconomic status (SES) variable in this context represents an individual's economic and social position and is commonly reflected by factors such as income, education, occupation, and occasionally, marital status [11]. Several population-based studies in affluent regions have prospectively examined the impact of life-course socioeconomic status and obesity [12–15]. These studies suggest that individuals with higher socioeconomic status generally experience better health outcomes than those with lower socioeconomic status. Among the main SES indicators, lower income and educational attainment have been associated with a range of adverse physical and mental health outcomes in adulthood [16]. Lower SES has also been linked to poorer health outcomes in children and adolescents, including obesity, type 2 diabetes, and hypertension [17]. However, while many studies assess nutritional status during childhood and adolescence, the relationship between nutritional status and household socioeconomic characteristics is often ignored [18–19]. This may overlook important social and household factors that contribute to health and nutritional outcomes in younger populations.

The global BMI reference standards have always been widely used as a measure for assessment of nutritional status in diverse populations [1], however, their ability to determine the sociodemographic predictors of nutritional status in preadolescent has been a challenge. There has always been a lingering debate on which of the three-reference standards best diagnose nutritional paradoxes in socioeconomically vulnerable settings. Globally, three reference standards are used to evaluate child and adolescent body mass index (BMI): the World Health Organisation (WHO) Z-score reference [20], the International Obesity Task Force (IOTF) [21] cutoff system, and the Centres for Disease Control and

Prevention (CDC) growth charts [22]. However, these frameworks were developed using distinct historical datasets and mathematical assumptions: For example, the WHO 2007 reference uses age- and sex-specific BMI-for-age z-scores; the CDC growth charts use BMI-for-age percentiles derived from a US reference population; and the IOTF applies international age- and sex-specific BMI cut-offs linked to adult BMI thresholds at age 18 [21]. On the other hand, there has been consensus that these classification frameworks rely on different statistical designs and can produce varying estimates of undernutrition and overnutrition within the same population. The misalignments between these systems can distort public health reporting, leading to misallocation of clinical resources and complicate localised interventions [9]. Amid this debate, it should be considered that tracking nutritional status at these critical stages requires valid, universally standardised screening tools. Therefore, this study evaluates the nutritional status of 556 school-going pre-adolescents (aged 9–14 years) in rural Limpopo, South Africa. We contrast the classification behaviours of the WHO, IOTF, and CDC reference standards, and analyse how structural socio-demographic variables intersect with growth and development and the health outcomes of these vulnerable populations.

2. Methods

2.1 Ethical Protocol

Formal ethical clearance was reviewed and approved by the University of Venda Research Ethics Committee (UNIVEN REC Ref: FHS/24/BSBK/01/3107), the Limpopo Provincial Research Ethics Committee (LPREC/70/2024/PG), and the National Department of Health Research Ethics Committee (Reg: 111513-038). Administrative permissions to access the research sites were formally obtained from the Limpopo Department of Basic Education, relevant district managers, and school governing bodies.

2.2 Assessment of Sociodemographic and Behavioural Factors

A structured self-reported sociodemographic questionnaire was developed and used to collect the children's demographic information. The school children self-reported their demographic information in a classroom under the supervision and guidance of well-trained research assistants. The demographic section included age, gender and information regarding maturation. The sociodemographic information covered variables which included their household size, number of siblings, whether they lived with grandparents, their birth ordinal number (whether first, second, third or fourth born) in the family. The sociodemographic information also covered the children's parental socioeconomic status (SES). This included employment status, marital status and the parental or caregiver's highest educational level.

2.3 Anthropometric Assessment

Anthropometric evaluations were executed by trained personnel in accordance with the standard protocols established by the International Society for the Advancement of Kinanthropometry (ISAK, 2012) [23]. Participants were measured barefoot and lightly dressed in standard attire (shorts and a T-

shirt). Body height was measured to the nearest 0.1 centimetres (cm) using a portable, mounted stadiometer (HM200P Portable Stand-Alone Stadiometer), with the participant standing upright and the head positioned in the Frankfurt horizontal plane. Body weight was recorded to the nearest 0.1 kilogram (kg) utilising a calibrated portable digital electronic scale (Omron Body Composition Monitor, Model HBF-214-EBW). All measurements were taken in duplicate, and the mean values were used to calculate BMI ($kg.m^2$). Nutritional status was classified according to age- and sex-specific criteria using the WHO 2007, IOTF, and CDC BMI reference systems.

2.4 Nutritional assessment

Nutritional status was classified according to age- and sex-specific criteria using the WHO 2007, IOTF and CDC BMI reference systems. WHO BMI-for-age z-scores, IOTF age- and sex-specific BMI cut-offs, and CDC BMI-for-age percentiles were applied according to the respective reference methods [20–22].

WHO-BMI-for-age z-scores: This system uses World Health Organisation (WHO) Z- scores (Standard Deviations) to gauge how far a child's BMI deviates from a reconstructed global baseline population median. It classifies pre-adolescents into strict categories like severe thinness, thinness, normal weight, overweight, and obesity [20]. The WHO-BMI- for age z-scores assessed the nutritional status of the adolescents according to gender categories. **Ages 9–10 (WHO- BMI classifications) for boys**: Underweight (BMI > = 13.5 and < 14.2), normal weight (BMI > = 14.2 and < 19.3), overweight (BMI > = 19.3 and < 22.0) and obese (BMI > = 22.0). **Ages 11–12**: Underweight (BMI > = 14.0 and < 15.0), normal weight (BMI > = 15.0 and < 21.2), overweight (BMI > = 21.2 and < 24.2) and obese (BMI > = 24.2). **Ages 13–14**: Underweight (BMI > = 14.4 and < 16.0), normal weight (BMI > = 16.0 and < 23.7), overweight (BMI > = 23.7 and < 26.8) and obese (BMI > = 26.8).

Ages 9–10 (WHO- BMI classifications) for the girls: Underweight (BMI > = 13.2 and < 14.0), normal weight (BMI > = 14.0 and < 20.0), overweight (BMI > = 20.0 and < 23.0) and obese (BMI > = 23.0). **Ages 11–12**: Underweight (BMI > = 13.8 and < 14.8), normal weight (BMI > = 14.8 and < 21.7), overweight (BMI > = 21.7 and < 25.2) and obese (BMI > = 25.2). **Ages 13–14**: Underweight (BMI > = 14.5 and < 15.8), normal weight (BMI > = 15.8 and < 23.7), overweight (BMI > = 23.7 and < 27.7) and obese (BMI > = 27.7).

IOTF-age and sex specific BMI cut-off points: The International Obesity Task Force (now under the World Obesity Federation) maps growth curves based on pooled international data. Its defining trait is that its child percentile tracks are mathematically anchored to land precisely on adult BMI markers (18.5, 25, 30 kg/m^2) at exactly 18 years of age. IOTF-age and sex specific BMI cut-off point classifications: underweight (17.0 kg/m^2), normal weight (18.5 kg/m^2), overweight (25.0 kg/m^2), obese (30.0 kg/m^2), and severe obese (35.0 kg/m^2) [21]. IOTF-age and sex specific BMI cut-off point were adjusted for age and gender categories. **Ages 9–10 (IOTF-BMI classifications) for boys**: Underweight (BMI < = 15.0 and < 16.0), normal weight (BMI > = 16.0 and < 19.0), overweight (BMI > = 19.0 and < 24.0) and obese (BMI > = 24.0). **Ages 11–12**: Underweight (BMI < = 16.0 and < 17.5), normal weight (BMI > = 17.5 and < 21.6), overweight (BMI > = 21.6 and < 26.0) and obese (BMI > = 26.0). **Ages 13–14**: Underweight (BMI < = 17.2

and < 19.9), normal weight (BMI > = 18.9 and < 23.3), overweight (BMI > = 23.3 and < 28.3) and obese (BMI > = 28.3).

Ages 9–10 (IOTF-BMI classifications) for girls: Underweight (BMI < = 14.8 and < 15.0), normal weight (BMI > = 15.0 and < 19.9), overweight (BMI > = 19.9 and < 24.1) and obese (BMI > = 24.1). **Ages 11–12**: Underweight (BMI < = 16.0 and < 17.4), normal weight (BMI > = 17.4 and < 22.1), overweight (BMI > = 22.1 and < 26.7) and obese (BMI > = 26.7). **Ages 13–14**: Underweight (BMI < = 17.2 and < 18.9), normal weight (BMI > = 18.9 and < 23.3), overweight (BMI > = 23.3 and < 28.3) and obese (BMI > = 28.3).

CDC-BMI-for age growth charts reference standards: Developed by the Centres for Disease Control and Prevention (CDC), this method relies on standard percentiles based on a historical health dataset of American children. Categories range from Underweight (< 5th percentile) to Obesity (≥ 95th percentile). CDC-BMI for age percentile range: Underweight (less than 5th percentile) normal weight (5th percentile to less than 80th percentiles) overweight (85th percentile to less than 95th percentile) obesity (95th percentile or greater) [22]. **Ages 9–10 (CDC-BMI classifications) for boys**: Underweight (BMI < = 14.0) normal weight (BMI > = 14.2 and < 19.9), overweight (BMI > = 19.9 and < 22.2) and obese (BMI > = 22.2). **Ages 11–12**: Underweight (BMI < = 15.0) normal weight (BMI > = 15.0 and < 21.1), overweight (BMI > = 21.1 and < 24.2) and obese (BMI > = 24.2). **Ages 13–14**: Underweight (BMI < = 16.0) normal weight (BMI > = 16.0 and < 22.8), overweight (BMI > = 22.8 and < 26.2) and obese (BMI > = 26.2).

Ages 9–10 (CDC-BMI classifications) for girls: Underweight (BMI < = 14.0) normal weight (BMI > = 14.0 and < 20.0), overweight (BMI > = 20.0 and < 23.0) and obese (BMI > = 23.0). **Ages 11–12**: Underweight (BMI < = 14.8) normal weight (BMI > = 14.8 and < 21.7), overweight (BMI > = 21.7 and < 25.3) and obese (BMI > = 25.3). **Ages 13–14**: Underweight (BMI < = 15.8) normal weight (BMI > = 15.8 and < 23.3), overweight (BMI > = 23.3 and < 27.3) and obese (BMI > = 27.3).

2.4 Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics (Version 32.0) [24]. Continuous anthropometric measurements (stature, body mass, and BMI) were presented as means and standard deviations, alongside the minimum and maximum values. Categorical variables were summarised using frequencies and valid percentages.

Pairwise agreements between the WHO 2007, IOTF and CDC classifications was assessed using Cohen's Kappa (kappa). Pearson chi-square tests were used to examine associations between nutritional status categories and age and sex within each reference system. The kappa values were interpreted according to Landis and Koch's criteria: k < 0.00 indicating poor agreement, 0.00-0.20 slight; 0.21–0.40 fair; 0.41–0.60 moderate; 0.61–0.80 substantial, and 0.81-1.00 almost perfect agreement [25]. Multinomial logistic regression models were constructed to evaluate the impact of sociodemographic and health variables on the global BMI reference standard classifications. Nutritional status was the dependent variable, with normal weight specified as the reference outcome category. Furthermore, adjusted Odds Ratios (aOR) with 95% Confidence Intervals (CI) were calculated, and statistical significance was set at $p < 0.05$.

3. Results

3.1 Baseline Sociodemographic and Household Characteristics

Table 1
Sociodemographic and Household Characteristics of Rural Limpopo Schoolchildren (N = 556)

Variable	Frequency (n)	Valid Percentage (%)
Child Demographics		
Gender		
Male	233	41.9%
Female	323	58.1%
Age (years)		
9	70	12.6%
10	124	22.3%
11	155	27.9%
12	130	23.4%
13	75	13.5%
14	2	0.4%
Household Characteristics		
Grandparents in Household		
Yes	235	42.3%
No	321	57.7%
Birth Order Position		
First	132	23.7%
Second	135	24.3%
Third	128	23.0%
Fourth	105	18.9%
Other	56	10.1%
Caregiver Socioeconomic Profile		
Primary Caregiver Role		
Mother	221	39.7%
Grandmother	119	21.4%
N= total number of the participants; n=subset number of the participants; %=percentages		

Variable	Frequency (n)	Valid Percentage (%)
Child Demographics		
Both Parents	53	9.5%
Grandfather	45	8.1%
Sibling/ Neighbour/Other	118	21.3%
Caregiver Employment Status		
Employed	150	27.0%
Unemployed	277	49.8%
Pensioner	74	13.3%
Other/Disability/Unknown	55	9.9%
Caregiver Marital Status		
Never Married	225	40.5%
Married /Cohabiting	183	32.9%
Widowed Male (19) Female (48)	67	17.4%
Separated/Divorced/Other	51	9.2%
Caregiver Highest Education Level		
Primary school or less Grade 6	51	9.1%
Secondary School Grade 8–10	60	10.8%
Matric Grade 12	195	35.1%
Unknown/ Other	250	45.0%
N= total number of the participants; n=subset number of the participants; %=percentages		

Presented in Table 1 are the descriptive profiles of the participants (N = 556) and their caregivers. The study population comprised more girls (n = 323, 58.1%) than boys n = 233 (41.9%). The mean age of the cohort was (11.04 ± 1.24) years, spanning from 9 to 14 years, with the highest concentration of participants at age 11, n = 155 (27.9%). Household sizes were relatively large, with an average of (6.20: 2.28) individuals per home. Notably, 42.3% (n = 235) of the children lived in multi-generational households where grandparents resided in the same home. For families with siblings, the average number of brothers and sisters was (1.54:0.78) and (1.66: 0.76), respectively. In terms of birth order, first-born (23.7%), second-born (24.3%), and third-born (23.0%) children were almost equally represented [Table 1].

3.2 Caregiver Profile and Socioeconomic Vulnerability

Most of the children were primary dependents of their biological mothers n = 221 (39.7%), followed closely by grandmothers n = 119 (21.4%). A stark socioeconomic baseline was observed: only 27.0% (n = 150) of the primary caregivers were formally employed, whereas 49.8% (n = 277) were unemployed, and 13.3% (n = 74) relied on old-age pensions. Descriptive analysis of caregiver marital status indicated that a substantial portion of the sample had never been married (n = 225, 40.5%), followed by those who were married or cohabiting (n = 183, 32.9%). Widowed caregivers constituted 17.4% (n = 67, comprising 19 males and 48 females), while a minority were separated, divorced, or categorised as other (n = 51, 9.2%). Educational attainment data showed that 35.1% (n = 195) of caregivers completed Grade 12, though a substantial portion of the children 45.0% (n = 250), were unaware of their caregiver's educational level.

3.3 Baseline Anthropometric Profiles

Table 2
Descriptive Anthropometric Parameters of the Cohort

Anthropometric Metric	Mean ± SD	Median	Minimum	Maximum
Stature (cm)	142.95 ± 10.44	143.00	111.00	173.50
Body Mass (kg)	36.15 ± 8.35	34.80	21.00	65.90
BMI (kg/m²)	17.77 ± 4.13	17.14	9.24	34.72

SD=standard deviation; cm= centimetres; kg=kilogram; BMI= body mass index; kg/m^2

The baseline physical growth indicators of the cohort are outlined in Table 2. The mean stature of the participants was 142.95 ± 10.44 cm (Range: 111.0 -173.5 cm). The mean body mass was recorded at 36.15 ± 8.35 kg, with a wide biological variance ranging from a minimum of 21.0 kg to a maximum of 65.9 kg. The calculated mean Body Mass Index (BMI) for the collective sample was 17.77 ± 4.13 kg/m² (Range: 9.24–34.72 kg/m²).

Table 3
Cross-Classification of Nutritional Status Stratified by Gender Across WHO, IOTF, and CDC References (N = 556)

Reference Standard & Classification	Male (n = 233) n (%)	Female (n = 323) n (%)	Total (N = 556) N (%)
WHO 2007 Reference			
Thinness	48 (20.6%)	56 (17.3%)	104 (18.7%)
Normal weight	144 (61.8%)	220 (68.1%)	364 (65.5%)
Overweight	25 (10.7%)	28 (8.7%)	53 (9.5%)
Obesity	16 (6.9%)	19 (5.9%)	35 (6.3%)
IOTF Framework			
Thinness	51 (21.9%)	57 (17.6%)	108 (19.4%)
Normal weight	134 (57.5%)	214 (66.3%)	348 (62.6%)
Overweight	33 (14.2%)	34 (10.5%)	67 (12.1%)
Obesity	15 (6.4%)	18 (5.6%)	33 (5.9%)
CDC BMI-for-Age			
Underweight	48 (20.6%)	50 (15.5%)	98 (17.6%)
Normal weight	132 (56.7%)	224 (69.3%)	356 (64.0%)
Overweight	31 (13.3%)	25 (7.7%)	56 (10.1%)
Obesity	22 (9.4%)	24 (7.4%)	46 (8.3%)

N= total number of the participants; n=subset number of the participants; %=percentages; WHO=World Health Organization; IOTF= International Obesity Task Force; CDC= Centre for Disease Control and Prevention; BMI= Body mass index

To evaluate the impact of reference choice on the determination of nutritional status, child BMI values were cross classified across the three global standard growth frameworks (Table 3). Marked variations were observed in the global prevalence estimates for both undernutrition and overnutrition. The IOTF standard classified the highest proportion of the cohort as thin (19.4% thinness; n = 108), followed by the WHO standard (18.7% thinness; n = 104) and the CDC standard (17.6% underweight; n = 98). Sex-stratified analyses revealed that boys were more frequently classified as thin than girls across all three reference systems, with IOTF classifying 21.9% of boys as thin compared to 17.6% of girls. Age-specific variances were prominent; at age 9, the WHO standard captured an underweight prevalence of 18.6% among children, which shifted dynamically across the normal weight brackets. For overnutrition, the CDC reference generated the most conservative estimates for normal weight (64.0%) while identifying the

highest aggregate pool of obesity (8.3%, n = 46). In contrast, the WHO and IOTF references yielded lower obesity numbers (WHO: 6.3%; IOTF: 5.9%), though they differed on intermediate overweight thresholds (WHO: 9.5% vs. IOTF: 12.1%).

3.4 Comparative Assessment of Nutritional Status across WHO, IOTF, and CDC Growth References

Table 4
Chi-Square Distribution Profiles Matrix by Age and Gender (N = 556)

Growth Reference	Feature Stratification	Pearson Chi-Square (chi^2$)	Degrees of Freedom (df)	Asymptotic Significance (p-value)
WHO 2007	Age Blocks (9–14 yrs)	27.097	15	.028*
	Child Gender	2.405	3	.493
IOTF	Age Blocks (9–14 yrs)	23.332	15	.077
	Child Gender	4.563	3	.207
CDC	Age Blocks (9–14 yrs)	25.667	15	.042*
	Child Gender	10.246	3	.017*

WHO=World Health Organization; IOTF= International Obesity Task Force; CDC= Centre for Disease Control and Prevention; chi^2 = chi-square; df=degree of freedom; yrs= years

**Statistically significant at the p < 0.05 level.*

The distribution of nutritional categories varied significantly across age brackets when using the WHO 2007 reference (chi^2(15) = 27.10, p = .028) and the CDC baseline (chi^2(15) = 25.67, p = .042). Conversely, no statistically significant association between age group and nutritional status was observed using the IOTF classification (p = .077). Gender-stratified chi-square evaluations revealed a crucial diagnostic divergence. Neither the WHO reference (chi^2(3) = 2.41, p = .493) nor the IOTF framework (chi^2(3) = 4.56, p = .207) showed significant variations in weight distribution between boys and girls. However, the CDC reference captured highly significant gender differences (chi^2(3) = 10.25, p = .017) (Table 4). This divergence occurs because the CDC chart classifies a substantially larger proportion of boys into extreme weight categories (13.3% overweight, 9.4% obese) compared to girls (7.7% overweight, 7.4% obese), highlighting that reference selection directly shifts gender-based epidemiological conclusions.

3.5 Methodological Concordance Analysis (Cohen's Kappa)

Table 5
Concordance Matrix and Discrepancy Interpretations between Standards

Growth Framework Pair	Kappa value	Asymptotic Std Error	Approx- T stats	*p*-value	Strength of Agreement
WHO vs IOTF	**.933**	**.015**	**32.551**	**< 0.001**	**Almost perfect**
IOTF vs CDC	**.898**	**.017**	**31.838**	**< 0.001**	**Almost perfect**
WHO vs CDC	**.875**	**.020**	**30.797**	**< 0.001**	**Almost perfect**

WHO=World Health Organization; IOTF= International Obesity Task Force; CDC= Centre for Disease Control and Prevention; vs= versus; Asymp. Std. Error=Asymptotic standard error; Approx T stats= Approximate Test Statistics

***Statistically significant at the p < 0.001.*

To evaluate the clinical interchangeability of these tools, cross-framework concordance was determined using Cohen's Kappa (Table 5). All comparisons achieved statistical significance ($p < 0.001$) and fell within standard definitions of excellent agreement. The highest agreement occurred between the WHO and IOTF frameworks (kappa = .933); (SE = 015); (T = 32.551); p<. 001), reflecting strong alignment regarding severe thinness and obesity classification boundaries. Similarly, the comparison between IOTF and CDC standards demonstrated almost perfect agreement (kappa = .898); (SE = .017); (T = 31.838); ($p < .001$). Finally, the WHO and CDC standards yielded a kappa value of (.875); (SE = .020); (T = 30.797); ($p < .001$). Overall, the three growth frameworks showed high classification consistency across the sample.

3.6 Socioeconomic Predictors of Nutritional Status (Multinomial Logistic Regression)

Table 6
Multinomial Logistic Regression Models Isolating SES Risk Adjustments (Reference: normal weight)

Independent Predictors	Thinness aOR (95% CI)	*p*-value	Overweight aOR (95% CI)	*p*-value	Obesity aOR (95% CI)	*p*-value
Child Baseline Demographics						
Age per year increment	1.01 (0.83–1.22)	.947	0.66 (0.51–0.86)	.002*	0.58 (0.41–0.81)	.001*
Gender Male vs Female	1.11 (0.69–1.78)	.660	1.53 (0.82–2.87)	.180	1.06 (0.48–2.35)	.880
Household & Care Environment						
Household Occupant Count	1.02 (0.90–1.14)	.798	1.02 (0.86–1.19)	.852	1.16 (0.93–1.43)	.183
Grandparents in Home *Yes/No*	1.44 (0.73–2.84)	.292	1.10 (0.42–2.85)	.849	0.18 (0.05–0.69)	.012*
Caregiver Employment Framework						
Employed Caregiver	0.83 (0.27–2.53)	.736	4.17 (0.64–26.98)	.134	1.86 (0.19–18.13)	.595
Unemployed Caregiver	0.97 (0.33–2.84)	.950	5.98 (0.88–40.52)	.067	1.77 (0.19–16.84)	.621
Pensioner Caregiver	0.79 (0.18–3.42)	.752	21.98 (2.26-213.67)	.008*	1.04 (0.07–15.84)	.976
Caregiver Highest Education Level						
Secondary School Grade (8–10)	0.18 (0.04–0.90)	.037*	0.19 (0.02–1.77)	.146	0.18 (0.02–1.93)	.156
Matric Grade 12	0.78 (0.25–2.41)	.662	0.54 (0.13–2.30)	.401	0.32 (0.06–1.62)	.169

**Statistically significant at the p < 0.05 level. aOR = Adjusted Odds Ratio; CI = Confidence Interval.*Multinomial logistic regression was performed to identify demographic and socioeconomic predictors of thinness, overweight, and obesity, using normal weight as the reference category (Table 6). For thinness, children whose caregivers attained secondary education (Grades 8–10) demonstrated significantly lower odds of undernutrition compared to the reference group (adjusted odds ratio [aOR] = 0.18, 95% confidence interval [CI] = 0.04–0.90, *p* = 0.037), whereas no other demographic or household factors reached statistical significance. For overweight, increasing child age was inversely associated with risk, with each additional year reducing the odds of overweight by 34% [aOR] = 0.66, 95% [CI] = 0.51–

0.86, *p* = 0.002). Conversely, having a pensioner caregiver was associated with markedly higher odds of overweight [aOR] = 21.98, 95%; [CI] = 2.26–213.67, *p* = 0.008), though the wide confidence interval reflects limited subgroup sample size. For obesity, both increasing child age [aOR] = 0.58, 95% [CI]=: 0.41–0.81, *p* = 0.001) and the presence of grandparents in the household (aOR = 0.18, 95% CI: 0.05–0.69, *p* = 0.012) were significantly protective, reducing the odds of obesity by 42% and 82%, respectively.

4. Discussion

The primary objective of this study was to evaluate the diagnostic concordance of the WHO 2007, IOTF, and CDC growth references [Table 3] and to determine how structural sociodemographic and household vulnerabilities shape the nutritional status of school-aged children in rural Limpopo, South Africa. Our findings reveal a critical double burden of malnutrition that is characterized by high rates of thinness alongside emerging overnutrition heavily modulated by the child's developmental age and the configuration of household caregiving structures [Table 6].

Agreement and Differences Between BMI Reference Systems

A central methodological finding of this study is that while all three global reference standards exhibited strong statistical concordance Kappa agreements ranging from 0.875 to 0.933 [Table 5], they yield highly divergent clinical and epidemiological conclusions. The IOTF reference flagged the highest rate of thinness (19.4%), while the CDC reference identified the highest prevalence of obesity (8.3%) [Table 3].

This systematic divergence has profound implications for public health tracking and interventions in rural South Africa. Although agreement between the reference systems was high, the prevalence estimates differed. The IOFT classification demonstrated the highest estimate of thinness, whereas the CDC reference produced the highest estimate of obesity. These differences may influence prevalence estimated used for nutritional surveillance and programme planning. Furthermore, our Chi-Square analyses demonstrated that the CDC reference captured highly significant gender variations (p = .017), which were completely absent when evaluating the cohort through the WHO or IOTF lenses [Table 4]. This aligns with broader South African literature highlighting that growth reference criteria are not passive measurement tools; they actively redefine gender-specific epidemiological profiles and can misdirect school-based health initiatives if not calibrated against local parameters.

Age Dynamics and the Early Window of Overnutrition Risk

The multinomial logistic regression analysis demonstrated a clear, statistically significant inverse relationship between a child's age and overnutrition risk. For every one-year increment in age, the odds of a child being classified as overweight dropped by 34% (p = .002), and the odds of obesity dropped by 42% (p = .001) [Table 6]. This indicates that the risk of overnutrition is heavily concentrated in the younger cohorts (9- to 10-year-olds) within these rural Limpopo schools. This age-related pattern warrants further investigation. Although the findings suggest that the overweight and obesity were more

common among the younger children in this cohort, the mechanisms underlying this association cannot be determined from the present study.

The Dual-Natured Role of Grandparents and Caregiver Configurations

Our multi-variable predictive regression isolated a compelling, dual-natured socio-familial phenomenon regarding the role of the older generation in rural households. On one hand, children whose primary caregivers were identified as pensioners were more than 21 times more likely to be classified as overweight (OR = 21.98, p = .008) compared to standard employment configurations [Table 6]. On the other hand, the physical co-habitation of grandparents within the household served as a powerful protective shield, associated with lower odds of childhood obesity (OR = 0.18, p = .012) [Table 6]. The apparently contrasting findings for pensioner caregiver status and grandparent co-residence should be interpreted cautiously, as these variables represent different aspects of the household environment. Pensioner status reflects the employment category of the primary caregiver whereas grandparent co-residence reflects household composition. In addition, the wide confidence interval around the association between pensioner caregiver status and overweight indicates considerable uncertainty in this estimate. Further research is needed to explore the household and caregiving mechanisms that may underlie these associations.

5. Limitations, Conclusion and Recommendations

5.1 Study Limitations

Several limitations must be acknowledged when interpreting the findings of this study. First, the cross-sectional design does not allow causal relationships to be established. In addition, while the samples cohort captured the late childhood to early adolescent developmental (9–14 years), the distribution across ages was uneven. The maximum age of 14 years was represented by only two female participants, which limits the ability to accurately examine nutritional and anthropometric patterns at the upper end of the age range. Consequently, the observed association between increasing age and lower odds of overweight and obesity should be interpreted cautiously and is primarily reflective of the younger age groups in the sample.

The findings may also not be generalisable beyond the rural Limpopo schools included in this study. BMI provides an indirect indicator of nutritional status and does not distinguish between fat mass and lean mass. Furthermore, some household and caregiver information may have been subject to reporting uncertainty, particularly in the current study where information was provided by the school children. Small subgroup sizes also resulted in wider confidence intervals for some regression estimates, particularly the association between pensioner caregiver status and overweight, and these findings should be interpreted cautiously.

Future public health and nutritional research in the Limpopo Province should include larger and more evenly distributed samples across age groups and, where possible, longitudinal designs to examine

changes in nutritional status over time. Further research exploring household and generational caregiving factors may also help clarify the associations observed in the present study.

5.2 Conclusion

This study demonstrates a double burden of malnutrition among school-going children in rural Limpopo, South Africa, where high rates of thinness coexist alongside emerging overnutrition [Table 3]. Our findings show that the choice of growth reference standard influences the resulting epidemiological profiles and gender-specific conclusions. The IOTF standard classified the highest prevalence of thinness (19.4%), whereas the CDC standard classified the highest prevalence of obesity (8.3%) and identified statistically significant gender differences [Table 4].

Sociodemographic patterns in nutritional status are associated with child age and household caregiving characteristics. Within this cohort, the odds of overweight and obesity decreased with increasing age [Table 6]; however, this finding should be interpreted considering the limited number of older participants. Furthermore, pensioner caregiver status was associated with higher odds of overweight, whereas grandparent co-residence was associated with lower odds of obesity [Table 6]. Collectively, these findings highlight the importance of considering both the choice of BMI reference standard and the broader household context when assessing nutritional status in rural school-going children.

5.3 Recommendations

Based on the empirical evidence generated in this study, the following structural and policy interventions are recommended:

- **Growth Chart Standardisation in School Screenings**: For routine integrated school health screenings in rural South African contexts, consistent use of an appropriate growth reference is important. The WHO 2007 growth reference may remain the primary standard, while the IOTF framework could be considered as a complementary reference where differences in thinness estimates are of interest. The observed differences between reference systems should be considered when interpreting prevalence estimates and planning national surveillance.
- **National School Nutrition Programme (NSNP)**: The findings suggest that greater attention may be warranted for younger children, particularly the 9- to 10-year-old age group in whom higher odds of overnutrition were observed. Further investigation of dietary intake and school food environments would help determine whether age-specific nutritional strategies within the NSNP are needed [26].
- **Support for Household Caregiving Structures**: The associations observed between caregiver characteristics and nutritional status highlight the importance of considering the household environment when planning nutrition-related support. Households in which pensioners are primary caregivers may warrant further investigation and targeted nutritional support. Community-based nutrition education could provide practical guidance on affordable, nutrient-dense food choice for caregivers and multi-generational households.

Declarations

Author contribution

VKM is the Principal Investigator of the Physical Activity, Nutrition and the Environment (PANE-study), designed and wrote the first draft of the manuscript. PSW performed the first review and editing of the draft, supervised, and input on the concept, methodologies and the statistical analysis of the manuscript. All authors participated in the final review, read and approved the final version of the manuscript for possible publication.

Acknowledgements

The authors wish to express their profound gratitude to the University of Venda Research Ethics Committee (UNIVEN REC), the Limpopo Provincial Research Ethics Committee (LPREC), and the National Department of Health Research Ethics Committee for their rigorous review and formal ethical clearances. We extend our sincere appreciation to the Limpopo Department of Basic Education, the relevant district managers, and the School Governing Bodies (SGBs) of the participating rural schools for granting administrative permissions for data collection. Most importantly, we thank the educators, field research assistants, parents/caregivers who provided consent, and the school-going children whose voluntary participation made this study possible. This research was supported by the institutional frameworks of the University of Venda.

Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding Statement

The present study is part of the Physical Activity, Nutrition & Environment (PANE-study) a multi-inter-transdisciplinary (MIT) project financially supported by the Department of Higher Education & Training (DHET) under University Staff Development Programme (USDP) Funding Framework- Ref. UCDP/UNIVEN/NL01). The DHET-USDP does not have any form of influence whatsoever on the contents of this manuscript.

Data Availability Statement

The datasets generated and analysed during the current study are not publicly available due to ethical restrictions regarding the confidentiality of minor participants in rural school settings, as mandated by the University of Venda Research Ethics Committee. However, the anonymised SPSS data file (2026 VK 1 PANE NCD NCD.sav) is available from the corresponding author upon reasonable academic request, subject to institutional data sharing approvals.

References

1. World Health Organization. Guideline: assessing and managing children at primary health-care facilities to prevent overweight and obesity in the context of the double burden of malnutrition: updates for the Integrated Management of Childhood Illness (IMCI). Geneva: World Health Organization. 2017. https://www.ncbi.nlm.nih.gov/books/NBK487902/. Accessed 11 Mar 2022.
2. Adedokun ST, Yaya S. Factors associated with adverse nutritional status of children in sub-Saharan Africa: evidence from the Demographic and Health Surveys from 31 countries. Matern Child Nutr. 2021;17:e13198.
3. Bhutta ZA. Global child nutrition and the Sustainable Development Goals. Lancet Child Adolesc Health. 2017;1:256–7.
4. Jaacks LM, Di Cesare M. The epidemiology and social determinants of obesity. Clin Obes Adult Child. 2022; 17–30.
5. Sanders RA. Adolescent psychosocial, social, and cognitive development. Pediatr Rev. 2013;34:354–9.
6. Tulloch T, Kaufman M. Adolescent sexuality. Pediatr Rev. 2013;34:29–37.
7. Meso MJ, Olutola AA, Faluyi OT. Primary determinants of poverty in Limpopo province: a case study of Polokwane Local Municipality. Afr J Dev Stud. 2026;16:297–319.
8. Shisana O, Labadarios D, Rehle T, Simbayi L, Zuma K, Dhansay A, et al. The South African National Health and Nutrition Examination Survey, 2012: SANHANES-1: the health and nutritional status of the nation. Cape Town: HSRC; 2014.
9. Corkins MR. Why is diagnosing paediatric malnutrition important? Nutr Clin Pract. 2017;32:15–8.
10. Hawkes C, Ruel MT, Salm L, Sinclair B, Branca F. Double-duty actions: seizing programme and policy opportunities to address malnutrition in all its forms. Lancet. 2020;395:142–55.
11. Galobardes B, Shaw M, Lawlor DA, Lynch JW, Davey Smith G. Indicators of socioeconomic position (part 1). J Epidemiol Community Health. 2006;60(1):7–12.
12. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet. 2014;384:766–81.
13. 2015 GBD, Collaborators O, Afshin A, Forouzanfar MH, Reitsma MB, Sur P, Estep K et al. Health effects of overweight and obesity in 195 countries over 25 years. N Engl J Med. 2017; 377:13–27.
14. Phillips CM. Metabolically healthy obesity across the life course: epidemiology, determinants, and implications. Ann N Y Acad Sci. 2017;1391:85–100.
15. Lau JD, Elbaar L, Chao E, Zhong O, Yu CR, Tse R, et al. Measuring overweight and obesity in Chinese American children using US, international and ethnic-specific growth charts. Public Health Nutr. 2020;23:2663–70.
16. Buli BG, Tillander A, Fell T, Bälter K. Active commuting and healthy behaviours among adolescents in neighbourhoods with varying socioeconomic status: the NESLA study. Int J Environ Res Public

Health. 2022;19:3784.

17. Craig A, Mapanga W, Mtintsilana A, Dlamini S, Norris S. Exploring the national prevalence of mental health risk, multimorbidity and the associations thereof: a repeated cross-sectional panel study. Front Public Health. 2023;11:1217699.
18. Victora CG, Christian P, Vidaletti LP, Gatica-Domínguez G, Menon P, Black RE. Revisiting maternal and child undernutrition in low-income and middle-income countries: variable progress towards an unfinished agenda. Lancet. 2021;397:1388–99.
19. Murray R, Kerr K, Brunton C, Williams J, DeWitt T, Wulf K. A first step towards eliminating malnutrition: a proposal for universal nutrition screening in pediatric practice. Nutr Diet Suppl. 2021;13:17–24.
20. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ. 2007;85(9):660–7.
21. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes. 2012;7(4):284–94.
22. Kuczmarski RJ, Ogden CL, Guo SS, et al. 2000 CDC Growth Charts for the United States: methods and development. Vital Health Stat. 2002;11(246):1–190.
23. Marfell-Jones MJ, Stewart AD, de Ridder JH. International standards for anthropometric assessment. Wellington, New Zealand: International Society for the Advancement of Kinanthropometry; 2012.
24. IBM Statistical. Package for Social Science Statistics (SPSS) (Version 32.0).
25. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977;33(1):159–74.
26. Wang D, Fawzi WW. Impacts of school feeding on educational and health outcomes of school-age children and adolescents in low-and middle-income countries: Protocol for a systematic review and meta-analysis. Syst Rev, 9(1): 1–8.