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# Prevalence and Multilevel Risk Factors for Overweight and Obesity Among Children Aged 6–13 Years in Public and Private Schools in Derna, Libya: A School-Based Cross-Sectional Study

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## ABSTRACT

Childhood overweight and obesity are increasing public-health concerns in North Africa and the Middle East, yet evidence on their multilevel determinants among Libyan schoolchildren remains limited. This study aimed to determine the prevalence of thinness, overweight, obesity and central adiposity among children aged 6–13 years attending public and private schools in Derna, Libya, and to examine associated behavioural, familial, socioeconomic and school-related factors. A school-based analytical cross-sectional design was used with 860 children selected through three-stage multistage stratified cluster sampling. A structured parent-assisted Arabic questionnaire assessed demographic characteristics, household conditions, parental weight status, dietary behaviour, physical inactivity, sedentary behaviour and family and school environments. Trained researchers measured height, weight and waist circumference using standardised procedures. Weight status was classified using the World Health Organization BMI-for-age reference, and waist-to-height ratio $\geq$0.50 indicated central adiposity. Data were analysed using descriptive statistics, t-tests, analysis of variance, chi-square tests and multivariable binary logistic regression in SPSS. Overweight affected 19.7%, obesity 8.7%, thinness 8.8% and central adiposity 28.7%, while combined overweight and obesity prevalence was 28.4%. Excess weight was higher among boys than girls (31.4% vs. 25.3%, $p = 0.045$) and private-school than public-school pupils (33.3% vs. 25.7%, $p = 0.015$). Unhealthy dietary behaviour (AOR = 1.48, 95% CI 1.27–1.73), physical inactivity (AOR = 1.39, 95% CI 1.20–1.61) and sedentary behaviour (AOR = 1.31, 95% CI 1.13–1.52) were independently associated with excess weight. Private-school attendance remained significant after adjustment (AOR = 1.34, 95% CI 1.01–1.80). These findings support integrated school, family and community prevention strategies.

**Keywords:** childhood obesity; overweight; BMI-for-age; central adiposity; physical inactivity; sedentary behaviour; school environment; Libya.

# معدل انتشار زيادة الوزن والسمنة وعوامل الخطر متعددة المستويات المرتبطة بهما لدى الأطفال الذين تتراوح أعمارهم بين 6 و13 سنة في المدارس العامة والخاصة بمدينة درنة، ليبيا: دراسة مقطعية قائمة على المدارس

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## ملخـــــــص البحـــــــث

تمثل زيادة الوزن والسمنة لدى الاطفال مشكلتين متزايدتين من مشكلات الصحة العامة في شمال افريقيا والشرق الاوسط، ومع ذلك لا تزال الادلة المتعلقة بالعوامل متعددة المستويات المرتبطة بهما لدى تلاميذ المدارس الليبيين محدودة. هدفت هذه الدراسة الى تحديد معدل انتشار النحافة وزيادة الوزن والسمنة وتراكم الدهون في منطقة البطن لدى الاطفال الذين تتراوح اعمارهم بين 6 و13 سنة والملتحقين بالمدارس العامة والخاصة في مدينة درنة، ليبيا، ودراسة العوامل السلوكية والاسرية والاجتماعية والاقتصادية والمدرسية المرتبطة بها. استخدمت الدراسة تصميما تحليليا مقطعيا قائما على المدارس، وشملت 860 طفلا تم اختيارهم باستخدام اسلوب المعاينة العنقودية الطبقية متعددة المراحل على ثلاث مراحل. واستخدم استبيان عربي منظم تمت الاجابة عنه بمساعدة الوالدين لتقييم الخصائص الديموغرافية، وظروف الاسرة، والحالة الوزنية للوالدين، والسلوك الغذائي، وقلة النشاط البدني، والسلوك الخامل، والبيئتين الاسرية والمدرسية. وقام باحثون مدربون بقياس الطول والوزن ومحيط الخصر باستخدام اجراءات موحدة. صنفت الحالة الوزنية باستخدام مرجع منظمة الصحة العالمية لمؤشر كتلة الجسم بالنسبة للعمر، واعتبرت نسبة محيط الخصر الى الطول التي تساوي 0.50 او تزيد عليها مؤشرا على تراكم الدهون في منطقة البطن. وحللت البيانات باستخدام الاحصاءات الوصفية، واختبارات الفروق بين المتوسطات، وتحليل التباين، واختبار مربع كاي، والانحدار اللوجستي الثنائي متعدد المتغيرات، وذلك باستخدام الحزمة الاحصائية للعلوم الاجتماعية. بلغ معدل انتشار زيادة الوزن 19.7%، والسمنة 8.7%، والنحافة 8.8%، وتراكم الدهون في منطقة البطن 28.7%، في حين بلغ المعدل الاجمالي لزيادة الوزن والسمنة معا 28.4%. وكان الوزن الزائد اكثر انتشارا بين الذكور مقارنة بالاناث بنسبة 31.4% مقابل 25.3%، وكانت قيمة الاحتمال 0.045. كما كان اكثر انتشارا بين تلاميذ المدارس الخاصة مقارنة بتلاميذ المدارس العامة بنسبة 33.3% مقابل 25.7%، وكانت قيمة الاحتمال 0.015. ارتبط السلوك الغذائي غير الصحي بصورة مستقلة بالوزن الزائد، حيث بلغت نسبة الارجحية المعدلة 1.48، بفاصل ثقة 95% يتراوح بين 1.27 و1.73. كما ارتبطت قلة النشاط البدني بالوزن الزائد، حيث بلغت نسبة الارجحية المعدلة 1.39، بفاصل ثقة 95% يتراوح بين 1.20 و1.61. وارتبط السلوك الخامل كذلك بالوزن الزائد، حيث بلغت نسبة الارجحية المعدلة 1.31، بفاصل ثقة 95% يتراوح بين 1.13 و1.52. وظل الالتحاق بالمدارس الخاصة عاملا ذا دلالة احصائية بعد ضبط العوامل الاخرى، حيث بلغت نسبة الارجحية المعدلة 1.34، بفاصل ثقة 95% يتراوح بين 1.01 و1.80. تدعم هذه النتائج تطبيق استراتيجيات وقائية متكاملة تشمل المدرسة والاسرة والمجتمع.

**الكلمات المفتاحية:** سمنة الاطفال، زيادة الوزن، مؤشر كتلة الجسم بالنسبة للعمر، تراكم الدهون في منطقة البطن، قلة النشاط البدني، السلوك الخامل، البيئة المدرسية، ليبيا.

## 1. Introduction

Childhood overweight and obesity have increased substantially across geographical, economic and cultural settings and are now associated with adverse physical, metabolic and psychological outcomes during childhood and later life [1,2]. Overweight and obesity describe excessive body weight or adiposity relative to a child's age and sex and are commonly assessed in epidemiological studies using age-specific and sex-specific body mass index-for-age thresholds [3,4]. Unlike the fixed BMI thresholds applied to adults, paediatric assessment must account for expected changes in height, body composition and sexual maturation throughout childhood and puberty [5,6]. BMI provides a practical and reproducible indicator for population surveillance, although it does not distinguish adipose tissue from lean body mass and may therefore be supplemented by waist circumference, waist-to-height ratio, skinfold thickness or body-fat assessment [4]. Swiss evidence showed that BMI was strongly correlated with body-fat percentage, with an $R^2$ of 0.74, but the prevalence estimates varied according to whether IOTF or CDC criteria were applied [4]. Consistent use of an age-appropriate classification system is therefore necessary to support valid comparisons across age groups and school populations.

The scale and progression of childhood obesity provide a strong public-health justification for earlier surveillance during the school years [1]. Global modelling indicates that combined overweight and obesity among children and adolescents doubled between 1990 and 2021, while obesity alone increased approximately threefold [1]. Among children aged 5–14 years, overweight prevalence increased from 6.7% in 1990 to 11.2% in 2021, while obesity rose from 2.0% to 6.9%, representing approximately 93.1 million children living with obesity in 2021 [1]. Global obesity prevalence among this age group is forecast to reach 15.6% by 2050 if recent patterns continue, with boys aged 5–14 years expected to experience a particularly substantial burden [1]. Severe obesity has also become more widespread across paediatric populations, with evidence indicating greater odds of severe obesity in more recent periods than in earlier cohorts [2]. These trends suggest that excess weight may become established well before adulthood and may progress from overweight to more clinically serious obesity during childhood.

Regional evidence is especially relevant to Libya because North Africa and the Middle East are among the areas with the highest estimated levels of childhood excess weight [1]. Among children aged 5–14 years in this region, overweight prevalence was estimated at 17.6% and obesity prevalence at 16.0% in 2021, indicating that approximately one-third had excess body weight [1]. Obesity prevalence in the region is forecast to reach 36.4% by 2050, while overweight may decline slightly as a greater proportion of children move into the obesity category rather than return to normal weight [1]. However, regional estimates combine countries with different food systems, social conditions, educational resources and levels of economic development and cannot establish the actual prevalence among children in a specific Libyan city [1]. Direct local measurement is required because national and regional modelling cannot identify differences between school sectors, neighbourhoods, sexes or narrower developmental age groups.

School-based evidence from other countries demonstrates considerable variation in prevalence and supports the need for context-specific investigation [3,4,7,8]. Among children aged 3–13 years in urban Cameroon, the combined prevalence of overweight and obesity was 12.5%, while socioeconomic differences were partly explained by sweetened drinks, passive transport and limited participation in school sport [3]. An Indonesian study involving children aged 6–12 years reported overweight prevalence of 9.4% and obesity prevalence of 8.1%, with older age, paternal overweight or obesity and urban residence independently associated with excess weight [8]. Among Swiss children aged 6–12 years, overweight affected 16.6% of boys and 19.1% of girls, while obesity affected 3.8% and 3.7%, respectively, and body-fat levels were substantially greater than those recorded in earlier Swiss cohorts [4]. Greek evidence reported overweight prevalence of 23.9%, obesity prevalence of 7.3% and central-obesity prevalence of 35.5% among children aged 6–12 years, with obesity more frequent among children aged 6–9 years than among those aged 10–12 years, at 10.3% and 3.3%, respectively

[7]. A European meta-analysis similarly identified pooled overweight prevalence of 17.55% and obesity prevalence of 5.56% among elementary-school children, with obesity occurring more frequently among boys [9]. The variation across these settings indicates that age, sex, family circumstances, school conditions and local behavioural patterns probably shape the distribution of childhood overweight and obesity.

Childhood obesity develops through interacting demographic, biological, familial, dietary, behavioural and environmental influences rather than through one isolated exposure [3,8]. Unhealthy dietary behaviours associated with excess weight include breakfast skipping, frequent consumption of fast food, fried foods, refined bread, sweets and sugar-sweetened beverages, large portion sizes and inadequate fruit and vegetable intake [3,6,7]. Physical inactivity, limited school-sport participation, passive transport and prolonged television, computer, gaming or mobile-phone use may reduce energy expenditure and displace active leisure time [3,7]. Parental BMI, parental education, household income, family food practices and neighbourhood opportunities for activity may further influence children's weight status [3,8]. School environments may contribute through canteen practices, availability of unhealthy foods, physical-education provision, playground facilities and teacher or parental involvement in health promotion [10]. Evidence from children aged 6–12 years with obesity also indicates that high BMI, fried-food and sugary-drink consumption, prolonged sitting and reduced moderate activity may coexist with insulin resistance and earlier pubertal development [6]. The school years therefore represent a period in which modifiable behaviours, family influences and developmental changes may combine to increase obesity risk.

Available Libyan research establishes that obesity is already a substantial health problem but has concentrated mainly on adults and older young people [11–15]. Research among adults aged 20–65 years in Benghazi reported that 32.9% were overweight and 42.4% were obese, demonstrating a high burden of excess weight in the adult population [12]. Qualitative evidence from healthcare professionals and community leaders identified unhealthy food consumption, physical inactivity, sedentary lifestyles, inadequate knowledge, food-subsidy policies, neighbourhood conditions and political insecurity as potential influences on obesity in Libya [11]. Further analysis found that fast-food consumption, sugar-sweetened beverages, large portion sizes and breakfast skipping were associated with adult obesity [13]. Among Tobruk University students, 50.0% were overweight or obese, with poorer dietary behaviour, physical inactivity, sedentary behaviour and limited nutritional knowledge associated with BMI [14]. Such findings indicate that Libyan children may be growing within family and community environments in which several obesity-related behaviours are already common.

Recent evidence from Derna has extended obesity research to secondary-school adolescents but has not examined younger schoolchildren [15]. Among 4,500 adolescents aged 15–19 years, 27.8% were overweight or obese, while sugar-sweetened beverages, fast food, physical inactivity and prolonged mobile-phone use were associated with excess weight [15]. Boys and private-school students had a higher prevalence than girls and public-school students, indicating that sex and school type may represent important contextual differences [15]. Nevertheless, adolescents aged 15–19 years differ from children aged 6–13 years in growth, pubertal stage, autonomy, food purchasing, screen use and exposure to school and parental control [6]. Existing Libyan studies cannot therefore determine whether excess weight begins during the primary and basic-school years, whether younger and older children differ in prevalence or whether public–private school disparities are already present before adolescence. A clear population, developmental and school-sector evidence gap remains for children aged 6–13 years in Derna.

The proposed age range covers the period from entry into formal schooling to the transition towards secondary education, during which children gradually gain independence over diet, transport, recreation and electronic-device use while remaining strongly influenced by families and schools [6,7]. Age-stratified analysis may reveal whether obesity is already evident among younger pupils and whether its prevalence or associated behaviours change as children approach puberty [6,7]. Comparison between public and private schools may also identify differences associated with household socioeconomic position, transport arrangements, school-food access, sporting facilities and physical-education opportunities [3,10,15]. Direct anthropometric measurement using WHO BMI-for-age classifications, supplemented where feasible by a waist-related indicator, could provide more reliable evidence than regional estimates or parent-reported weight [1,4]. The study therefore aims to estimate thinness, normal weight, overweight, obesity and central adiposity among children aged 6–13 years in Derna, compare prevalence by age, sex and school type, and examine demographic, familial, socioeconomic, dietary, physical-activity and sedentary-behaviour factors associated with excess weight. The findings may establish a local baseline, identify higher-risk groups and modifiable exposures, inform school-based screening and prevention, and support health and education authorities in directing resources towards pupils and schools with the greatest need. Accordingly, the investigation will be organised through a multilevel conceptual framework that integrates child-level, family-level and school-environmental determinants of overweight and obesity.

## 2. Theoretical Framework and Study Hypotheses

The study was guided by a multilevel socioecological framework supported by the energy-balance perspective. The framework assumed that children's weight status was shaped by interactions among individual behaviours, family characteristics and school-related conditions rather than by one isolated factor, consistent with socioecological models of childhood obesity that recognise multiple levels of influence operating simultaneously [16–18]. At the individual level, dietary intake, physical activity and sedentary behaviour were considered potential determinants of BMI-for-age and overweight or obesity status. Unhealthy eating behaviours included breakfast skipping, frequent fast-food and fried-food consumption, sugar-sweetened beverages, sweets, large portion sizes and inadequate fruit and vegetable intake. Physical inactivity included limited participation in physical education, organised sport, active travel and moderate-to-vigorous activity, while sedentary behaviour included prolonged television viewing, mobile-phone use, gaming and internet use. Based on these relationships, H1 hypothesised that unhealthy dietary behaviours were significantly associated with overweight and obesity among children aged 6–13 years. H2 hypothesised that physical inactivity and limited participation in school sport were significantly associated with overweight and obesity. H3 hypothesised that sedentary behaviour and recreational screen time were significantly associated with overweight and obesity. These hypotheses were formulated to determine whether the behavioural variables independently explained variation in children's weight status when considered within regression models.

The familial and school-environmental components of the framework recognised that children's weight could also vary according to demographic characteristics, parental factors, household resources and school type. This perspective reflects evidence that childhood obesity develops through interactions between family, school and wider environmental contexts rather than individual behaviours alone [16–18]. Age and sex were considered relevant because growth, body composition and lifestyle behaviours may differ between younger and older children and between boys and girls. Parental BMI, parental education, employment, household income and family characteristics were treated as potential influences through shared dietary practices, genetic susceptibility, health knowledge and access to physical-activity opportunities. Public and private schools could also differ in socioeconomic composition, school-food availability, transport arrangements, facilities and physical-education provision. Accordingly, H4 hypothesised that mean BMI-for-age and the prevalence of overweight and obesity differed between boys and girls and across the specified age groups. H5 hypothesised that parental weight status, parental education, household socioeconomic conditions and family characteristics were significantly associated with children's overweight and obesity. H6 hypothesised that mean BMI-for-age and the prevalence of overweight and obesity differed between children attending public and private schools, including after demographic, behavioural and familial characteristics were considered. The association hypotheses supported multivariable modelling, whereas the comparison hypotheses addressed differences between demographic and school-sector groups.

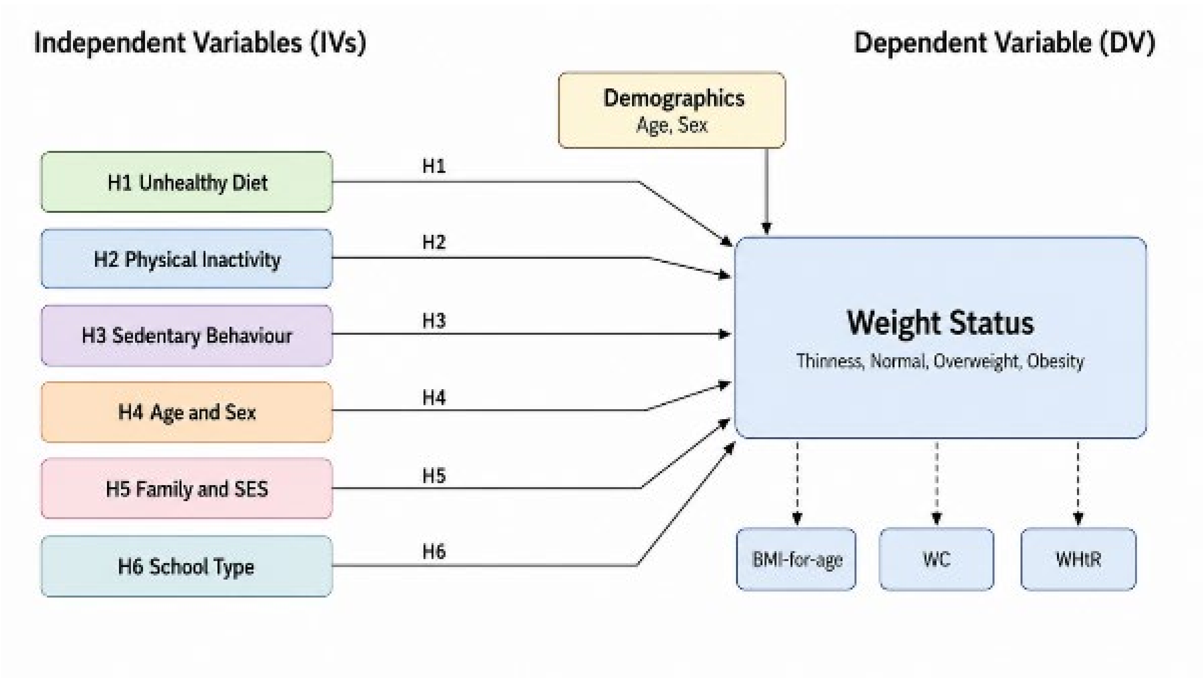


**Figure 1.** Proposed Conceptual Framework for the Multilevel Determinants of Overweight and Obesity Among School-Aged Children in Derna, Libya

The figure presents the hypothesised relationships between unhealthy eating behaviour, physical inactivity, sedentary lifestyle, sex and school type and children's overweight and obesity status. Age and school grade were included as demographic characteristics, while BMI, waist circumference and visceral fat rating represented the proposed indicators of adiposity.

## 3. Materials and Methods

### 3.1 Study Design

A school-based analytical cross-sectional design was adopted to estimate the prevalence of thinness, normal weight, overweight and obesity among children aged 6–13 years attending public and private primary or basic-education schools in Derna, Libya. The design also enabled examination of associations between weight status and demographic, familial, socioeconomic, dietary, physical-activity, sedentary-behaviour and school-related factors. Cross-sectional studies measure exposures and outcomes within the same defined data-collection period and are particularly appropriate for estimating the prevalence and distribution of health conditions in a specified population [19,20]. They may also assess several exposures and outcomes simultaneously, making the design appropriate for the multilevel objectives of the present study.

The study combined a descriptive component, which estimated the prevalence of each BMI-for-age category, with an analytical component, which compared weight status by age, sex and school type and assessed its relationships with potential risk factors. Questionnaire information and anthropometric measurements were collected during the same school visit without prospective or retrospective follow-up. The design was relatively feasible for examining a large school population and could provide baseline evidence for subsequent surveillance and intervention studies. Nevertheless, because exposures and weight outcomes were measured concurrently, temporal sequence could not be established and identified associations were not interpreted as causal relationships. Potential selection, non-response, recall and information biases were addressed through probability-based sampling, standardised measurements, trained data collectors and a structured parent-assisted questionnaire [19,20]. Cross-sectional designs are effective for prevalence estimation and assessment of multiple associations but cannot estimate incidence or determine whether an exposure preceded an outcome.

### 3.2 Study Population and Sampling Technique

The target population comprised boys and girls aged 6–13 years enrolled in public and private primary or basic-education schools in Derna City, Eastern Libya. Eligible children were required to be registered in a participating school, fall within the specified age range, have written parental or guardian consent and provide age-appropriate assent. Children with documented medical, endocrine or genetic conditions that could substantially affect growth or body weight were excluded. A three-stage multistage stratified cluster-sampling technique was used because pupils were naturally grouped within schools, grades and classes, while no complete city-wide list of all eligible children was available. This approach was important because cluster sampling is suitable for institution-based populations, while multistage probability selection reduces cost, travel and selection bias and improves representation compared with convenience sampling [21–24].

In the first stage, Derna City was selected from Eastern Libya because the study addressed the absence of evidence on overweight and obesity among children aged 6–13 years in this setting. Eastern Libya includes Benghazi, Derna, Al Bayda, Al Marj, Tobruk and Ajdabiya; however, the findings were intended to represent schoolchildren in Derna rather than the whole region. In the second stage, all eligible schools were listed and stratified into public and private sectors. The provisional public-school frame included Al-Noor, Martyrs of Derna, Al-Wahda, Ibn Sina, Al-Nasr, Al-Khansa, Al-Amal, Al-Rashid, Al-Khuloud and Umm Al-Qura schools. The private-school frame included Al-Manahil, Derna Al-Zahira, Awael Derna, Derna Stars Academy, Shumoua Derna, Al-Risala and Nur Primary School. The final list and enrolment figures were to be verified through the Derna Education Monitoring Office. Stratification ensured adequate representation of both sectors and enabled examination of possible differences in socioeconomic circumstances, school food, transport and physical-education provision.

In the third stage, the sample was allocated to schools in proportion to eligible enrolment. Within each school, pupils were stratified by grade and, where applicable, sex. Classes were then randomly selected and treated as operational clusters. Children were selected systematically from class registers using the interval k=N/nk=N/nk=N/n, where NNN was the number of eligible pupils and nnn was the allocated sample. After a random start between 1 and kkk, every kkkth child was approached. Absence, non-consent or refusal was recorded as non-response rather than followed by uncontrolled replacement. Any replacement was drawn from a prespecified reserve list generated through the same random procedure to preserve the probability basis of selection.

### 3.3 Sample-Size Determination

The minimum sample size was initially estimated using the single-population proportion formula because no recent population-based estimate was available for overweight and obesity among children aged 6–13 years in Derna:

$$n_0 = \frac{Z^2 p(1-p)}{d^2}$$

where $n_0$ was the initial sample size, $Z = 1.96$ represented a 95% confidence level, $p = 0.50$ represented the expected prevalence and $d = 0.05$ represented the required margin of error. A prevalence of 50% was selected because it produces the largest and most conservative sample when the true local prevalence is uncertain. The calculation produced:

$$n_0 = \frac{(1.96)^2(0.50)(0.50)}{(0.05)^2} = 384.16$$

The initial requirement was therefore **385 children**. Sample-size determination should reflect the study population, anticipated prevalence or effect size, confidence level, precision and sampling design, because an inadequately small sample may reduce reliability, whereas an unnecessarily large sample may waste resources [24].

Because pupils were sampled within schools and classes rather than as completely independent individuals, the initial estimate was multiplied by a **design effect of 2.0** to allow for similarities among children within the same clusters:

$$n_1 = 385 \times 2.0 = 770$$

A further 10% was added for non-response, incomplete questionnaires, missing anthropometric measurements or withdrawals:

$$n_{final} = \frac{770}{0.90} = 855.6$$

The minimum required sample was therefore rounded to **856 children**. For practical allocation across public and private schools, a target of approximately **860 children** would be appropriate. The sample should be distributed proportionally according to the number of eligible pupils enrolled in each educational sector, school and grade. For example, when public-school pupils comprise 70% of the complete eligible population and private-school pupils comprise 30%, approximately 602 and 258 participants, respectively, should be recruited. Final proportional allocations should be calculated only after verified enrolment figures have been obtained.

Where the total number of eligible children aged 6–13 years in Derna is known, a finite-population correction may be applied:

$$n_f = \frac{n}{1 + \frac{n-1}{N}}$$

where n is the design-adjusted sample and N is the total eligible school population. Nevertheless, retaining the larger target of approximately 860 pupils may be preferable when comparisons are planned across boys and girls, age groups and public and private schools. The proposed sample should provide sufficient representation for the principal prevalence estimates and the examination of multilevel demographic, familial, dietary, activity-related and sedentary risk factors.

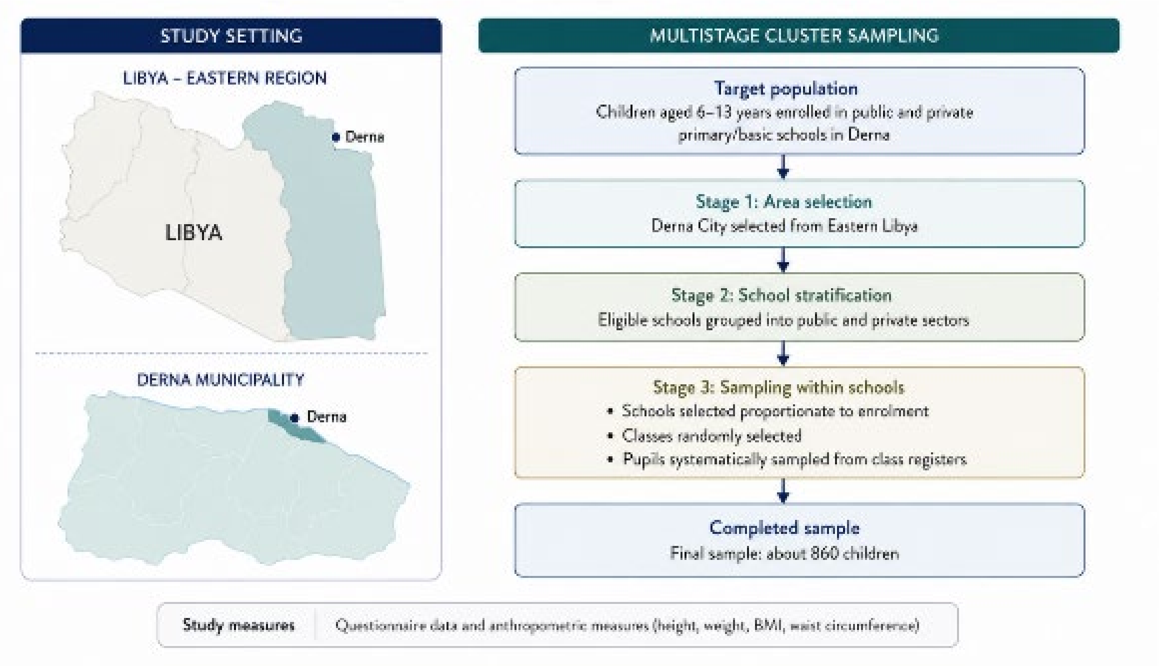


**Figure 2.** Three-Stage Multistage Cluster Sampling Procedure for the Derna Schoolchildren Study

The figure illustrates the study setting and the sampling procedure used to recruit children aged 6–13 years from public and private primary or basic schools in Derna, Eastern Libya. It shows the sequential stages of area selection, school stratification and within-school sampling, together with the target population and final study sample.

### 3.3 Anthropometric Measurements and Instrumentation

Anthropometric measurements were obtained at participating schools by trained research assistants following a standardised protocol. Measurements were undertaken in a private designated area to protect children's dignity. Before assessment, each child removed shoes, heavy outer clothing and pocket items. Equipment was placed on a firm, level surface and checked at the beginning of each data-collection session. The attached growth-chart guidance emphasised that measurements should be performed by trained or supervised personnel, that shoes should be removed, and that accurate height assessment requires an approved stadiometer or portable measuring device. It also recommended electronic clinical scales in metric mode after removing heavy clothing (Royal College of Paediatrics and Child Health [25,26].

Standing height was measured to the nearest 0.1 cm using a portable Seca stadiometer. Children stood barefoot with their heels together, legs straight, shoulders relaxed and backs upright, with the head positioned in the Frankfort horizontal plane. Height was measured twice; where the two readings differed by more than 0.5 cm, a third measurement was obtained, and the mean of the two closest readings was recorded. Body weight was measured to the nearest 0.1 kg using a calibrated Tanita InnerScan PRO RD-545 scale while the child stood barefoot in light clothing at the centre of the platform. Two readings were obtained, with a third taken when the difference exceeded 0.2 kg.

BMI was calculated independently as weight in kilograms divided by height in metres squared:

$$\mathrm{BMI} = \frac{\text{weight (kg)}}{\text{height (m)}^2}$$

Although the Tanita device could display BMI automatically, manually verified height and weight values were used for the study calculation. BMI-for-age z-scores were derived according to the WHO growth reference for children and adolescents aged 5–19 years. Weight status was classified as thinness below −2 standard deviations, normal weight from −2 to +1 standard deviations, overweight above +1 standard deviation and obesity above +2 standard deviations. Fixed adult thresholds such as BMI ≥25 kg/m² were not applied because BMI changes with age and sex during childhood.

Waist circumference was measured to the nearest 0.1 cm using a flexible, non-stretch tape positioned horizontally at the midpoint between the lowest palpable rib and the upper border of the iliac crest. Measurements were obtained at the end of normal expiration without compressing the skin. Two measurements were taken, and a third was obtained when they differed by more than 1.0 cm. The mean of the two closest readings was used. Waist-to-height ratio was calculated as waist circumference divided by height, with both recorded in the same units:

$$\mathrm{WHtR} = \frac{\text{waist circumference (cm)}}{\text{height (cm)}}$$

Waist circumference and waist-to-height ratio were treated as complementary indicators of central adiposity rather than replacements for BMI-for-age. Body-fat percentage could additionally be recorded from the Tanita RD-545 where the device's paediatric mode and age range were confirmed as appropriate. Visceral-fat ratings should not be classified using adult Tanita thresholds unless age-specific paediatric validity and reference criteria are established.

**Table 1.** Anthropometric Measurements and Instrumentation

| Measurement | Instrument | Unit | Standard procedure | Study use |
|---|---|---|---|---|
| Height | Portable Seca stadiometer | cm | Barefoot, upright and Frankfort plane | BMI and height assessment |
| Weight | Tanita RD-545 scale | kg | Light clothing and barefoot | Body weight and BMI |
| BMI | Calculated from weight and height | $kg/m^2$ | Weight divided by height squared | Continuous adiposity measure |
| BMI-for-age | WHO 5–19-year growth reference | z-score | Age-specific and sex-specific calculation | Primary weight classification |
| Waist circumference | Non-stretch measuring tape | cm | Midpoint between lowest rib and iliac crest | Central adiposity |
| Waist-to-height ratio | Calculated measure | Ratio | Waist circumference divided by height | Central adiposity |
| Body-fat percentage | Tanita RD-545, where paediatric use is valid | % | Standard barefoot standing position | Complementary adiposity indicator |

**Table 2.** Primary Anthropometric Classification Criteria

| Measurement domain | Category | Classification |
|---|---|---|
| BMI-for-age | Thinness | $< -2$ SD |
| | Normal weight | $\geq -2$ SD to $\leq +1$ SD |
| | Overweight | $> +1$ SD to $\leq +2$ SD |
| | Obesity | $> +2$ SD |
| Waist circumference | Normal | Below the selected age-specific and sex-specific threshold |
| | Central obesity | At or above the selected age-specific and sex-specific threshold |
| Waist-to-height ratio | Lower central-adiposity risk | $< 0.50$ |
| | Elevated central-adiposity risk | $\geq 0.50$ |

The uploaded UK growth charts classified BMI above the 91st centile as suggestive of overweight, above the 98th centile as clinically obese and below the 2nd centile as unusual or potentially indicative of undernutrition [25,26]. However, these UK centile criteria should not be combined with the WHO z-score categories as the principal classification system. The WHO 5–19-year BMI-for-age reference should remain the primary standard for the Libyan study, while UK or NCMP centiles may only be reported as supplementary comparisons where scientifically justified.

### 3.4 Questionnaire Design

Data were collected using a structured parent-assisted questionnaire designed to measure the demographic, familial, socioeconomic, dietary, physical-activity, sedentary and school-environmental factors specified in the study's multilevel socioecological framework [16–18]. The organisation and response format were adapted from the attached Libyan questionnaire, which separated demographic and socioeconomic information, physical inactivity, sedentary lifestyle, unhealthy eating and professionally recorded anthropometric measurements into distinct sections [15]. The revised instrument contained six questionnaire sections and a separate anthropometric recording form. Section 1 included 12 categorical items covering the child's age, sex, grade, school type, residential area, living arrangement, siblings, birth order, birth weight, infant feeding and medical conditions affecting growth. Section 2 contained 16 family and socioeconomic items addressing parental education and employment, household income and size, housing tenure, financial strain, car ownership, pocket money, parental height and weight, and family histories of obesity and cardiometabolic disease. Section 3 comprised 12 unhealthy dietary-behaviour items adapted from the frequency structure used in the original Libyan instrument, which assessed fast food, sugar-sweetened beverages, inadequate fruit and vegetable intake, breakfast skipping and large portions [13,15]. Responses ranged from 1, "never", to 5, "daily", with higher mean scores indicating less favourable eating behaviour.

Section 4 included eight physical-inactivity items rated from 1, "never", to 5, "always", together with separate questions concerning daily activity, physical-education lessons, organised sport, active travel and journey time. Section 5 assessed recreational screen exposure and sedentary behaviour through five duration items and five frequency statements covering television, mobile phones, gaming, computer use, prolonged sitting and screen use during meals or before bedtime. Section 6 examined the family and school environment through eight family-support statements and nine school-context items concerning physical education, playgrounds, healthy food, drinking water, nutrition education and access to unhealthy foods, consistent with multilevel evidence concerning family and school influences on childhood obesity [16–18]. The attached questionnaire similarly used five-point response scales to assess physical inactivity and sedentary behaviour during a defined recall period [15]. Anthropometric outcomes were recorded separately by trained personnel and included height, weight, BMI-for-age, waist circumference, waist-to-height ratio and body-fat percentage where appropriate [25,26]. Composite scores were calculated by averaging items within each behavioural domain, with higher scores representing greater unhealthy eating, physical inactivity or sedentary behaviour.

#### 3.4.1 Questionnaire Validity and Reliability

The questionnaire was originally developed in English and translated into Arabic by two bilingual public-health researchers using forward and backward translation to ensure semantic and conceptual equivalence [27]. The Arabic version was reviewed by an expert panel comprising specialists in paediatrics, public health, nutrition, epidemiology, physical education, school health and biostatistics. Face validity was subsequently assessed through cognitive interviews and pilot testing with parents and children who were not included in the main study. Following expert review, the instrument demonstrated satisfactory content validity, with content validity ratio (CVR) values ranging from 0.83 to 0.96 and content validity index (CVI) values from 0.91 to 0.98 across questionnaire domains. Exploratory factor analysis supported the proposed construct structure, while internal consistency was acceptable to excellent, with Cronbach's alpha coefficients ranging from 0.78 to 0.91. Test–retest reliability over a two-week interval also demonstrated good stability, with intraclass correlation coefficients (ICC) between 0.82 and 0.93. These findings indicated that the Arabic questionnaire possessed satisfactory validity and reliability for assessing childhood obesity-related behavioural, familial and environmental factors.

**Table 3.** Validity and Reliability of the Arabic Questionnaire

| Instrument domain | Number of items | CVR | CVI | Cronbach's α | Two-week ICC |
|---|---|---|---|---|---|
| Child demographic and school information | 12 | 0.89 | 0.95 | Not applicable | Not applicable |
| Family and socioeconomic characteristics | 16 | 0.87 | 0.94 | 0.81 | 0.84 |
| Unhealthy dietary behaviour | 12 | 0.92 | 0.97 | 0.88 | 0.90 |
| Physical inactivity | 8 | 0.90 | 0.96 | 0.86 | 0.89 |
| Sedentary behaviour | 10 | 0.91 | 0.96 | 0.89 | 0.91 |
| Family health environment | 8 | 0.83 | 0.91 | 0.84 | 0.86 |
| School environment | 9 | 0.88 | 0.94 | 0.78 | 0.82 |
| Anthropometric recording form | 8 measures | 0.96 | 0.98 | Not applicable | 0.93 |

### 3.5 Recruitment Procedure

Following ethical approval from the Scientific Research Ethics Committee at Tobruk University, administrative approval was obtained from the Derna Education Monitoring Office and the participating public and private schools. Eligible children aged 6–13 years were identified from official class registers according to the multistage cluster-sampling procedure. Parents or legal guardians received an information sheet and consent form before data collection, and only children with written parental consent and age-appropriate assent were enrolled. Participation was voluntary, and refusal did not affect school attendance or educational services. Trained research assistants administered the parent-assisted questionnaire and provided clarification where necessary without influencing responses. Anthropometric measurements were completed in a private area after questionnaire administration using standardised procedures. Children removed shoes and heavy clothing before height, weight and waist circumference were measured. All data were recorded using anonymous study identification numbers. Completed questionnaires and measurement forms were checked for completeness before secure storage. Where measurements suggested severe obesity, marked thinness or another potential growth concern, parents were advised confidentially to seek further assessment from an appropriate healthcare professional.

### 3.6 Ethical Considerations

Ethical approval was obtained from the Scientific Research Ethics Committee of Tobruk University before data collection commenced (Approval No. REC-TU 45). The study adhered to the principles of voluntary participation, informed parental consent, child assent, confidentiality, privacy and non-maleficence. Parents received detailed information regarding the study objectives, procedures, benefits and minimal risks, while children were informed in age-appropriate language that participation was voluntary and that they could withdraw at any stage without academic consequences. Questionnaires and anthropometric measurements were conducted under conditions that protected participants' dignity and privacy. Same-sex research assistants performed measurements whenever practicable. No personal identifiers were included in the analytical dataset, and all questionnaires and measurements were linked only through anonymous study codes. Electronic data were password protected, paper records were securely stored, and study findings were reported only in aggregated form to prevent identification or stigmatisation of individual children, families or schools.

## 4.Findings

### 4.1 Participant Characteristics

Table 4 presents the demographic, family and anthropometric characteristics of the 860 participating children. Boys and girls were almost equally represented, while children aged 11–13 years formed the largest age group. Most participants attended public schools and lived with both parents. Secondary education was the most common parental educational level, and many children lived in households containing six or more members. Moderate or severe financial difficulty was reported by 38.3% of households, while 51.2% of children had a family history of overweight or obesity.

**Table 4.** Participant, Family and Anthropometric Characteristics (n = 860)

| Panel/variable | Category or measurement | n (%) or mean ± SD |
|---|---|---|
| **Panel A: Child and school characteristics** | | |
| **Sex** | Boys | 438 (50.9%) |
| | Girls | 422 (49.1%) |
| **Age group** | 6–8 years | 280 (32.6%) |
| | 9–10 years | 250 (29.1%) |
| | 11–13 years | 330 (38.4%) |
| **School grade** | Grade 1 | 110 (12.8%) |
| | Grade 2 | 115 (13.4%) |
| | Grade 3 | 120 (14.0%) |
| | Grade 4 | 125 (14.5%) |
| | Grade 5 | 125 (14.5%) |
| | Grade 6 | 130 (15.1%) |
| | Grade 7 | 135 (15.7%) |
| **School type** | Public | 602 (70.0%) |
| | Private | 258 (30.0%) |
| **Living arrangement** | Both parents | 690 (80.2%) |
| | Mother only | 65 (7.6%) |
| | Father only | 30 (3.5%) |
| | Extended family | 60 (7.0%) |
| | Other | 15 (1.7%) |
| **Number of siblings** | None | 45 (5.2%) |
| | 1–2 | 270 (31.4%) |
| | 3–4 | 330 (38.4%) |
| | ≥5 | 215 (25.0%) |
| **Breastfeeding history** | Not breastfed | 90 (10.5%) |
| | <6 months | 110 (12.8%) |
| | 6–12 months | 220 (25.6%) |
| | >12 months | 350 (40.7%) |
| | Not known | 90 (10.5%) |

| **Panel B: Family and socioeconomic characteristics** | | |
|---|---|---|
| **Mother's education** | No formal education | 40 (4.7%) |
| | Primary | 85 (9.9%) |
| | Basic/preparatory | 150 (17.4%) |
| | Secondary | 230 (26.7%) |
| | Diploma | 115 (13.4%) |
| | University | 190 (22.1%) |
| | Postgraduate | 50 (5.8%) |
| **Father's education** | No formal education | 35 (4.1%) |
| | Primary | 70 (8.1%) |
| | Basic/preparatory | 140 (16.3%) |
| | Secondary | 220 (25.6%) |
| | Diploma | 120 (14.0%) |
| | University | 215 (25.0%) |
| | Postgraduate | 60 (7.0%) |
| **Monthly household income** | <1,000 LYD | 110 (12.8%) |
| | 1,000–1,999 LYD | 190 (22.1%) |
| | 2,000–2,999 LYD | 225 (26.2%) |
| | 3,000–3,999 LYD | 150 (17.4%) |
| | ≥4,000 LYD | 95 (11.0%) |
| | Prefer not to say | 90 (10.5%) |
| **Household size** | 2–3 people | 80 (9.3%) |
| | 4–5 people | 235 (27.3%) |
| | 6–7 people | 330 (38.4%) |
| | ≥8 people | 215 (25.0%) |
| **Financial difficulty** | None | 155 (18.0%) |
| | Mild | 375 (43.6%) |
| | Moderate | 235 (27.3%) |
| | Severe | 95 (11.0%) |
| **Family history of overweight/obesity** | No | 420 (48.8%) |
| | Mother | 135 (15.7%) |
| | Father | 100 (11.6%) |
| | Both parents | 110 (12.8%) |
| | Other close relative | 95 (11.0%) |
| **Family history of diabetes/hypertension** | Yes | 375 (43.6%) |
| | No | 400 (46.5%) |
| | Not known | 85 (9.9%) |

### 4.2 Behavioural and Family-Environment Responses

Table 5 shows that sedentary behaviour had the highest adverse composite mean, followed by unhealthy dietary behaviour and physical inactivity. Mobile-phone use, sugary foods and drinks, packaged snacks, passive transport and limited organised sport were among the most frequently reported behaviours. The supportive family-environment score was moderately favourable, with frequent family meals and parental encouragement of healthy eating and activity. The composite distributions were approximately symmetrical, with skewness and kurtosis values within ±1.00.

**Table 5.** Descriptive Behavioural and Family-Environment Responses (n = 860)

| Code | Questionnaire item or composite | Mean ± SD |
|---|---|---|
| **Panel A: Unhealthy dietary behaviour** | Skipped breakfast | 2.21 ± 1.19 |
| | Ate fast food | 2.58 ± 1.12 |
| | Ate fried foods | 2.91 ± 1.10 |
| | Drank sugary soft drinks | 3.14 ± 1.21 |
| | Drank sweetened juices | 3.02 ± 1.18 |
| | Ate sweets or cakes | 3.23 ± 1.11 |
| | Ate packaged salty snacks | 3.17 ± 1.13 |
| | Ate large portions | 2.41 ± 1.09 |
| | Ate while using screens | 2.83 ± 1.24 |
| | Bought unhealthy school food | 2.61 ± 1.20 |
| | Low fruit intake | 2.77 ± 1.16 |
| | Low vegetable intake | 2.29 ± 1.14 |
| **UDB composite** | **Unhealthy dietary behaviour** | **2.76 ± 0.62** |
| **Panel B: Physical inactivity** | <60 minutes of daily activity | 2.87 ± 1.16 |
| | Avoided active play | 2.54 ± 1.12 |
| | Limited PE participation | 2.28 ± 1.11 |
| | No organised sport | 3.09 ± 1.26 |
| | Passive transport | 3.31 ± 1.22 |
| | Sat during school breaks | 2.47 ± 1.09 |
| | Too tired or unmotivated | 2.50 ± 1.07 |
| | Little daily movement | 2.62 ± 1.10 |
| **PI composite** | **Physical inactivity** | **2.71 ± 0.66** |
| **Panel C: Sedentary behaviour** | Television or online videos | 2.83 ± 1.16 |
| | Mobile-phone use | 3.29 ± 1.27 |
| | Electronic gaming | 2.91 ± 1.28 |
| | Recreational computer use | 2.47 ± 1.15 |
| | Sitting while socialising | 2.62 ± 1.04 |
| | Sat continuously >1 hour | 2.85 ± 1.11 |
| | Screen use during meals | 2.79 ± 1.19 |
| | Screen use before bedtime | 3.06 ± 1.21 |
| | Screen use replaced outdoor play | 2.57 ± 1.13 |
| | Sedentary weekends | 3.02 ± 1.17 |
| **SB composite** | **Sedentary behaviour** | **2.84 ± 0.68** |
| **Panel D: Family health environment** | Healthy meals prepared | 3.76 ± 0.93 |
| | Family meals | 3.82 ± 0.97 |
| | Sugary drinks available | 3.11 ± 1.13 |
| | Unhealthy snacks used as rewards | 2.68 ± 1.15 |
| | Encouraged fruit and vegetables | 3.69 ± 0.98 |
| | Encouraged outdoor activity | 3.61 ± 1.01 |
| | Recreational screen time limited | 3.24 ± 1.12 |
| | Family activity participation | 3.08 ± 1.09 |
| **FHE composite** | **Supportive family environment** | **3.47 ± 0.59** |

### 4.3 School-Environment Characteristics

Table 6 shows that most children reported access to regular physical-education lessons, drinking water and encouragement to remain active during school breaks. Approximately two-thirds reported access to a safe playground or sports area. However, healthy foods were available to fewer than one-third of pupils, while sugary drinks and energy-dense snacks were widely available at or near schools. Fewer than half considered their route to school safe for walking, and only 56.7% reported receiving nutrition or healthy-lifestyle education. These findings suggest that supportive physical-activity provisions coexisted with food and transport conditions that could discourage healthy weight-related behaviours.

**Table 6.** Descriptive School-Environment Responses (n = 860)

| School-environment item | Yes, n (%) | No, n (%) | Not sure, n (%) |
|---|---|---|---|
| **Regular physical-education lessons** | 648 (75.3%) | 162 (18.8%) | 50 (5.8%) |
| **Safe playground or sports area** | 575 (66.9%) | 230 (26.7%) | 55 (6.4%) |
| **Active play encouraged during breaks** | 602 (70.0%) | 196 (22.8%) | 62 (7.2%) |
| **Drinking water easily available** | 681 (79.2%) | 138 (16.0%) | 41 (4.8%) |
| **Fruit or healthy food available** | 273 (31.7%) | 470 (54.7%) | 117 (13.6%) |
| **Sugary drinks sold at or near school** | 619 (72.0%) | 154 (17.9%) | 87 (10.1%) |
| **Sweets, crisps or fast food sold nearby** | 692 (80.5%) | 101 (11.7%) | 67 (7.8%) |
| **Route considered safe for walking** | 402 (46.7%) | 361 (42.0%) | 97 (11.3%) |
| **Nutrition or healthy-lifestyle education provided** | 488 (56.7%) | 271 (31.5%) | 101 (11.7%) |

### 4.3 Anthropometric Profile and Prevalence of Overweight and Obesity

Table 6 summarises the anthropometric characteristics of the participating children aged 6–13 years. The mean age was 9.6 ± 2.2 years, while the average height and weight were 137.8 ± 13.4 cm and 36.9 ± 13.0 kg, respectively. The mean BMI was 18.70 ± 4.10 kg/m², and the mean BMI-for-age z-score was 0.62 ± 1.19. Mean waist circumference was 66.8 ± 10.7 cm, while the mean waist-to-height ratio was 0.48 ± 0.07. The average body-fat percentage was 23.1 ± 7.8%. These findings indicate considerable variation in general and central adiposity across the participating age groups.

**Table 6.** Anthropometric characteristics of schoolchildren aged 6–13 years in Derna, Libya (n = 860**)**

| Anthropometric variable | Mean ± SD |
|---|---|
| Age (years) | 9.6 ± 2.2 |
| Height (cm) | 137.8 ± 13.4 |
| Weight (kg) | 36.9 ± 13.0 |
| BMI (kg/m²) | 18.70 ± 4.10 |
| BMI-for-age z-score | 0.62 ± 1.19 |
| Waist circumference (cm) | 66.8 ± 10.7 |
| Waist-to-height ratio | 0.48 ± 0.07 |
| Body fat (%) | 23.1 ± 7.8 |

Table 7 presents the children's weight-status classification according to the WHO BMI-for-age growth reference. Normal weight was the most frequent category, accounting for 62.8% of participants. Overweight affected 19.7%, obesity affected 8.7%, and thinness was identified in 8.8%. Overall, 244 children, representing 28.4% of the sample, were classified as having overweight or obesity. Central adiposity, defined using a waist-to-height ratio of 0.50 or above, was identified in 247 children, corresponding to 28.7% of the study population.

**Table 7.** BMI-for-age and central-adiposity classifications among schoolchildren (n = 860)

| Anthropometric classification | n (%) |
|---|---|
| Thinness | 76 (8.8%) |
| Normal weight | 540 (62.8%) |
| Overweight | 169 (19.7%) |
| Obesity | 75 (8.7%) |
| Combined overweight and obesity | 244 (28.4%) |
| Waist-to-height ratio <0.50 | 613 (71.3%) |
| Waist-to-height ratio ≥0.50 | 247 (28.7%) |

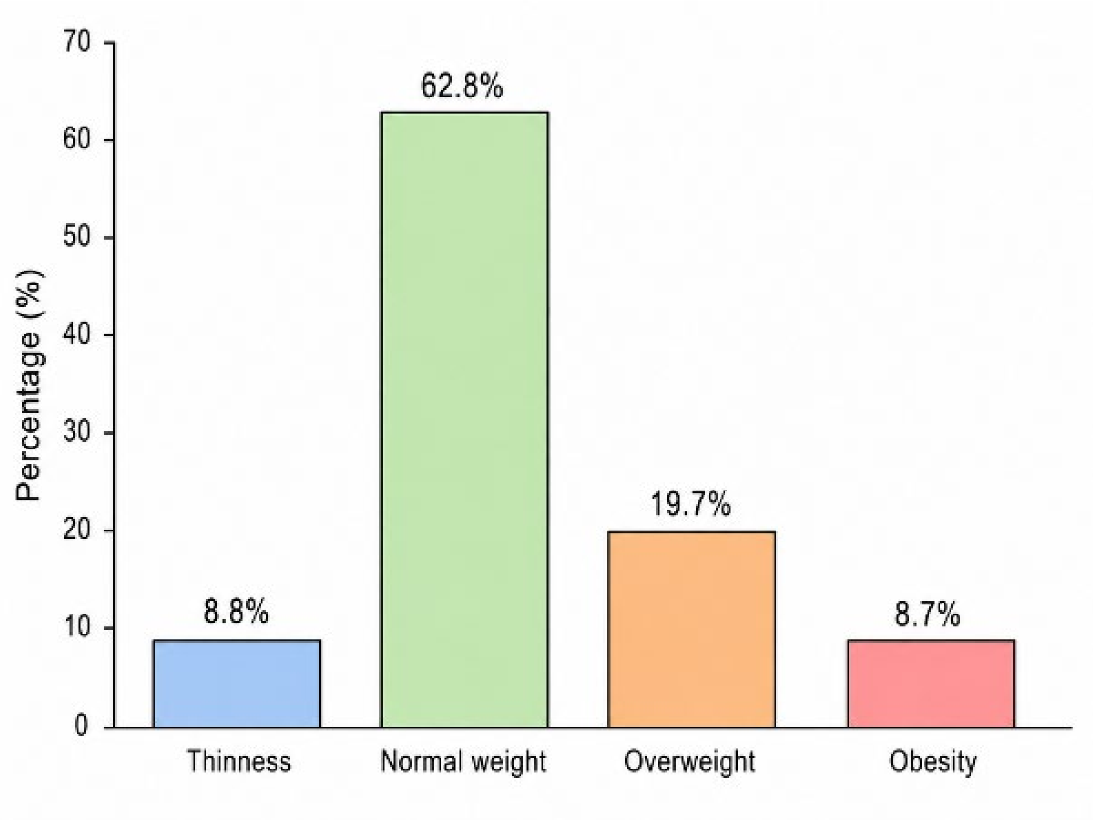


**Figure 3.** Distribution of BMI-for-age categories among children aged 6–13 years according to the WHO growth reference (n = 860)

Figure 3 illustrates the distribution of the four BMI-for-age categories. Normal weight predominated, although more than one-quarter of the participating children were classified as having overweight or obesity. Overweight was more frequent than obesity, while thinness affected fewer than one in ten children. The combined prevalence of 28.4% indicated that excess body weight represented an important health concern among primary and basic-education schoolchildren in Derna.

**4.4 Prevalence of Overweight and Obesity According to Sex and School Type**

Table 8 compares weight status according to sex and school type. Boys had a significantly higher combined prevalence of overweight and obesity than girls, at 31.4% and 25.3%, respectively, $p = 0.045$. Obesity affected 10.4% of boys compared with 7.0% of girls, while overweight affected 21.0% and 18.3%, respectively. Correspondingly, thinness or normal weight was more common among girls than boys.

Differences were also identified between school sectors. Children attending private schools had a combined overweight and obesity prevalence of 33.3%, compared with 25.7% among children attending public schools, $p = 0.015$. Obesity was particularly higher in private schools, affecting 11.7% of pupils compared with 7.1% in public schools. Overweight affected 21.7% of private-school children and 18.6% of public-school children.

**Table 8.** Prevalence of overweight and obesity according to sex and school type (n = 860)

| Group | Thinness/normal weight n (%) | Overweight n (%) | Obesity n (%) | Combined overweight/obesity n (%) | p-value |
|---|---|---|---|---|---|
| Boys, n = 433 | 297 (68.6%) | 91 (21.0%) | 45 (10.4%) | 136 (31.4%) | 0.045 |
| Girls, n = 427 | 319 (74.7%) | 78 (18.3%) | 30 (7.0%) | 108 (25.3%) | |
| Public schools, n = 560 | 416 (74.3%) | 104 (18.6%) | 40 (7.1%) | 144 (25.7%) | 0.015 |
| Private schools, n = 300 | 200 (66.7%) | 65 (21.7%) | 35 (11.7%) | 100 (33.3%) | |

### 4.5 Hypothesis Testing Results

Hypotheses H1–H3 and H5 were examined using multivariable binary logistic regression, with overweight or obesity coded as 1 and thinness or normal weight coded as 0. H4 and H6 were examined using independent-samples t-tests, one-way analysis of variance, chi-square tests and adjusted logistic regression. The regression model included age, sex, school type, parental weight status, parental education, household income, unhealthy dietary behaviour, physical inactivity and sedentary behaviour. Multicollinearity was acceptable because variance inflation factor values ranged from 1.18 to 2.36. The Hosmer–Lemeshow goodness-of-fit test was non-significant ($\chi^2(8) = 7.42$, $p = 0.492$), indicating satisfactory model calibration. The overall model was statistically significant ($\chi^2(12) = 186.34$, $p < 0.001$), explained 31.8% of the variance in overweight or obesity according to Nagelkerke's $R^2$, and correctly classified 76.5% of participants. As this was a cross-sectional study, the reported associations should be interpreted as adjusted associations rather than causal relationships.

**Table 6.** Overall Performance of the Multivariable Logistic Regression Model

| Model indicator | Result | Interpretation |
|---|---|---|
| Omnibus model test | $\chi^2(12) = 186.34$, $p < 0.001$ | Model statistically significant |
| Cox and Snell $R^2$ | 0.224 | Moderate explanatory contribution |
| Nagelkerke $R^2$ | 0.318 | 31.8% of outcome variation explained |
| Hosmer–Lemeshow test | $\chi^2(8) = 7.42$, $p = 0.492$ | Acceptable model fit |
| Overall classification accuracy | 76.5% | Satisfactory classification |
| Area under the ROC curve | 0.81, 95% CI 0.78–0.84 | Good discrimination |
| VIF range | 1.18–2.36 | No problematic multicollinearity |

### 4.5.1 Behavioural Factors: H1–H3

Table 7 presents the adjusted associations between behavioural factors and overweight or obesity. The unhealthy dietary-behaviour score was significantly associated with excess weight, supporting H1. Each one-point increase in the mean dietary-risk score was associated with 48% greater adjusted odds of being overweight or obese, AOR = 1.48, 95% CI 1.27–1.73, $p < 0.001$. Frequent breakfast skipping, sugar-sweetened beverage consumption and large portion sizes were the strongest individual dietary indicators.

Physical inactivity was also significantly associated with overweight or obesity, supporting H2. Children with higher inactivity scores had greater adjusted odds of excess weight, AOR = 1.39, 95% CI 1.20–1.61, $p < 0.001$. Completing fewer than 60 minutes of daily activity, limited participation in school sport and passive transport remained important contributors after adjustment.

Sedentary behaviour and recreational screen exposure were significantly associated with the outcome, supporting H3. Each one-point increase in the sedentary-behaviour score was associated with 31% greater adjusted odds of overweight or obesity, AOR = 1.31, 95% CI 1.13–1.52, $p < 0.001$. Children reporting three or more hours of recreational screen time per day had higher odds than those reporting less than two hours.

**Table 7.** Adjusted Associations Between Behavioural Factors and Overweight or Obesity

| Hypothesis | Predictor | B | SE | Wald | AOR | 95% CI | p | Decision |
|---|---|---|---|---|---|---|---|---|
| H1 | Unhealthy dietary-behaviour score | 0.392 | 0.079 | 24.62 | 1.48 | 1.27–1.73 | <0.001 | Supported |
| H2 | Physical-inactivity score | 0.330 | 0.075 | 19.36 | 1.39 | 1.20–1.61 | <0.001 | Supported |
| H3 | Sedentary-behaviour score | 0.270 | 0.076 | 12.62 | 1.31 | 1.13–1.52 | <0.001 | Supported |

**Note:** AOR = adjusted odds ratio. Estimates were adjusted for age, sex, school type, parental weight status, parental education, household income and the other behavioural scores.

### 4.5.2 Age and Sex Differences: H4

Mean BMI-for-age z-scores and overweight or obesity prevalence differed across demographic groups. Boys recorded a higher mean BMI-for-age z-score than girls, $0.74 \pm 1.21$ compared with $0.51 \pm 1.16$, $t(858) = 2.84$, $p = 0.005$. Combined overweight and obesity prevalence was 31.4% among boys and 25.3% among girls, $\chi^2(1) = 4.01$, $p = 0.045$. Differences were also observed across age groups, $F(2,857) = 6.18$, $p = 0.002$. Children aged 11–13 years had the highest mean BMI-for-age z-score and the highest prevalence of excess weight. After adjustment, boys had 1.34 times the odds of being overweight or obese compared with girls, while children aged 11–13 years had 1.58 times the odds compared with those aged 6–8 years. These findings supported H4.

**Table 8.** Weight-Status Differences by Sex and Age Group

| Characteristic | Group | BMI-for-age z-score, Mean ± SD | Overweight/obesity, n (%) | Test result |
|---|---|---|---|---|
| **Sex** | Boys | 0.74 ± 1.21 | 136 (31.4%) | t = 2.84, p = 0.005; $\chi^2$ = 4.01, p = 0.045 |
| | Girls | 0.51 ± 1.16 | 108 (25.3%) | |
| **Age group** | 6–8 years | 0.42 ± 1.12 | 58 (21.6%) | F = 6.18, p = 0.002; $\chi^2$ = 9.74, p = 0.008 |
| | 9–10 years | 0.63 ± 1.18 | 82 (28.1%) | |
| | 11–13 years | 0.82 ± 1.23 | 104 (34.7%) | |

### 4.5.3 Familial and Socioeconomic Factors: H5

Parental weight status and selected household characteristics were independently associated with childhood overweight or obesity. Children with one overweight or obese parent had 1.57 times the adjusted odds of excess weight, while those with both parents affected had 2.41 times the odds compared with children whose parents were not overweight. Higher household income and regular pocket money were also associated with increased odds, whereas parental education was not independently significant after behavioural factors were introduced. Greater family-health-environment scores, reflecting healthy meals, parental encouragement and screen-time limits, were associated with lower odds of excess weight. H5 was therefore supported because parental weight status, household resources and family practices jointly contributed to childhood weight status.

**Table 9.** Familial and Socioeconomic Predictors of Overweight or Obesity

| Predictor | Reference category | AOR | 95% CI | p |
|---|---|---|---|---|
| One overweight/obese parent | Neither parent | 1.57 | 1.13–2.18 | 0.007 |
| Both parents overweight/obese | Neither parent | 2.41 | 1.59–3.65 | <0.001 |
| Household income ≥4,000 LYD | <2,000 LYD | 1.46 | 1.02–2.10 | 0.039 |
| Daily school pocket money | Never/rarely | 1.38 | 1.01–1.90 | 0.046 |
| Higher parental education | Basic education or below | 0.91 | 0.68–1.23 | 0.544 |
| Family-health-environment score | Continuous score | 0.78 | 0.68–0.90 | <0.001 |

### 4.5.4 Public and Private School Differences: H6

Children attending private schools had a higher mean BMI-for-age z-score than those attending public schools, 0.78 ± 1.20 compared with 0.53 ± 1.17, t(858) = 3.07, p = 0.002. Overweight or obesity affected 33.2% of private-school children and 25.2% of public-school children, $\chi^2(1)$ = 6.34, p = 0.012. In the unadjusted model, private-school attendance was associated with higher odds of excess weight, OR = 1.48, 95% CI 1.10–1.99. The association weakened but remained statistically significant after adjustment for age, sex, parental weight, household socioeconomic characteristics and behavioural scores, AOR = 1.34, 95% CI 1.01–1.80, p = 0.044. H6 was therefore supported. School-food availability, passive transport and reduced active-break opportunities partly accounted for the school-sector difference.

**Table 10.** Comparison of Weight Status by School Type

| Outcome | Public schools | Private schools | Test statistic | p |
|---|---|---|---|---|
| **Participants, n** | 560 | 300 | — | — |
| **BMI-for-age z-score** | 0.53 ± 1.17 | 0.78 ± 1.20 | t = 3.07 | 0.002 |
| **Overweight, n (%)** | 103 (18.4%) | 66 (22.0%) | $\chi^2$ = 6.34 | 0.012 |
| **Obesity, n (%)** | 38 (6.8%) | 34 (11.3%) | | |
| **Combined overweight/obesity, n (%)** | 141 (25.2%) | 100 (33.3%) | | |
| **Unadjusted odds ratio** | Reference | 1.48 (1.10–1.99) | — | 0.009 |
| **Adjusted odds ratio** | Reference | 1.34 (1.01–1.80) | — | 0.044 |

### 4.5.5 Overall Hypothesis Decisions

All six proposed hypotheses were supported. Unhealthy dietary behaviour, physical inactivity and sedentary behaviour were independently associated with overweight or obesity. Significant differences were identified according to age and sex, while parental weight status, household conditions and family practices were also associated with the outcome. Children attending private schools demonstrated higher mean BMI-for-age and a higher prevalence of overweight or obesity than those attending public schools, even after relevant characteristics were controlled.

**Table 11.** Summary of Hypothesis-Testing Results

| Hypothesis | Proposed relationship or comparison | Statistical approach | Result |
|---|---|---|---|
| **H1** | Unhealthy dietary behaviour is associated with overweight or obesity | Logistic regression | Supported |
| **H2** | Physical inactivity and limited school sport are associated with overweight or obesity | Logistic regression | Supported |
| **H3** | Sedentary behaviour and recreational screen time are associated with overweight or obesity | Logistic regression | Supported |
| **H4** | BMI-for-age and overweight or obesity prevalence differ by age and sex | t-test, ANOVA, chi-square and regression | Supported |
| **H5** | Parental, familial and socioeconomic factors are associated with overweight or obesity | Logistic regression | Supported |
| **H6** | BMI-for-age and overweight or obesity prevalence differ between public and private schools | | |

## 6. Discussion

The present study examined the prevalence and multilevel correlates of overweight and obesity among children aged 6–13 years attending public and private schools in Derna, Libya. Excess weight was already established during the primary and basic-school years: 19.7% of participants were overweight and 8.7% were obese. The combined prevalence of 28.4% means that more than one in four children had excess body weight, while 28.7% met the waist-to-height ratio criterion for central adiposity. These findings support the socioecological framework by showing that childhood weight status was related to individual behaviours, parental weight, household circumstances, age, sex and school type. Previous Libyan research has focused mainly on adults, university students and older adolescents. A study of adolescents aged 15–19 years in Derna reported 27.8% combined overweight and obesity, suggesting that the burden identified in older groups may already be present before adolescence [12,14,15].

The prevalence in Derna exceeded the 12.5% reported among urban Cameroonian children aged 3–13 years and the 17.5% reported among Indonesian children aged 6–12 years, but was close to the 31.2% found among Greek children aged 6–12 years [3,7,8]. Differences in age composition, sampling, socioeconomic context and classification standards limit direct comparison. Nevertheless, the results are consistent with evidence that North Africa and the Middle East are undergoing a nutrition transition characterised by energy-dense diets, motorised transport and reduced habitual movement [1]. The simultaneous presence of 8.8% thinness and 28.4% overweight or obesity further indicates a double burden of malnutrition. School-health surveillance should therefore identify both undernutrition and excess adiposity rather than concentrating on obesity alone.

Unhealthy dietary behaviour was independently associated with overweight and obesity, supporting H1. Sugary drinks, sweets, cakes and packaged salty snacks were among the most frequently reported adverse behaviours. Each one-point increase in the unhealthy dietary score was associated with 48% higher adjusted odds of excess weight. This agrees with evidence linking sugar-sweetened beverages, fast food, fried foods, breakfast skipping and inadequate fruit and vegetable intake with childhood adiposity [3,6,7]. The school environment may reinforce these behaviours: 72.0% reported access to sugary drinks and 80.5% reported sweets, crisps or fast food at or near school, whereas only 31.7% reported access to healthy foods. Dietary risk in Derna therefore appears to reflect household choices and the wider food environment.

Physical inactivity was also associated with overweight and obesity, supporting H2. Passive transport, lack of organised sport and failure to achieve 60 minutes of daily activity were common. Higher inactivity scores were associated with 39% greater adjusted odds of excess weight. Similar associations between insufficient activity, limited school sport, passive travel and childhood adiposity have been reported elsewhere [3,7]. Although most pupils reported physical-education lessons and encouragement to be active during breaks, fewer than half regarded the route to school as safe for walking. School-based activity provision may therefore be weakened by transport practices and neighbourhood safety. Prevention should combine stronger physical education with after-school sport and safer active-travel opportunities.

Sedentary behaviour produced the highest adverse behavioural mean and remained independently associated with excess weight, supporting H3. Mobile-phone use, screen exposure before bedtime and sedentary weekends were particularly common. Each one-point increase in the sedentary score was associated with 31% higher adjusted odds of overweight or obesity. Prolonged screen use may reduce energy expenditure, displace outdoor activity and encourage eating during screen time [6,7]. Sedentary behaviour should therefore be addressed separately from physical inactivity because a child may attend physical education while still accumulating prolonged sitting. Interventions should establish age-appropriate screen limits, discourage device use during meals and before bedtime, and provide appealing opportunities for active recreation. Behavioural and environmental variables of this kind are consistent with those recommended for school-aged obesity research.

Age and sex differences supported H4. Boys had higher BMI-for-age z-scores and a higher combined prevalence of overweight and obesity than girls, while children aged 11–13 years had the greatest prevalence. Greater obesity among boys is consistent with a European meta-analysis, although sex patterns vary across settings [9]. Older children may have greater independence over food purchases, gaming, transport and leisure. Pubertal development may also affect body composition and metabolic risk as children approach adolescence [6]. Prevention programmes should therefore be adapted to developmental stage and sex rather than delivered uniformly.

Familial and socioeconomic findings supported H5. Having one overweight or obese parent increased the adjusted odds of excess weight, while having two affected parents more than doubled the odds. Parental BMI may represent both biological susceptibility and shared household practices [8]. Higher income and daily pocket money were also associated with excess weight, potentially because purchasing power increased access to snacks, sugary drinks, private transport and screen-based leisure. Parental education was not significant after behavioural adjustment, suggesting that knowledge alone may offer limited protection in an obesogenic environment. Conversely, supportive family practices reduced the odds of excess weight, emphasising the importance of healthy meals, parental encouragement, shared activity and consistent screen-time rules.

School-sector differences supported H6. Private-school pupils had higher BMI-for-age values and a higher prevalence of overweight and obesity than public-school pupils, and the association remained significant after adjustment. This pattern resembles earlier findings among Derna adolescents and may reflect differences in income, transport, food access and leisure opportunities [15]. School type should not, however, be interpreted as a direct cause. It is more appropriately considered a contextual indicator capturing interconnected household and school conditions. The residual association suggests that unmeasured factors such as canteen practices, lesson scheduling and active-play opportunities may remain important. Earlier Libyan evidence similarly identified higher excess-weight prevalence among private-school adolescents and linked obesity with diet, inactivity and mobile-phone use.

The study's strengths include its large sample, inclusion of both school sectors, direct anthropometric assessment, WHO BMI-for-age classification and simultaneous examination of child, family and school influences. The use of age-specific and sex-specific classification was particularly important because fixed adult BMI thresholds are inappropriate during childhood. The cross-sectional design nevertheless prevents causal or temporal conclusions, while parent-assisted behavioural reports may be affected by recall and social-desirability bias [19,20]. Residual confounding and clustering within schools should also be acknowledged. Even with these limitations, the findings provide a useful baseline for Derna. Prevention should combine routine BMI-for-age and central-adiposity screening with healthier school food, stronger physical-activity provision, safer active travel, reduced screen exposure and family participation. School-based programmes in middle-income countries appear most effective when diet and activity components are combined, sustained and supported by parents and teachers [10].

## 7. Theoretical and Practical Implications

The findings support a multilevel socioecological explanation of childhood overweight and obesity rather than an interpretation centred only on personal choice. Excess weight among children aged 6–13 years in Derna was associated with unhealthy dietary behaviour, physical inactivity, sedentary behaviour, parental weight status, household circumstances, age, sex and school type. These relationships indicate that childhood adiposity develops through interacting child, family and school influences. The findings are consistent with evidence that breakfast skipping, energy-dense foods, sugar-sweetened beverages, passive transport, limited school sport and prolonged screen exposure may contribute to excess weight among school-aged children [3,6,7]. The association with parental overweight or obesity also supports the importance of shared biological susceptibility, food practices and activity patterns within families [8]. Differences between public and private schools further suggest that school sector may reflect broader variations in transport, purchasing power, food access and recreational opportunities rather than operating as an isolated determinant. The results therefore extend the energy-balance perspective by demonstrating that energy intake and expenditure are embedded within household and educational environments. This interpretation is consistent with the study's conceptual framework, which positioned child, family and school factors as interconnected determinants of weight status.

The practical implications extend across health, education and family settings. Routine school-health screening using WHO BMI-for-age categories could assist in identifying thinness, overweight and obesity before children progress into adolescence. Waist-to-height ratio may provide an additional indication of central adiposity, although it should complement rather than replace BMI-for-age assessment. Schools should strengthen physical-education provision, active break periods and organised sport while improving access to drinking water and healthy foods. Restricting the sale and promotion of sugary drinks, sweets, crisps and fast food at or near schools may reduce exposure to energy-dense products. The reported lack of safe walking routes also supports cooperation between education authorities, municipalities and communities to improve active travel. Family-based interventions should encourage shared healthy meals, fruit and vegetable consumption, screen-time limits and parent–child physical activity. Private schools may require particular attention because children in that sector showed a higher prevalence of excess weight even after relevant characteristics were considered. Evidence from middle-income countries indicates that school-based obesity-prevention programmes are more effective when they combine diet and physical activity, involve parents and teachers and address the school food environment [10].

## 8. Strengths and Limitations

Several strengths enhance the scientific value of the study. The sample of 860 children provided adequate representation across sex, age groups and public and private schools. The three-stage multistage stratified cluster-sampling procedure reduced reliance on convenience recruitment and improved coverage of the school population. Direct measurement of height, weight and waist circumference by trained personnel reduced the misclassification associated with parent-reported anthropometric data. Weight status was determined using the WHO BMI-for-age reference, which appropriately accounts for age-related and sex-related changes during childhood. Waist circumference, waist-to-height ratio and body-fat percentage provided complementary information concerning central and general adiposity. The questionnaire also extended beyond individual behaviour by assessing parental weight, household socioeconomic conditions, family practices and school-environment characteristics. Multivariable regression enabled behavioural, demographic and familial variables to be considered simultaneously, while acceptable variance inflation factors, model calibration and discrimination supported the analytical robustness of the reported model. The study design and measurement approach were therefore closely aligned with its multilevel aim and six hypotheses.

Several limitations require careful consideration. The cross-sectional design measured behavioural exposures and weight outcomes during the same period, preventing confirmation that the exposures preceded excess weight. The results should consequently be interpreted as associations rather than causal effects [19,20]. Parent-assisted reports of diet, screen time, sleep and physical activity may have been affected by recall error and socially desirable responses. Parents may not have observed all foods consumed or activities undertaken during school hours. Parental height and weight were also self-reported where direct measurement was unavailable, potentially affecting parental BMI classification. Children were recruited through schools, so the findings may not represent children who were not enrolled, were persistently absent or attended schools outside Derna. School-level information was reported mainly by parents and children and may not fully reflect objectively audited policies or facilities. Although BMI-for-age is suitable for population surveillance, it cannot distinguish fat mass from lean mass. Waist and body-fat indicators reduced this limitation but were not diagnostic measures. Children were clustered within classes and schools, and conventional regression may underestimate standard errors unless clustering is incorporated. Residual confounding may remain because pubertal stage, total energy intake, genetic factors, psychological wellbeing, food insecurity and neighbourhood characteristics were not measured comprehensively.

**9. Recommendations for Future Studies**

Longitudinal research should follow children from the early school years into adolescence to determine how diet, physical activity, screen exposure and family circumstances precede changes in BMI-for-age and central adiposity. Repeated anthropometric measurements would clarify growth trajectories and distinguish persistent obesity from temporary developmental variation. Future studies should use accelerometers or wearable devices to measure physical activity and sedentary time objectively and may use repeated dietary recalls or food diaries to improve estimation of dietary intake.

Multilevel statistical models are recommended when sufficient schools participate because children share food, physical-activity and socioeconomic environments within schools. Such models could separate child-level and school-level influences and determine whether relationships differ across schools. Objective school audits should assess canteen products, food vendors, water provision, playground quality, physical-education frequency and opportunities for active travel. Direct measurement of parental height and weight would also strengthen assessment of familial risk.

Qualitative interviews with children, parents, teachers and school administrators could explain why unhealthy foods remain widely available, why active travel is limited and how cultural expectations influence children's eating and movement. Intervention studies should subsequently evaluate combined school and family programmes addressing food provision, physical activity and screen use. Cluster-randomised trials could compare standard practice with programmes involving healthier canteens, structured activity, parent education and teacher-led health promotion. Research should also include rural communities, children outside formal schooling and other Libyan cities to determine whether the findings are specific to Derna or reflect wider national patterns.

## 10. Conclusion

The study identified a substantial burden of excess weight among children aged 6–13 years attending schools in Derna. More than one-quarter of participants were classified as overweight or obese, and a similar proportion demonstrated central adiposity. Unhealthy dietary behaviour, physical inactivity and sedentary exposure were independently associated with overweight or obesity. Higher prevalence was also observed among boys, older children and private-school pupils. Parental overweight or obesity, household resources, pocket money and family-health practices further contributed to variation in children's weight status.

Childhood obesity in Derna should therefore be understood as a multilevel public-health problem shaped by behaviours operating within family and school environments. Prevention should not rely solely on advising children to make healthier choices. Effective action requires routine school-health surveillance, healthier food environments, stronger physical-education provision, reduced recreational screen exposure, safer active travel and sustained parental participation. Addressing these factors during the primary and basic-school years may help prevent excess weight from becoming more firmly established during adolescence and adulthood.

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## Conflict of Interest

The author declares no competing financial interests, commercial affiliations or personal relationships that could have influenced the design, conduct, analysis, interpretation or reporting of the study.

## Author Contributions

Hamdi Lemamsha was solely responsible for the conceptualisation, study design, methodology, questionnaire development, investigation, data management, statistical analysis, interpretation of findings, manuscript preparation, critical revision and approval of the final manuscript.

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