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Body Mass Index Cut-off Points for Tunisian Children and Adolescents: Derivation and Comparison with International Standards

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Abstract

Background: Population-specific body mass index references account for genetic and environmental variations affecting pediatric growth patterns. Tunisia established BMI reference curves in 2018 and 2021 but lacked validated clinical cut-off points for routine health assessments.

Aim: The study aimed to (i) derive BMI cut-off points for Tunisian children and adolescents aged 6-17.99 years using the Lambda-Mu-Sigma method, and (ii) evaluate agreement between Tunisian cut-offs and International Obesity Task Force and World Health Organization standards.

Methods: We analyzed cross-sectional anthropometric data from 3,533 participants (1,760 girls, 1,773 boys; age 6.00-18.99 years) collected during 2012-2013 through stratified random sampling across northern, central, and southern Tunisia. The LMS method identified percentiles corresponding to adult BMI thresholds of 18.5 kg/m² (thinness), 25 kg/m² (overweight), and 30 kg/m² (obesity) at age 18 years. Agreement between classification systems was quantified using Cohen's kappa coefficients and chi-square tests.

Results: Cut-off points corresponded to the 18.41st percentile (thinness), 88.69th percentile (overweight), and 98.81st percentile (obesity) for girls. Boys showed cut-offs at the 17.88th, 86.65th, and 96.86th percentiles respectively. Maximum deviations from IOTF reached 1.08 kg/m². Deviations from WHO reached 3.12 kg/m². Thinness frequency using Tunisian cut-offs (15.57%) exceeded IOTF (10.4%) and WHO (2.8%) estimates ($P<0.001$). Agreement with IOTF was substantial (kappa=0.772 for thinness) but fair with WHO (kappa=0.274).

Conclusion: Tunisia-specific BMI cut-offs differ from international standards, particularly for thinness classification. External validation in independent samples should precede widespread clinical adoption. These findings support development of population-tailored growth assessment tools for North African contexts.

Keywords: adolescent, body mass index, child, cut-off values, growth charts, obesity, pediatric, reference standards, thinness

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1. INTRODUCTION

Physical growth assessment forms the cornerstone of pediatric health surveillance worldwide **[1]**. Body mass index serves as the primary anthropometric indicator for evaluating weight status in children and adolescents **[2]**. However, BMI interpretation requires age-specific and sex-specific reference standards because growth patterns change substantially during development [3, 4].

Childhood obesity has emerged as a major public health concern, affecting approximately 340 million children and adolescents globally **[5]**. Excess adiposity during childhood increases immediate health risks including metabolic dysfunction, cardiovascular abnormalities, and psychosocial complications [6, 7]. Long-term consequences extend into adulthood with elevated risks for type 2 diabetes mellitus, cardiovascular disease, certain cancers, and premature mortality [8-10].

Conversely, undernutrition and thinness during childhood impair physical development, cognitive function, immune competence, and academic performance [11, 12]. Accurate identification of both extremes of the weight spectrum enables timely interventions to optimize child health outcomes **[13]**. Establishing appropriate BMI cut-off points requires careful consideration of statistical, clinical, and epidemiological factors **[14]**. Cut-offs must balance sensitivity (identifying truly at-risk children) with specificity (avoiding false classifications) **[15]**. The process involves selecting BMI thresholds that correspond to health risks in adulthood while accounting for normal developmental changes during childhood **[16]**.

Two major international systems provide BMI references for pediatric populations. The International Obesity Task Force developed cut-offs based on pooled data from six countries (Brazil, Great Britain, Hong Kong, Netherlands, Singapore, United States), creating percentile curves that pass through adult BMI values of 25 kg/m² and 30 kg/m² at age 18 years **[17]**. The World Health Organization constructed growth standards using data from the Multicentre Growth Reference Study (children 0-5 years) and the National Center for Health Statistics datasets (children 5-19 years), expressing BMI relative to age using Z-scores **[18]**. These international references provide valuable tools for global comparisons and epidemiological research.

However, substantial evidence indicates that genetic background, environmental conditions, dietary patterns, and socioeconomic factors create population-specific variations in growth trajectories [19-21]. Applying universal standards to diverse populations may result in systematic misclassification, potentially underestimating or overestimating health risks in specific ethnic or geographic groups [22, 23].

Recognition of these limitations has prompted numerous countries to develop population-specific BMI references. Egypt established Z-score references for Egyptian schoolchildren aged 5-19 years **[24]**. China developed BMI cut-offs tailored to urban Chinese children and adolescents, accounting for earlier adiposity rebound and distinct body composition patterns compared to Western populations **[25]**. Hungary created national BMI references with age-specific and sex-specific percentile curves for children aged 3-18 years **[26]**. India derived BMI cut-offs based on affluent urban children, recognizing that international standards may not reflect Indian growth patterns **[27]**. These population-specific efforts share common objectives: improving accuracy of corpulence status assessment, enabling appropriate clinical decision-making, and supporting targeted public health interventions.

Despite the availability of international references, several critical gaps remain in the application of BMI standards to North African populations. First, genetic ancestry in Tunisia reflects a unique admixture of Mediterranean, Arab, and Berber populations, distinct from the ethnic compositions in datasets used to develop IOTF and WHO references **[28]**. This genetic distinctiveness may influence body composition, fat distribution patterns, and the relationship between BMI and metabolic risk **[29]**. Second, nutritional transition in Tunisia has occurred rapidly over recent decades, characterized by shifts toward Western dietary patterns, increased consumption of processed foods, and reduced physical activity **[30]**. These environmental changes may alter growth trajectories in ways not captured by references developed from populations experiencing different nutritional contexts **[31]**. Third, methodological differences between reference systems create confusion for clinicians. Studies comparing IOTF and WHO classifications report substantial discordance in obesity prevalence estimates, with WHO typically identifying more children as overweight or obese compared to IOTF [32, 33]. This variability complicates clinical interpretation and public health surveillance when different standards yield conflicting classifications for the same child.

Fourth, the applicability of Z-score-based WHO standards versus percentile-based IOTF approaches remains debated, with each system offering distinct advantages for different applications **[34]**. Fifth, limited data exist comparing North African growth patterns with international references. Algeria recently published BMI charts for Algerian children and adolescents [35, 36]. However, these studies did not derive operational cut-off points anchored to adult BMI thresholds,

nor did they validate their curves against IOTF or WHO classification systems. As a result, no North African country to date has established population-specific BMI cut-off points for thinness, overweight, and obesity suitable for routine clinical decision-making. Sixth, previous Tunisian research established reference curves but did not derive operational cut-off points for clinical decision-making or validate their performance against international standards [37, 38]. This gap limits practical application of available Tunisian data in clinical practice and school health programs.

Based on these identified gaps, the present cross-sectional study aimed to (i) establish specific BMI cut-off points for Tunisian children and adolescents aged 6-17.99 years using the LMS method, and (ii) assess agreement between Tunisian-derived cut-offs and established IOTF and WHO classification systems. We hypothesized that Tunisian cut-offs would show better agreement with IOTF compared to WHO references based on methodological similarities in the percentile-based approach. These objectives address a practical need for population-appropriate growth assessment tools in Tunisia while contributing to broader understanding of BMI variation across diverse pediatric populations.

2. MATERIALS AND METHODS

2.1. Ethics Approval

The study was conducted in accordance with the Declaration of Helsinki. The research protocol received retrospective approval from the Institutional Review Board of the High Institute of Sport and Physical Activity of Kef, University of Jendouba (approval code: 02-2023). This approval covered secondary analysis of de-identified anthropometric data originally collected during 2012-2013 under approved protocols. Written informed consent was obtained from all participants and their legal guardians prior to the original data collection.

2.2. Sample Size Calculation

Sample size was determined using established statistical procedures with reference to previous research examining BMI distributions in pediatric populations. Ghouili et al. established BMI reference curves for 1,313 Tunisian children aged 6-12 years **[37]**, while their subsequent study extended coverage to 3,533 children aged 6-18 years **[38]**. These studies provided reference points for expected BMI variability and sample requirements for developing robust percentile curves. The sample size calculation employed the following formula: $n = Z^2p(1-p)/d^2$ Where n represents required sample size, Z represents the Z-score corresponding to 95% confidence level (1.96), p represents expected proportion (0.50, representing maximum variability), and d represents margin of error (0.17). This calculation was confirmed using GPower software (version 3.1.9.6) with a priori power analysis for repeated measures designs. The analysis considered an effect size of f=0.25 (representing small to medium effects in anthropometric comparisons), statistical power of 0.80, alpha level of 0.05, number of age groups (13 categories), and number of sex groups (2).

The G*Power analysis yielded a minimum required total sample size of 3,100 participants. Based on these calculations, a minimum sample of 3,100-3,200 participants was required to ensure adequate representation across all age and sex strata. The final sample size of 3,533 participants exceeded this minimum requirement and provided sufficient statistical power to derive stable percentile estimates across the entire age range. This sample size is comparable to previous studies developing national BMI references [24-27] and sufficient to address the study's aims of establishing BMI cut-off points and comparing them with international standards.

2.3. Participants

This study analyzed data from 3,533 children and adolescents (1,760 girls, 1,773 boys) aged 6.00-18.99 years. Data were collected between September 2012 and May 2013 through stratified random sampling to ensure geographic representation across Tunisia. Sampling targeted three major regions: northern, central, and southern governorates. Within each region, schools were randomly selected. Participants were recruited through school-based programs coordinated with regional education directorates. Inclusion criteria specified: (i) children and adolescents aged 6.00 to 18.99 years enrolled in public primary, middle, and secondary schools in the selected regions, (ii) parental consent and child assent obtained, and (iii) ability to stand independently for anthropometric measurements. Exclusion criteria removed children with: (i) diagnosed chronic diseases affecting growth (diabetes mellitus, congenital heart disease, chronic kidney disease, genetic syndromes, malabsorption disorders), (ii) acute illness at time of assessment, (iii) medications known to affect growth or body composition (corticosteroids, growth hormone, chemotherapy), and (iv) physical disabilities preventing standard anthropometric measurement. Medical questionnaires completed by parents identified exclusions.

2.4. Study Design

This cross-sectional observational study utilized anthropometric data collected during a single time point for each participant. The study represents the third phase of a comprehensive research program to develop Tunisian pediatric growth references. The first phase, published in 2018, presented BMI reference curves for children and adolescent **[37]**. The second phase, published in 2021, extended these curves through age 18 and incorporated additional anthropometric parameters (height, weight, sitting height and leg length) **[38]**. Neither previous publication established specific clinical cut-off points or validated performance against international standards. The current analysis addresses this gap. We derive operational BMI cut-offs from the established reference curves **[38]** and assess their concordance with IOTF **[17]** and WHO **[18]** classification systems. This represents a distinct research contribution focusing on clinical application and international comparison rather than curve construction.

Data collection occurred during regular school hours in dedicated health facilities within each school. Measurements were conducted between 09:00 and 11:00 hours to minimize diurnal variation effects **[39]**. All participants wore light clothing without shoes during assessment. Environmental conditions were standardized with measurements performed indoors at ambient temperatures of 20-25°C.

2.5. Anthropometric Measurements

Six trained examiners conducted all anthropometric measurements following standardized WHO protocols **[40]**. All examiners completed intensive 2-day training programs that included theoretical instruction on measurement techniques, practical demonstrations, and supervised practice sessions. Inter-rater reliability was assessed before data collection through repeated measurements on 30 children. Technical error of measurement was calculated and remained below 0.5 cm for height and 0.1 kg for weight, meeting acceptable standards for anthropometric research **[41]**. Identical measurement equipment was used across all study centers to ensure standardization. Equipment underwent weekly calibration against certified reference standards throughout the data collection period.

2.5.1. Height Measurement

Height was measured using portable stadiometers (Seca 206, Hamburg, Germany) with 0.1 cm precision. Participants stood barefoot or in thin socks on a flat surface with weight distributed evenly between both feet and heels together. The head was positioned to maintain the Frankfort horizontal plane (lower border of the eye orbit aligned horizontally with the upper margin of the external auditory meatus). Participants were instructed to stand erect, take a deep breath, and hold the position during measurement. The stadiometer headboard was lowered to compress the hair and contact the superior aspect of the head. Two measurements were obtained for each participant. When measurements differed by less than 0.5 cm, the mean value was recorded. If the difference exceeded 0.5 cm, a third measurement was obtained and the median of the three values was recorded.

2.5.2. Weight Measurement

Weight was measured using calibrated electronic scales (Tanita BF-681 W, Tokyo, Japan) with 0.1 kg precision. Participants wore light clothing (physical education uniforms) without shoes. The scale was zeroed before each measurement session and recalibrated after every 20 measurements to maintain accuracy. Participants stood motionless in the center of the scale platform with weight distributed evenly and arms hanging naturally at the sides. Two measurements were obtained for each participant. When measurements differed by less than 0.2 kg, the mean value was recorded. If the difference exceeded 0.2 kg, a third measurement was obtained and the median of the three values was recorded.

2.5.3. Body Mass Index Calculation

BMI was calculated as weight in kilograms divided by height in meters squared (kg/m²). All calculations used the mean or median values obtained from repeated measurements to minimize measurement error.

2.6. Derivation of Cut-off Points

We followed the methodology established by Cole and Lobstein for deriving IOTF cut-offs **[17]**. This approach creates smooth percentile curves that pass through specified adult BMI values at age 18 years. Adult BMI thresholds of 18.5 kg/m² (thinness), 25 kg/m² (overweight), and 30 kg/m² (obesity) served as anchoring points **[42]**. These values represent internationally recognized thresholds associated with health risks in adult populations. Z-scores for these target BMI values at age 18 were calculated using LMS parameters from our previously published Tunisian reference curves **[38]**. The LMS method transforms skewed distributions into normal distributions through three age-specific and sex-specific parameters: L (Box-Cox power transformation), M (median value), and S (coefficient of variation) **[43]**. At age 18, LMS parameters were L=-0.80, M=20.84, S=0.14 for girls and L=-1.99, M=20.77, S=0.14 for boys. The formula for calculating Z-scores was: z = [(BMI/M)^L - 1] / (L*S). These Z-scores were then converted to percentiles that passed through the specified BMI values at age 18. The percentile was applied across all younger ages using age-specific LMS parameters through the formula: C100α = M [1 + L*S*Zα]^(1/L) where Zα represents the normal equivalent deviate for tail area α, and $C_{100}\alpha$ represents the BMI value at a given percentile. This process created smooth curves anchored at adult thresholds while accounting for age-specific and sex-specific growth patterns throughout childhood and adolescence.

2.7. Statistical Analysis

Descriptive statistics expressed continuous variables as means ± standard deviations. Shapiro-Wilk tests assessed normality of distributions. Levene's tests evaluated homogeneity of variance. Statistical analyses were performed using SPSS version 28.0 for Windows (IBM Corporation, Armonk, New York, USA). Statistical significance was set at $P<0.05$ for all comparisons. Chi-square tests compared frequency distributions of corpulence status categories (thinness, normal weight, overweight, obesity) classified according to Tunisian, IOTF, and WHO cut-offs. Cohen's kappa coefficient quantified agreement between classification systems **[44]**. Kappa values were interpreted as: 0.00-0.40 (poor to fair agreement), 0.41-0.80 (moderate to substantial agreement), and 0.81-1.00 (almost perfect agreement). This interpretation follows established guidelines for kappa coefficient interpretation in medical research **[44]**.

2.8. Methodological Limitations

We acknowledge using the same sample for both reference curve construction (previous publications [37, 38]) and cut-off validation (current analysis). Ideally, cut-off validation requires an independent sample to avoid circular reasoning and

overfitting. This limitation means our findings represent preliminary estimates of agreement between classification systems. External validation in independent Tunisian samples should be conducted before widespread clinical adoption of these cut-offs.

3. RESULTS

3.1. Sample Characteristics

Table 1 presents descriptive statistics for BMI across age groups stratified by sex. Mean BMI increased progressively with age in both sexes. Girls showed mean BMI values increasing from 16.17±1.94 kg/m² at age 6-6.99 years to 21.20±3.36 kg/m² at age 18-18.99 years. Boys demonstrated similar patterns with mean BMI increasing from 16.03±1.64 kg/m² at age 6-6.99 years to 22.07±3.73 kg/m² at age 18-18.99 years.

Table 1. Mean, standard deviation (SD), minimum (min), and maximum (max) body mass index values of 3,533 Tunisian children and adolescents (1,760 girls and 1,773 boys) per age group

Age group (years)	Girls N	Girls Mean	Girls SD	Girls Min	Girls Max	Boys N	Boys Mean	Boys SD	Boys Min	Boys Max
6-6.99	149	16.17	1.94	12.93	22.12	144	16.03	1.64	12.82	21.02
7-7.99	156	16.22	2.22	12.72	23.83	149	16.36	1.93	12.60	22.84
8-8.99	165	16.69	2.24	12.36	24.03	168	16.88	2.24	13.26	24.40
9-9.99	127	16.96	2.55	13.23	24.34	160	16.67	1.99	12.33	25.33
10-10.99	150	16.88	2.50	12.36	25.29	139	17.12	2.35	12.49	24.15
11-11.99	122	17.83	3.16	13.29	25.97	131	18.05	2.76	13.03	26.10
12-12.99	94	18.66	2.47	13.84	26.84	87	18.03	2.92	12.94	27.66
13-13.99	105	19.83	3.02	13.81	27.53	108	18.57	2.72	13.60	28.55
14-14.99	121	20.82	2.88	13.99	28.51	104	19.18	2.73	15.04	28.12
15-15.99	145	20.85	2.73	14.75	29.52	152	19.92	2.86	14.71	29.18
16-16.99	109	21.33	2.91	16.45	29.88	148	20.31	3.19	15.01	30.69
17-17.99	161	20.81	2.96	14.85	30.01	158	21.29	3.69	15.52	31.98
18-18.99	156	21.20	3.36	15.24	30.70	125	22.07	3.73	15.30	33.55

3.2. Cut-off Point Derivation

Table 2 presents Z-scores calculated at age 18 years for target adult BMI values. For girls, Z-scores were -0.92 for thinness (BMI 18.5 kg/m²), 1.19 for overweight (BMI 25 kg/m²), and 2.41 for obesity (BMI 30 kg/m²). For boys, Z-scores were -0.92 for thinness, 1.11 for overweight, and 2.17 for obesity.

Supplementary Table S1 presents complete LMS parameters and corresponding cut-off values across all ages from 6.0 to 18.0 years. Thinness, overweight, and obesity cut-offs corresponded to the 18.41st, 88.69th, and 98.81st percentiles respectively for girls. Boys showed cut-offs at the 17.88th, 86.65th, and 96.86th percentiles respectively.

Table 2. Calculation of Z-scores of different corpulence categories using the LMS method at age 18 years

Sex	L	M	S	Z-score for BMI 18.5 kg/m²	Z-score for BMI 25 kg/m²	Z-score for BMI 30 kg/m²
Girls	-0.80	20.84	0.14	-0.92	1.19	2.41
Boys	-1.99	20.77	0.14	-0.92	1.11	2.17

Note: L: Lambda (Box-Cox power transformation); M: Median; S: Coefficient of variation

3.3. Comparison with International Standards

Figures 1 and 2 illustrate discrepancies between Tunisian cut-offs and international references across the age range studied. Compared to IOTF standards, maximum differences for

thinness thresholds were 0.69 kg/m² in girls at age 7 years and 0.71 kg/m² in boys at age 8 years. Overweight thresholds showed maximum deviations of 0.70 kg/m² in girls at age 7.5 years and 1.08 kg/m² in boys at age 8 years. Obesity cut-offs differed maximally by 0.96 kg/m² in girls at age 6 years and 0.71 kg/m² in boys at age 8 years. Relative to WHO standards, discrepancies were substantially larger. Thinness thresholds diverged with maximum differences of 2.15 kg/m² in girls at age 15.5 years and 1.54 kg/m² in boys at age 8 years. Overweight thresholds showed maximum deviations of 1.24 kg/m² in girls at age 8 years and 1.06 kg/m² in boys at age 7.5 years. Obesity cut-offs demonstrated the largest discrepancies: 3.12 kg/m² in girls at age 8.5 years and 1.06 kg/m² in boys at age 7.5 years. Discrepancies were generally largest during middle childhood (ages 7-9 years). Differences decreased during adolescence, with curves converging toward the shared adult threshold values at age 18 years.

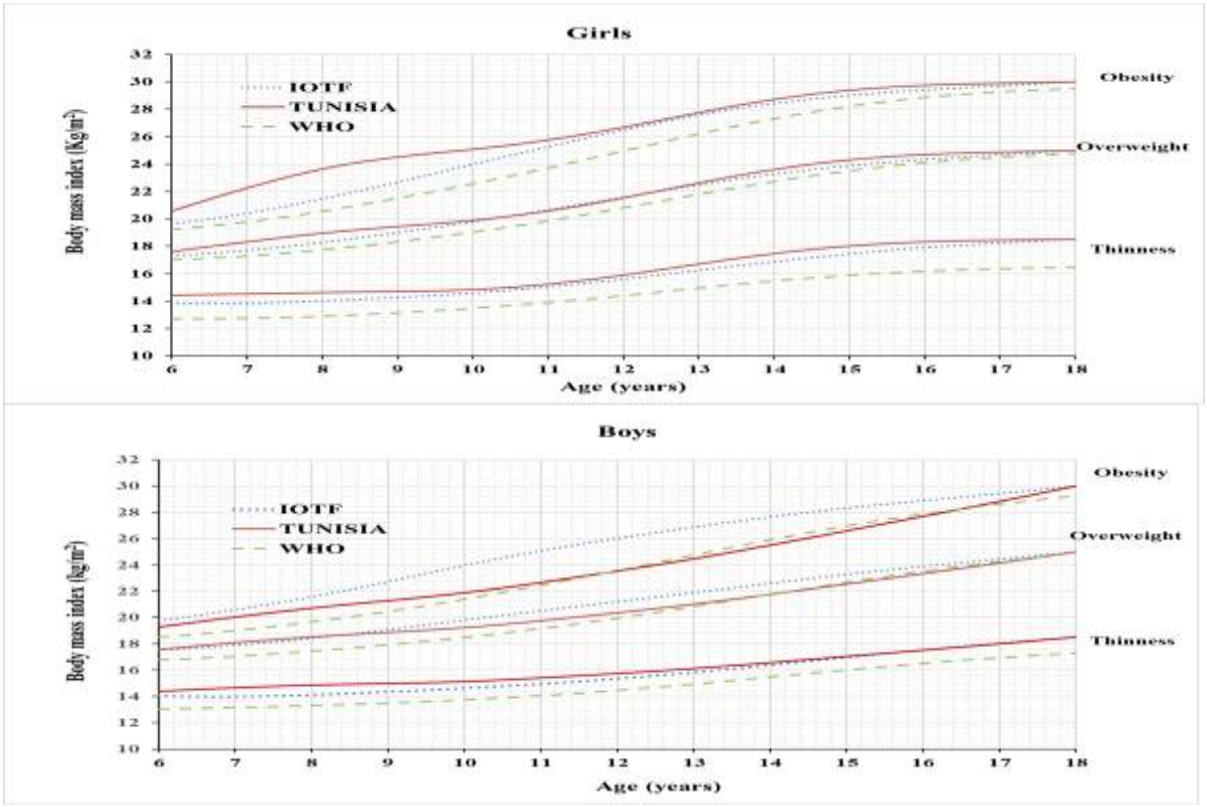

Figure 1. Comparison of identified Tunisian cut-off points with IOTF and WHO cut-off points across ages 6-18 years for girls (panel A) and boys (panel B).

Note: Solid lines represent Tunisian cut-offs, dashed lines represent IOTF cut-offs, and dotted lines represent WHO cut-offs. Three curves are shown for each reference system corresponding to thinness (bottom), overweight (middle), and obesity (top) thresholds. Y-axis shows BMI in kg/m². X-axis shows age in years. n=3,533.

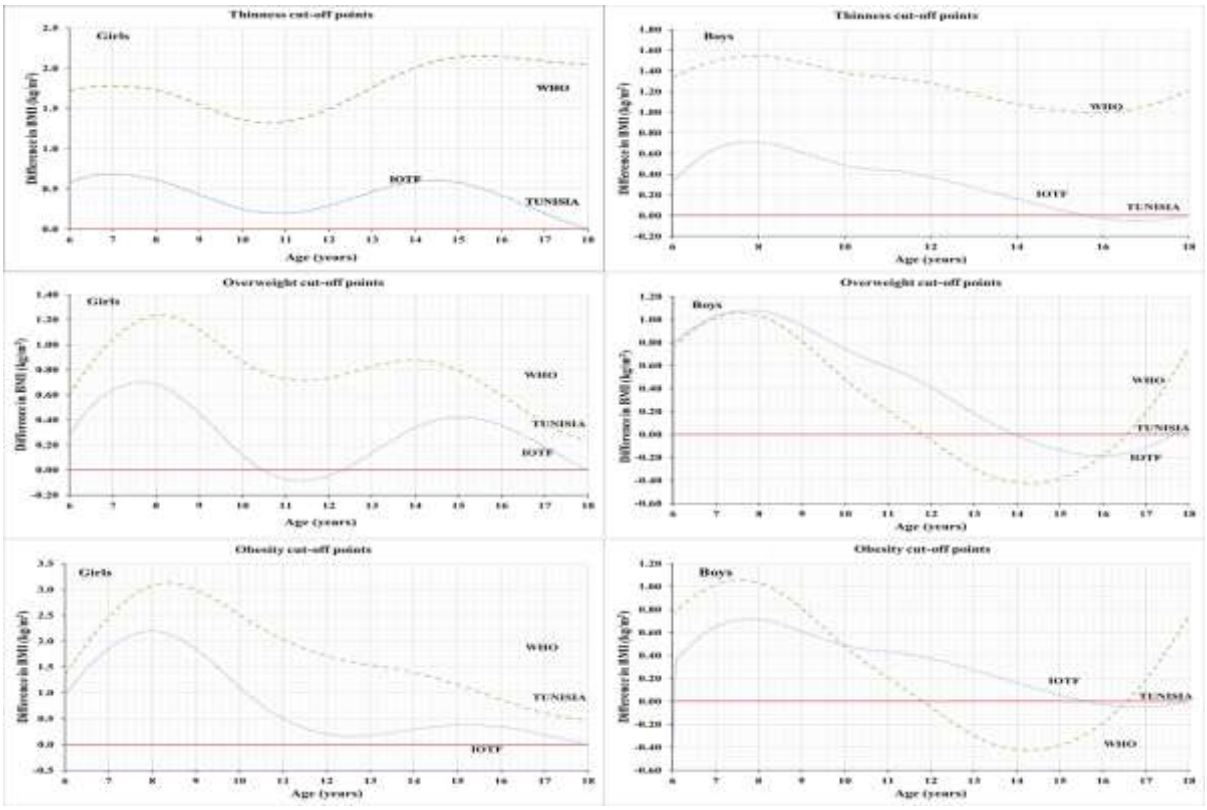

Figure 2. Difference values between identified Tunisian cut-off points for BMI-for-age compared with IOTF (panel A) and WHO (panel B) cut-off points across ages 6-18 years.

Note: Positive values indicate Tunisian cut-offs are higher than the comparison reference. Negative values indicate Tunisian cut-offs are lower. Separate lines show differences for thinness (circles), overweight (triangles), and obesity (squares) thresholds. Solid symbols represent girls; open symbols represent boys. Y-axis shows BMI difference in kg/m². X-axis shows age in years. n=3,533.

3.4. Frequency Distributions

Table 3 presents corpulence status frequencies classified according to Tunisian, IOTF, and WHO cut-offs. Using Tunisian cut-offs, thinness frequency was 15.57% overall. This significantly exceeded frequencies identified by IOTF standards (10.4%, P<0.001) and WHO standards (2.8%, P<0.001).

The pattern remained consistent when stratified by sex. Among girls, thinness frequencies were 16.37% (Tunisian) versus 10.7% (IOTF) versus 2.4% (WHO). Among boys, frequencies were 14.7% (Tunisian) versus 10.1% (IOTF) versus 3.3% (WHO). Normal weight frequency differed between classification systems. Tunisian standards classified 70.0% as normal weight overall. IOTF standards identified 75.2% as normal weight (P<0.01 for difference from Tunisian). WHO standards classified 78.5% as normal weight (P<0.001 for difference from Tunisian). Sex-stratified analysis showed similar patterns.

Among girls, normal weight frequencies were 70.5% (Tunisian) versus 74.4% (IOTF, P<0.01) versus 79.3% (WHO, P<0.001). Among boys, frequencies were 69.6% (Tunisian) versus 76.1% (IOTF, P<0.001) versus 77.6% (WHO, P<0.001). Overweight frequency showed less variation between Tunisian and IOTF standards. Overall, Tunisian standards identified 11.3% as overweight compared to 11.8% using IOTF (P>0.05). WHO standards classified significantly more boys as overweight (13.1%) compared to Tunisian standards (10.4%, P<0.01). No significant difference emerged for girls between Tunisian (12.2%) and WHO (13.2%) classifications.

Obesity frequency revealed notable differences between classification systems. Overall, Tunisian standards identified 3.2% as obese. IOTF standards classified 2.6% as obese. WHO standards identified 5.3% as obese (P<0.001 for difference from Tunisian). Sex-stratified analysis showed Tunisian standards classified 5.3% of boys as obese compared to 2.8% using IOTF (P<0.001) and 6.0% using WHO (P>0.05). For girls, Tunisian standards identified 1.0% as obese compared to 2.4% using IOTF (P<0.01) and 4.7% using WHO (P<0.001).

Table 3. Frequency (%) of thinness, normal weight, overweight and obesity according to international (IOTF and WHO) and Tunisian cut-off points

	Thinness	Normal weight	Overweight	Obesity
Boys (n=1,729)				
Tunisian	14.7	69.6	10.4	5.3
IOTF	10.1***	76.1***	11.0	2.8**
WHO	3.3***	77.6***	13.1*	6.0
Girls (n=1,760)				
Tunisian	16.4	70.5	12.2	1.0
IOTF	10.7***	74.4*	12.5	2.4*
WHO	2.4***	79.3***	13.2	4.7***
Total (n=3,489)				
Tunisian	15.6	70.0	11.3	3.2
IOTF	10.4***	75.2*	11.8	2.6
WHO	2.8***	78.5***	13.3*	5.3***

Note: IOTF: International Obesity Task Force; WHO: World Health Organization. *P<0.01; ** P<0.001; *** P<0.0001 (difference compared to Tunisian cut-off points using chi-square tests)

3.5. Agreement Analysis

Table 4 presents kappa coefficients measuring agreement between classification systems for each corpulence status category. For thinness classification, agreement between Tunisian and WHO references was fair overall (kappa=0.274, P<0.001). Sex-stratified values were kappa=0.223 for girls and kappa=0.329 for boys.

Agreement between Tunisian and IOTF references was substantially higher, reaching kappa=0.772 overall (P<0.001), with similar values for girls (kappa=0.763) and boys (kappa=0.780). For normal weight classification, agreement between Tunisian and WHO references ranged from moderate to almost perfect.

Girls showed moderate agreement (kappa=0.501). Boys demonstrated substantial agreement (kappa=0.615). The total sample showed almost perfect agreement (kappa=0.858, all P<0.001). Compared with IOTF references, Tunisian standards showed almost perfect agreement across all groups (kappa>0.82, P<0.001).

For overweight classification, substantial agreement emerged between Tunisian and WHO references. Kappa values were 0.614 for girls, 0.768 for boys, and 0.686 overall (all P<0.001). Tunisian references showed almost perfect agreement with IOTF references for girls and overall (kappa>0.820, P<0.001), while boys showed substantial agreement (kappa=0.754, P<0.001). For obesity classification, agreement between Tunisian and WHO references was moderate to almost perfect. Girls showed moderate agreement (kappa=0.349). Boys demonstrated almost perfect agreement (kappa=0.892). The total sample showed substantial agreement (kappa=0.708, all P<0.001). Comparing Tunisian with IOTF references revealed moderate agreement for girls (kappa=0.594, P<0.001) and substantial agreement for boys (kappa=0.683) and total sample (kappa=0.663, both P<0.001).

Table 4. Agreement (kappa coefficient) between the Tunisian, IOTF and WHO references for classification of children and adolescents according to BMI values

	Thinness	Normal weight	Overweight	Obesity
Tunisian vs WHO				
Girls	0.223***	0.501***	0.614***	0.349***
Boys	0.329***	0.615***	0.768***	0.892***
Total	0.274***	0.858***	0.686***	0.708***
Tunisian vs IOTF				
Girls	0.763***	0.820***	0.861***	0.594***

	Thinness	Normal weight	Overweight	Obesity
Boys	0.780***	0.824***	0.754***	0.683***
Total	0.772***	0.822***	0.811***	0.663***

Note: IOTF: International Obesity Task Force; WHO: World Health Organization *** P<0.001

4. DISCUSSION

This cross-sectional study established specific BMI cut-off points for Tunisian children and adolescents aged 6-18 years and evaluated their agreement with IOTF and WHO classification systems. Results revealed three major findings. First, Tunisian-derived cut-offs corresponded to distinct percentiles (18.41st for thinness, 88.69th for overweight, 98.81st for obesity in girls; 17.88th, 86.65th, 96.86th in boys) that differ from those implied by international standards. Second, substantial discrepancies emerged between Tunisian and WHO cut-offs (maximum 3.12 kg/m²) while differences from IOTF were more modest (maximum 1.08 kg/m²). Third, classification agreement was substantially better with IOTF (kappa=0.772 for thinness) than WHO (kappa=0.274 for thinness), supporting our hypothesis that methodological similarities would yield greater concordance with IOTF approaches.

4.1. Thinness Classification and Frequency Discrepancies

Tunisian cut-offs identified significantly higher frequencies of thinness (15.57%) compared to IOTF (10.4%) and WHO (2.8%) estimates (P<0.001 for both comparisons). These effect sizes represent large practical differences in population surveillance. The finding aligns with previous research demonstrating that classification system choice substantially influences prevalence estimates [32, 33]. Kêkê et al. compared French, IOTF, and WHO references among 1,458 French children and found that WHO identified fewer thin children compared to IOTF **[32]**. Similarly, Qian et al. examined multiple BMI screening tools in 5,692 Chinese children and reported that different cut-offs produced thinness prevalence estimates ranging from 4.1% to 15.3% **[25]**. The convergence with these studies suggests robust evidence that cut-off selection meaningfully affects public health surveillance and resource allocation decisions.

The divergence from WHO is particularly pronounced. WHO standards were developed from the Multicentre Growth Reference Study, which selected children from environments supporting optimal growth with breastfeeding, adequate nutrition, and disease prevention **[18]**. These standards represent aspirational growth under ideal conditions rather than descriptive norms for typical populations. Tunisia faces ongoing challenges with both undernutrition in rural/disadvantaged areas and overnutrition in urban/affluent populations **[30]**. The Tunisian BMI distribution may reflect this nutritional transition period, making WHO standards inappropriate for identifying truly at-risk children in this context.

Several biological and environmental factors contribute to observed differences. Genetic ancestry in Tunisia reflects Mediterranean, Arab, and Berber admixture patterns distinct from populations in WHO reference studies [28, 29]. This genetic background may influence skeletal proportions, lean mass distribution, and adiposity patterns independent of nutritional status **[45]**. Dietary patterns in Tunisia emphasize Mediterranean foods including olive oil, vegetables, legumes, and moderate animal protein **[46]**, creating different body composition profiles compared to populations consuming Western diets. Socioeconomic factors including household income, parental education, and food security vary substantially across Tunisian regions **[46]**, introducing heterogeneity not captured by single reference curves.

This suggests that clinicians using Tunisian cut-offs will identify more children requiring nutritional assessment and potential intervention compared to international standards. Schools and public health programs should allocate resources accordingly. However, increased identification rates require careful interpretation to distinguish constitutional thinness from pathological undernutrition requiring intervention **[47]**.

4.2. Agreement Patterns Between Classification Systems

Tunisian cut-offs demonstrated substantial agreement with IOTF (kappa=0.772 for thinness) but only fair agreement with WHO (kappa=0.274 for thinness). This pattern reflects fundamental methodological differences between systems. IOTF used pooled data from six countries to create empirical percentile curves anchored at adult BMI thresholds **[17]**. Our approach employed identical methodology applied to Tunisian data, naturally producing similar classification patterns. WHO used different statistical methods (LMS for 0-5 years, modified LMS for 5-19 years) and different conceptual frameworks (prescriptive standards versus descriptive references) **[18]**. Studies comparing IOTF and WHO consistently report better agreement for overweight and obesity classification than for thinness [32, 33, 48]. Our findings confirm this pattern. Agreement for obesity classification between Tunisian and IOTF reached kappa=0.663 overall, while agreement with WHO was kappa=0.708. The higher concordance for extreme categories (obesity) compared to thinness reflects that extreme BMI values show more consistent relationships with health risks across populations **[49]**.

Regional data from Algeria provide relevant comparison. Bahchachi et al. developed BMI curves for 23,000 Algerian

children aged 6-18 years [35, 36]. Although they did not report specific percentile cut-offs, their smoothed curves show similar patterns to Tunisian data in middle childhood with slightly higher median BMI values during adolescence. Direct comparison of Algerian and Tunisian cut-offs would clarify whether unified North African references are feasible or whether country-specific standards remain necessary **[50]**. The practical implication is that Tunisian clinicians currently using IOTF references as interim standards will achieve reasonable concordance with population-specific thresholds. However, discrepancies remain clinically meaningful for individual patient assessment and population surveillance requiring Tunisian-specific cut-offs for optimal accuracy.

4.3. Sex-Specific Patterns in Obesity Classification

An unexpected finding emerged in obesity classification. Tunisian cut-offs identified 5.3% of boys as obese compared to 2.8% using IOTF, representing an 89% relative increase. For girls, Tunisian cut-offs classified 1.0% as obese compared to 2.4% using IOTF, representing a 58% relative decrease. This sex-specific reversal in classification patterns requires mechanistic explanation. Pubertal timing differences may contribute. Boys enter puberty approximately 2 years later than girls on average **[51]**. Earlier female pubertal maturation leads to earlier adiposity rebound and fat mass accrual **[52]**. If Tunisian girls experience pubertal timing patterns different from IOTF reference populations, this could shift the obesity percentile.

Body composition differences between sexes become pronounced during adolescence **[53]**. Boys gain substantially more lean mass relative to fat mass compared to girls during pubertal development **[54]**. For the same BMI value, boys may carry proportionally more muscle mass while girls carry more adipose tissue **[55]**. Population-specific body composition patterns could therefore create sex-differential effects on obesity thresholds.

Physical activity and dietary patterns may differ between sexes in Tunisia. Traditional gender roles influence sport participation, with boys more frequently engaged in organized athletics and outdoor play **[56]**. These behavioral differences affect body composition development during adolescence. The magnitude of sex differences in our obesity classification (5.3% versus 1.0%) substantially exceeds typical sex ratios in pediatric obesity prevalence **[57]**, suggesting that population-specific factors amplify sex divergence beyond universal biological patterns. This suggests that obesity prevention programs in Tunisia should employ sex-specific approaches. Interventions for boys should emphasize obesity risk, while programs for girls should balance obesity prevention with avoiding excessive focus on thinness given higher thinness prevalence in this group. Physical education curricula should accommodate different developmental trajectories between sexes during adolescence **[58]**.

4.4. Age-Specific Variations in Cut-off Discrepancies

Maximum discrepancies between Tunisian and international cut-offs occurred during ages 7-9 years, with differences decreasing during adolescence. This age-specific pattern reflects the adiposity rebound phenomenon. BMI typically reaches a minimum around age 5-7 years before increasing again through adolescence **[59]**. The timing and magnitude of this rebound vary across populations and predict later obesity risk **[60]**. Earlier adiposity rebound associates with increased obesity risk in adulthood **[61]**. Studies examining adiposity rebound timing across ethnic groups report variations of 1-2 years in rebound age **[62]**. If Tunisian children experience adiposity rebound timing different from reference populations, BMI distributions will diverge most during this transition period. Growth velocity patterns also vary. Peak height velocity occurs around age 12 in girls and age 14 in boys on average **[63]**, but substantial individual and population variation exists **[64]**. Different growth tempo affects the relationship between age, height, weight, and resulting BMI values.

Nutritional transition effects may be most pronounced in younger cohorts. Children aged 7-9 during 2012-2013 data collection (born 2003-2006) experienced different early-life nutritional environments compared to adolescents in the sample. Secular trends in obesity prevalence have accelerated in Tunisia over recent decades **[30]**, potentially creating cohort effects visible as age-specific deviations from older reference data. This suggests that cut-off validation should stratify results by age category. The performance of cut-offs for identifying health risks may differ between younger children and adolescents. Longitudinal follow-up studies should examine whether children classified as obese at different ages show similar cardiometabolic risk profiles and health trajectories.

4.5. Clinical and Public Health Implications

Establishing Tunisia-specific BMI cut-offs addresses several practical needs in pediatric health assessment. Current clinical practice in Tunisia relies on international references, creating uncertainty when different standards yield conflicting classifications. National cut-offs provide standardized assessment tools appropriate for the population being evaluated. School health programs require clear guidelines for obesity screening and nutritional surveillance **[59]**. Tunisian cut-offs enable consistent application across educational settings. Public health surveillance systems benefit from population-appropriate thresholds that accurately track temporal trends rather than artifacts of mismatched references **[65]**. Research applications improve when comparing Tunisian data with other North African or Mediterranean populations using methodologically consistent approaches.

However, several important caveats apply. First, cut-offs derived from statistical criteria (percentiles anchored at adult thresholds) require validation against health outcomes. We cannot confirm whether children exceeding obesity cut-offs actually experience elevated cardiometabolic risk without

prospective follow-up data **[66]**. Second, BMI provides a convenient but imperfect indicator of adiposity **[67]**. Children classified as obese by BMI may have elevated muscle mass rather than excess fat mass, particularly athletic adolescent boys. Body composition assessment would clarify this limitation **[68]**. Third, single cut-offs cannot accommodate regional, urban-rural, or socioeconomic variations within Tunisia. Future research should examine whether stratified references improve classification accuracy for specific subpopulations **[69]**. Fourth, secular trends require periodic reference updating. Growth patterns change over time with nutritional transition, requiring regular reassessment **[70]**. These cut-offs represent a starting point requiring ongoing refinement rather than permanent standards.

4.6. Comparison with Other Population-Specific References

Multiple countries have developed population-specific BMI references recognizing limitations of universal standards. India established cut-offs using adult BMI values of 23 kg/m² and 28 kg/m² for overweight and obesity **[27]**, reflecting evidence that Asian populations show metabolic risk at lower BMI thresholds compared to European populations **[71]**. China defined overweight and obesity as BMI at or above the 85th and 95th percentiles respectively, with smooth transition to adult cut-offs of 24 kg/m² and 28 kg/m² **[25]**. These lower adult thresholds compared to Western standards (25 and 30 kg/m²) reflect population-specific adiposity-disease relationships. Hungary developed references using the 90th and 97th percentiles for overweight and obesity **[26]**, similar to CDC percentiles. England uses the UK90 reference with the 85th and 95th percentiles **[72]**. Our Tunisian cut-offs (88.69th and 98.81st percentiles for girls; 86.65th and 96.86th for boys) align more closely with IOTF methodology than other national approaches. This methodological choice facilitates international comparisons while accommodating population-specific distributions. The key principle across all population-specific efforts is matching assessment tools to the population being evaluated rather than assuming universal applicability. Tunisia's development of national references follows this evidence-based practice while maintaining methodological rigor and international compatibility **[73]**.

4.7. Methodological Considerations and Limitations

Several methodological limitations require acknowledgment. First, the cross-sectional design captures BMI distributions at single time points rather than tracking individual growth trajectories. Longitudinal studies following children from early childhood through adolescence would better characterize growth patterns and validate whether children exceeding cut-offs develop health complications **[74]**. Second, we used the same sample for both reference curve construction (previous publications [37, 38]) and cut-off validation (current analysis). Ideally, cut-off validation requires an independent sample to avoid overfitting and circular reasoning **[75]**. Our agreement analyses should be interpreted as preliminary estimates requiring external validation in separate Tunisian cohorts. Third, data collection occurred during 2012-2013. Secular trends in pediatric growth patterns may have altered BMI distributions in the intervening decade **[76]**. Periodic reassessment ensures continued relevance of references for contemporary clinical practice. International recommendations suggest reviewing growth references every 10-15 years **[77]**. Fourth, we excluded children with chronic diseases to ensure healthy reference population. However, this limits generalizability to the complete pediatric population. Children with chronic conditions often show distinct growth patterns requiring separate consideration **[78]**.

Fifth, the study focused exclusively on BMI without incorporating other anthropometric indicators such as waist circumference, waist-to-height ratio, or skinfold measurements **[79]**. A comprehensive corpulence assessment system might integrate multiple parameters for improved accuracy. Sixth, sample size limitations prevented detailed subgroup analyses by socioeconomic status, urban versus rural residence, or geographic region within Tunisia. These factors likely influence growth patterns and might warrant stratified references **[80]**. Seventh, the cut-off derivation relies on statistical criteria (percentiles passing through adult BMI thresholds) rather than outcome-based validation. We did not establish whether BMI values of 18.5, 25, and 30 kg/m² at age 18 represent equivalent health risks in Tunisian adults as in populations where these thresholds were originally defined. Validation against metabolic outcomes in Tunisian adults would strengthen this assumption. Eighth, we did not account for pubertal status in cut-off derivation. Pubertal maturation substantially affects body composition independent of chronological age **[81]**. Future refinements might incorporate pubertal stage for improved classification accuracy during adolescence. These limitations suggest findings should be interpreted as preliminary standards requiring prospective validation, periodic updating, and potential refinement through incorporation of additional data sources and methodological approaches.

5. CONCLUSIONS

This cross-sectional study established BMI cut-off points specifically tailored for Tunisian children and adolescents aged 6-17.99 years using rigorous statistical methods applied to nationally representative data. The cut-offs corresponded to the 18.41st, 88.69th, and 98.81st percentiles for thinness, overweight, and obesity respectively in girls, with corresponding values of 17.88th, 86.65th, and 96.86th percentiles in boys.

Substantial differences emerged when compared to international standards. Maximum deviations reached 1.08 kg/m² from IOTF and 3.12 kg/m² from WHO references. These differences translated into meaningful classification discrepancies. Tunisian cut-offs identified 15.57% of children

as thin compared to 10.4% using IOTF and 2.8% using WHO, representing 50% and 456% relative increases respectively.

Agreement analysis revealed that Tunisian cut-offs aligned substantially better with IOTF methodology (kappa=0.772 for thinness) compared to WHO approaches (kappa=0.274 for thinness), confirming our hypothesis regarding methodological concordance. The clinical implications are substantial. Population-specific cut-offs enable more accurate identification of children at nutritional risk in Tunisian contexts. Healthcare providers can use these cut-offs with confidence that they reflect local growth patterns rather than applying potentially inappropriate international standards. School health programs benefit from standardized assessment tools appropriate for Tunisian students. Public health surveillance systems can track temporal trends in corpulence status using references matched to the population being evaluated.

However, several important caveats apply. The same sample was used for both reference construction and validation, creating potential circular reasoning that limits generalizability. External validation in independent Tunisian samples remains essential before widespread clinical adoption. The cut-offs derive from statistical criteria rather than outcome-based validation. We cannot confirm that children exceeding these thresholds experience elevated health risks without prospective follow-up demonstrating associations with metabolic complications, cardiovascular abnormalities, or other adverse outcomes. Data collection occurred during 2012-2013, potentially limiting applicability to contemporary populations experiencing ongoing nutritional transition. Periodic reassessment will ensure continued relevance as growth patterns evolve.

The practical recommendations are clear. Tunisia should adopt these population-specific cut-offs for national health assessments while acknowledging their provisional status pending validation. Clinicians should use Tunisian references as primary tools while maintaining awareness of international standards for global comparisons. Research programs should prioritize prospective validation studies linking BMI classifications to health outcomes across childhood and into adulthood. School health initiatives should implement standardized screening using Tunisian cut-offs with appropriate follow-up protocols for children identified at nutritional risk. Public health surveillance should transition to Tunisian references for monitoring temporal trends in pediatric corpulence status.

The broader significance extends beyond Tunisia. This study demonstrates that population-specific growth references serve critical roles even when international standards exist. Genetic diversity, environmental variations, nutritional transitions, and cultural factors create meaningful differences in growth trajectories across populations. Acknowledging and accommodating this diversity through locally derived references strengthens both clinical care and public health practice. The methodology employed here provides a model for other countries seeking to develop population-specific standards while maintaining compatibility with international approaches through shared adult threshold values. Future research should validate these cut-offs against cardiometabolic outcomes, examine performance across socioeconomic and geographic subgroups, compare Tunisian patterns with other North African populations, incorporate body composition assessments, and establish updating schedules for continued relevance. This comprehensive approach will transform preliminary statistical cut-offs into validated clinical tools supporting optimal child health in Tunisia and providing insights applicable to diverse pediatric populations globally.

Ethical Approval and Consent to Participate

The study was conducted in accordance with the Declaration of Helsinki. The research protocol received retrospective approval from the Institutional Review Board of the High Institute of Sport and Physical Activity of Kef, University of Jendouba (approval code: 02-2023). Written informed consent was obtained from all participants and their legal guardians prior to data collection.

Consent for Publication

All participants provided informed consent for anonymous data use for research purposes and publication. All authors approved the final version to be published and agree to be accountable for all aspects of the work.

Competing Interests

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Authors' Contributions

Conceptualization: HG, ZF, AB, LBE. Methodology: HG, LBE. Formal analysis: NS, MBA. Investigation: ZF, WBK. Data curation: NG. Writing—original draft: HG. Writing—review and editing: AB, WD, WM. Visualization: ZF. Supervision: WM, NS. Project administration: LBE. All authors have read and agreed to the published version of the manuscript.

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References

1. WHO. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. World Health Organ Tech Rep Ser. 1995;854:1-452.

2. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes. 2012;7(4):284-94.

3. Więch P, Sałacińska I, Bączek M, Bazaliński D. The nutritional status of healthy children using bioelectrical impedance and anthropometric measurement. J Pediatr (Rio J). 2022;98(2):161-7.

4. Cole TJ. The development of growth references and growth charts. Ann Hum Biol. 2012;39(5):382-94.

5. WHO. Obesity and overweight [Internet]. Geneva: World Health Organization; 2021 [Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

6. Sanyaolu A, Okorie C, Qi X, Locke J, Rehman S. Childhood and Adolescent Obesity in the United States: A Public Health Concern. Glob Pediatr Health. 2019;6:2333794x19891305.

7. Weihrauch-Blüher S, Schwarz P, Klusmann JH. Childhood obesity: increased risk for cardiometabolic disease and cancer in adulthood. Metabolism. 2019;92:147-52.

8. Powell-Wiley TM, Poirier P, Burke LE, Després JP, Gordon-Larsen P, Lavie CJ, et al. Obesity and Cardiovascular Disease: A Scientific Statement From the American Heart Association. Circulation. 2021;143(21):e984-e1010.

9. Ruze R, Liu T, Zou X, Song J, Chen Y, Xu R, et al. Obesity and type 2 diabetes mellitus: connections in epidemiology, pathogenesis, and treatments. Front Endocrinol (Lausanne). 2023;14:1161521.

10. Lauby-Secretan B, Scoccianti C, Loomis D, Grosse Y, Bianchini F, Straif K. Body Fatness and Cancer--Viewpoint of the IARC Working Group. N Engl J Med. 2016;375(8):794-8.

11. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de Onis M, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet. 2013;382(9890):427-51.

12. Grantham-McGregor S, Cheung YB, Cueto S, Glewwe P, Richter L, Strupp B. Developmental potential in the first 5 years for children in developing countries. Lancet. 2007;369(9555):60-70.

13. Weir CB, Jan A. BMI classification percentile and cut off points. 2019.

14. Habibzadeh F, Habibzadeh P, Yadollahie M. On determining the most appropriate test cut-off value: the case of tests with continuous results. Biochem Med (Zagreb). 2016;26(3):297-307.

15. Akobeng AK. Understanding diagnostic tests 3: Receiver operating characteristic curves. Acta Paediatr. 2007;96(5):644-7.

16. Must A, Anderson SE. Body mass index in children and adolescents: considerations for population-based applications. Int J Obes (Lond). 2006;30(4):590-4.

17. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. Bmj. 2000;320(7244):1240-3.

18. 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.

19. Silventoinen K, Jelenkovic A, Sund R, Hur YM, Yokoyama Y, Honda C, et al. Genetic and environmental effects on body mass index from infancy to the onset of adulthood: an individual-based pooled analysis of 45 twin cohorts participating in the COllaborative project of Development of Anthropometrical measures in Twins (CODATwins) study. Am J Clin Nutr. 2016;104(2):371-9.

20. Elks CE, den Hoed M, Zhao JH, Sharp SJ, Wareham NJ, Loos RJ, et al. Variability in the heritability of body mass index: a systematic review and meta-regression. Front Endocrinol (Lausanne). 2012;3:29.

21. Chao M, Manz WJ, Fink J, Coleman MM, Kadakia RJ, Bariteau JT. Body Mass Index (BMI) Cutoffs and Racial, Ethnic, Sex, or Age Disparities in Patients Treated With Total Ankle Arthroplasty. Foot Ankle Orthop. 2023;8(3):24730114231184189.

22. Rush EC, Freitas I, Plank LD. Body size, body composition and fat distribution: comparative analysis of European, Maori, Pacific Island and Asian Indian adults. Br J Nutr. 2009;102(4):632-41.

23. Deurenberg P, Deurenberg-Yap M, Guricci S. Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. Obes Rev. 2002;3(3):141-6.

24. El Shafie AM, El-Gendy FM, Allahony DM, Omar ZA, Samir MA, El-Bazzar AN, et al. Establishment of Z Score Reference of Growth Parameters for Egyptian School Children and Adolescents Aged From 5 to 19 Years: A Cross Sectional Study. Front Pediatr. 2020;8:368.

25. Qian K, Tan L, Li S, Li Z, Yu F, Liang H, et al. Comparison of different BMI cut-offs to screen for child and adolescent obesity in urban China. Public Health Nutr. 2020;23(14):2485-93.

26. Kovacs VA, Bakacs M, Kaposvari C, Illes E, Erdei G, Martos E, et al. Weight Status of 7-Year-Old Hungarian Children between 2010 and 2016 Using Different Classifications (COSI Hungary). Obes Facts. 2018;11(3):195-205.

27. Khadilkar VV, Khadilkar AV, Borade AB, Chiplonkar SA. Body mass index cut-offs for screening for childhood overweight and obesity in Indian children. Indian Pediatr. 2012;49(1):29-34.

28. Henn BM, Botigué LR, Gravel S, Wang W, Brisbin A, Byrnes JK, et al. Genomic ancestry of North Africans supports back-to-Africa migrations. PLoS Genet. 2012;8(1):e1002397.

29. Arauna LR, Hellenthal G, Comas D. Dissecting human North African gene-flow into its western coastal surroundings. Proc Biol Sci. 2019;286(1902):20190471.

30. Aounallah-Skhiri H, Traissac P, El Ati J, Eymard-Duvernay S, Landais E, Achour N, et al. Nutrition transition among adolescents of a south-Mediterranean country: dietary patterns, association with socio-economic factors, overweight and blood pressure. A cross-sectional study in Tunisia. Nutr J. 2011;10:38.

31. Popkin BM. Nutrition Transition and the Global Diabetes Epidemic. Curr Diab Rep. 2015;15(9):64.

32. Kêkê LM, Samouda H, Jacobs J, di Pompeo C, Lemdani M, Hubert H, et al. Body mass index and childhood obesity classification systems: A comparison of the French, International Obesity Task Force (IOTF) and World Health Organization (WHO) references. Rev Epidemiol Sante Publique. 2015;63(3):173-82.

33. Shields M, Tremblay MS. Canadian childhood obesity estimates based on WHO, IOTF and CDC cut-points. Int J Pediatr Obes. 2010;5(3):265-73.

34. Wang Y, Wang JQ. A comparison of international references for the assessment of child and adolescent overweight and obesity in different populations. Eur J Clin Nutr. 2002;56(10):973-82.

35. Bahchachi N, Dahel-Mekhancha CC, Rolland-Cachera MF, Badis N, Roelants M, Hauspie R, et al. [Weight and height local growth charts of Algerian children and adolescents (6-18 years of age)]. Arch Pediatr. 2016;23(4):340-7.

36. Bahchachi N, Dahel-Mekhancha CC, Rolland-Cachera MF, Roelants M, Hauspie R, Nezzal L. [Body mass index charts of Algerian children and adolescents (6-18 years)]. Arch Pediatr. 2017;24(12):1205-13.

37. Ghouili H, Ben Khalifa W, Ouerghi N, Zouaoui M, Dridi A, Gmada N, et al. Body mass index reference curves for Tunisian children. Arch Pediatr. 2018;25(8):459-63.

38. Ghouili H, Ouerghi N, Boughalmi A, Dridi A, Rhibi F, Bouassida A. First growth reference curves for Tunisian children and adolescents. Arch Pediatr. 2021;28(5):381-91.

39. Olds TS, Tomkinson GR, Ferrar KE, Maher CA. Trends in the prevalence of childhood overweight and obesity in Australia between 1985 and 2008. Int J Obes (Lond). 2010;34(1):57-66.

40. WHO. WHO child growth standards: training course on child growth assessment. 2008.

41. Ulijaszek SJ, Kerr DA. Anthropometric measurement error and the assessment of nutritional status. Br J Nutr. 1999;82(3):165-77.

42. WHO. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. World Health Organ Tech Rep Ser. 2000;894:i-xii, 1-253.

43. Cole TJ. The LMS method for constructing normalized growth standards. Eur J Clin Nutr. 1990;44(1):45-60.

44. McHugh ML. Interrater reliability: the kappa statistic. Biochem Med (Zagreb). 2012;22(3):276-82.

45. Wells JC. Ethnic variability in adiposity, thrifty phenotypes and cardiometabolic risk: addressing the full range of ethnicity, including those of mixed ethnicity. Obes Rev. 2012;13 Suppl 2:14-29.

46. Boujelbane MA, Ammar A, Salem A, Kerkeni M, Trabelsi K, Bouaziz B, et al. Regional variations in Mediterranean diet adherence: a sociodemographic and lifestyle analysis across Mediterranean and non-Mediterranean regions within the MEDIET4ALL project. Front Public Health. 2025;13:1596681.

47. Cole TJ, Flegal KM, Nicholls D, Jackson AA. Body mass index cut offs to define thinness in children and adolescents: international survey. Bmj. 2007;335(7612):194.

48. Twells LK, Newhook LA. Obesity prevalence estimates in a Canadian regional population of preschool children using variant growth references. BMC Pediatr. 2011;11:21.

49. Rolland-Cachera MF, Akrout M, Péneau S. Nutrient Intakes in Early Life and Risk of Obesity. Int J Environ Res Public Health. 2016;13(6).

50. Willis M. Politics and power in the Maghreb: Algeria, Tunisia and Morocco from independence to the Arab Spring: Oxford University Press, USA; 2014.

51. Marshall WA, Tanner JM. Variations in pattern of pubertal changes in girls. Arch Dis Child. 1969;44(235):291-303.

52. Kaplowitz PB. Link between body fat and the timing of puberty. Pediatrics. 2008;121 Suppl 3:S208-17.

53. Veldhuis JD, Roemmich JN, Richmond EJ, Rogol AD, Lovejoy JC, Sheffield-Moore M, et al. Endocrine control of body composition in infancy, childhood, and puberty. Endocr Rev. 2005;26(1):114-46.

54. Maynard LM, Wisemandle W, Roche AF, Chumlea WC, Guo SS, Siervogel RM. Childhood body composition in relation to body mass index. Pediatrics. 2001;107(2):344-50.

55. Taylor RW, Jones IE, Williams SM, Goulding A. Evaluation of waist circumference, waist-to-hip ratio, and the conicity index as screening tools for high trunk fat mass, as measured by dual-energy X-ray absorptiometry, in children aged 3-19 y. Am J Clin Nutr. 2000;72(2):490-5.

56. Telford RM, Telford RD, Olive LS, Cochrane T, Davey R. Why Are Girls Less Physically Active than Boys? Findings from the LOOK Longitudinal Study. PLoS One. 2016;11(3):e0150041.

57. 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(9945):766-81.

58. Cairney J, Kwan MY, Velduizen S, Hay J, Bray SR, Faught BE. Gender, perceived competence and the enjoyment of physical education in children: a longitudinal examination. Int J Behav Nutr Phys Act. 2012;9:26.

59. Rolland-Cachera MF, Deheeger M, Maillot M, Bellisle F. Early adiposity rebound: causes and consequences for obesity in children and adults. Int J Obes (Lond). 2006;30 Suppl 4:S11-7.

60. Williams SM, Goulding A. Patterns of growth associated with the timing of adiposity rebound. Obesity (Silver Spring). 2009;17(2):335-41.

61. Taylor RW, Grant AM, Goulding A, Williams SM. Early adiposity rebound: review of papers linking this to subsequent obesity in children and adults. Curr Opin Clin Nutr Metab Care. 2005;8(6):607-12.

62. Kroke A, Hahn S, Buyken AE, Liese AD. A comparative evaluation of two different approaches to estimating age at adiposity rebound. Int J Obes (Lond). 2006;30(2):261-6.

63. Tanner JM, Whitehouse RH, Takaishi M. Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965. II. Arch Dis Child. 1966;41(220):613-35.

64. Parent AS, Teilmann G, Juul A, Skakkebaek NE, Toppari J, Bourguignon JP. The timing of normal puberty and the age limits of sexual precocity: variations around the world, secular trends, and changes after migration. Endocr Rev. 2003;24(5):668-93.

65. Lobstein T, Jackson-Leach R, Moodie ML, Hall KD, Gortmaker SL, Swinburn BA, et al. Child and adolescent obesity: part of a bigger picture. Lancet. 2015;385(9986):2510-20.

66. Freedman DS, Mei Z, Srinivasan SR, Berenson GS, Dietz WH. Cardiovascular risk factors and excess adiposity among overweight children and adolescents: the Bogalusa Heart Study. J Pediatr. 2007;150(1):12-7.e2.

67. Prentice AM, Jebb SA. Beyond body mass index. Obes Rev. 2001;2(3):141-7.

68. McCarthy HD, Cole TJ, Fry T, Jebb SA, Prentice AM. Body fat reference curves for children. Int J Obes (Lond). 2006;30(4):598-602.

69. Singh AS, Mulder C, Twisk JW, van Mechelen W, Chinapaw MJ. Tracking of childhood overweight into adulthood: a systematic review of the literature. Obes Rev. 2008;9(5):474-88.

70. Cole TJ. Secular trends in growth. Proc Nutr Soc. 2000;59(2):317-24.

71. WHO. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet. 2004;363(9403):157-63.

72. Wright CM, Booth IW, Buckler JM, Cameron N, Cole TJ, Healy MJ, et al. Growth reference charts for use in the United Kingdom. Arch Dis Child. 2002;86(1):11-4.

73. Butte NF, Garza C, de Onis M. Evaluation of the feasibility of international growth standards for school-aged children and adolescents. J Nutr. 2007;137(1):153-7.

74. Guo SS, Wu W, Chumlea WC, Roche AF. Predicting overweight and obesity in adulthood from body mass index values in childhood and adolescence. Am J Clin Nutr. 2002;76(3):653-8.

75. Harrell FE, Jr., Lee KL, Mark DB. Multivariable prognostic models: issues in developing models, evaluating assumptions and adequacy, and measuring and reducing errors. Stat Med. 1996;15(4):361-87.

76. Olds T, Maher C, Zumin S, Péneau S, Lioret S, Castetbon K, et al. Evidence that the prevalence of childhood overweight is plateauing: data from nine countries. Int J Pediatr Obes. 2011;6(5-6):342-60.

77. Garza C, de Onis M. Rationale for developing a new international growth reference. Food Nutr Bull. 2004;25(1 Suppl):S5-14.

78. Toulany A, Gorter JW, Harrison M. A call for action: Recommendations to improve transition to adult care for youth with complex health care needs. Paediatr Child Health. 2022;27(5):297-309.

79. Freedman DS, Sherry B. The validity of BMI as an indicator of body fatness and risk among children. Pediatrics. 2009;124 Suppl 1:S23-34.

80. Wang Y, Lobstein T. Worldwide trends in childhood overweight and obesity. Int J Pediatr Obes. 2006;1(1):11-25.

81. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, et al. 2000 CDC Growth Charts for the United States: methods and development. Vital Health Stat 11. 2002(246):1-190.